A HOLISTIC CONCEPTUAL MODEL FOR MANAGING CONSTRUCTION LOGISTICS IN BUILDING PROJECTS: THE CASE OF IRAN

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Copyright Statement

Searching hurriedly in the desert of this world,

I found out nothing, but I minutely investigated everything.

In my heart, thousand lights of knowledge shone,

but I could not perceive the perfection of even a bit.

Avicenna (Iranian physician and philosopher, 980-1037)

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DEDICATION

I wish to dedicate this work to:

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ABSTRACT

Logistics, as a factor that affects the total cost of a product, has attracted attention in many industries. However, construction is behind other industries, such as manufacturing and food, in terms of obtaining value through application of effective logistics management. Some specific characteristics of the construction industry, such as fragmented supply chain, indirect employment, temporary location and matchless products, have prevented organisations utilising logistic management in their projects.

In construction, logistics is about the mobilisation of different types of resources to feed the project with the required materials and components at the right time, in the right place, right quantity and right quality. To do so, a new approach to construction logistics should be undertaken that respects the special characteristics of this industry. This research aims to develop a conceptual model based on the current practice of construction logistics in building projects. This model, in addition to complying with the special characteristics of the construction industry, is also adapted to the economic, cultural, technological and environmental specifications of the building sector in Iran. The complexity mindset is adopted in this research which allows considering a construction logistics system as a whole and the system may assert an aggregate behaviour. This approach is called holism and investigates the performance of complex adaptive systems.

The study is focused on the Iranian construction industry as the main source of data collection. To achieve the aim and objectives of the research, a literature review was followed by qualitative and quantitative data collection. This research adopted the complementarity approach that uses qualitative and quantitative strategies in a way that complement each other. In the qualitative phase, twenty four open-ended interviews were conducted with construction practitioners who work in the building sector in Iran. Gathered data was analysed using NVivo. This involves codifying the textual data to find themes, categories and relationships. The results of the first phase were rich and exploratory and explained opinions, norms and attitudes. Based on the results of the first phase, a questionnaire with ten sections was designed to investigate different aspects of construction logistics from wider perspectives by conducting a survey on a large sample. The data gathered from the second phase were analysed in a descriptive manner to provide statistical information about the present practice of construction logistics in the Iranian building sector.

The final product of this research is a holistic conceptual model that has four subsystems: (a) environmental factors (b) operational factors, (c) commercial factors, and (d) managerial factors. Each subsystem has several agents that are different functions of logistics in a building project. The environmental factors include project size and location, peak working seasons, resource conservation and weather conditions. The operational factors discuss technological matters, construction methods, new materials, waste and transportation. The commercial factors encompass the supply chain, finance, economic conditions, material costs, estimation, supplier selection, packaging, purchasing, inspection, and material quality. The managerial factors cover material management, warehousing, material handling, information management, scheduling, delivery, organisation, personnel, knowledge, culture and site layout designing. All of these functions are integrated under the topic of construction logistics model. The model also illustrates the relationships among agents of the system. The developed model, in addition to technical factors, has paid attention to soft factors such as culture, economy and knowledge. The model is adaptable to changing environments and elements may be added or deleted from the system whenever required.

Keywords: building sector, construction industry, construction logistics, Iran, logistics management, logistics model.

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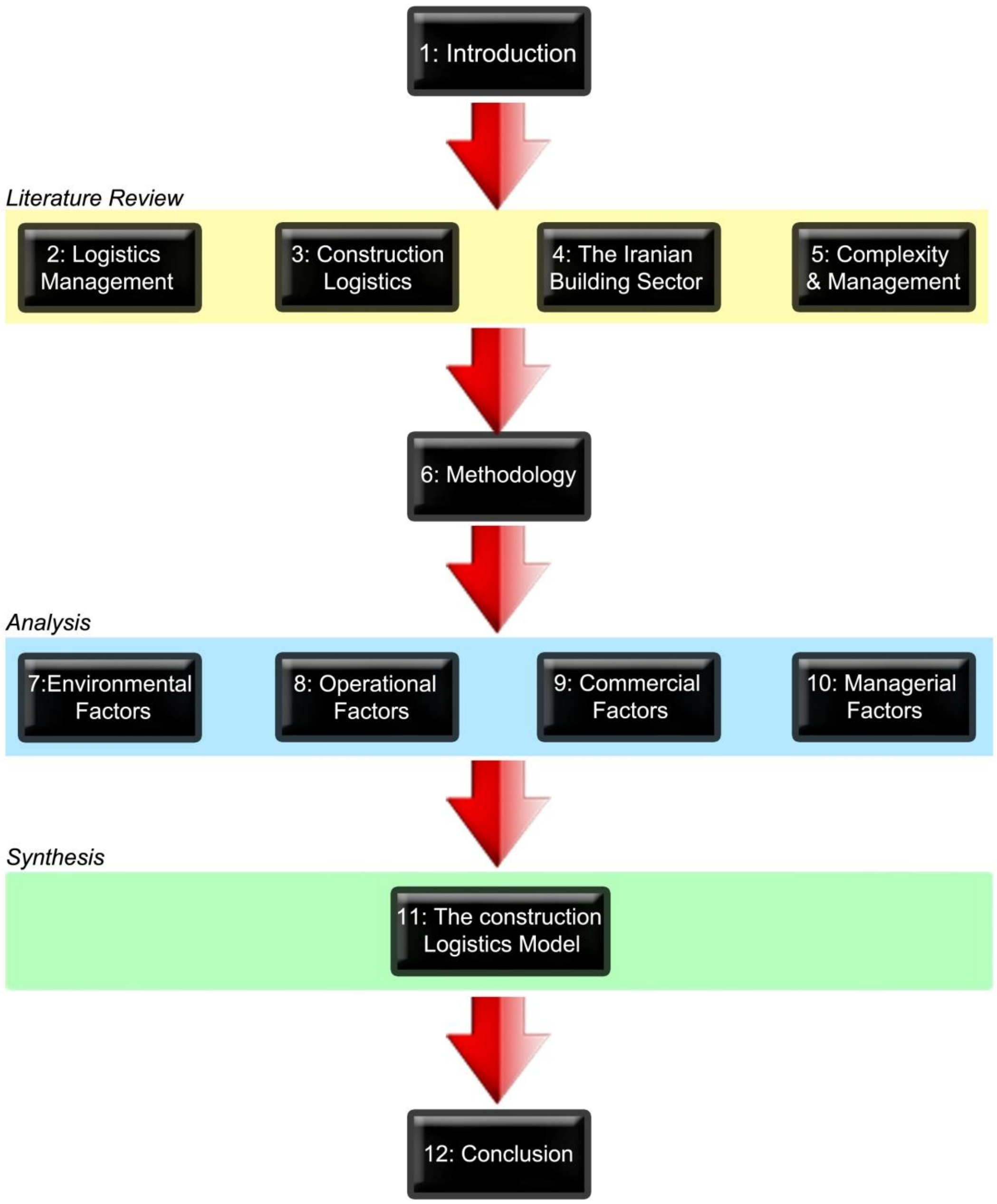
LIST OF ABBREVIATIONS

ACCO	Association of Construction Companies
ARCOM	Association of Research in Construction Management
BHRC	Building and Housing Research Centre
CAD	Computer-Aided Design
CAIS	The Circle of Ancient Iranian Studies
CAQDAS	Computer Assisted Qualitative Data Analysis Software
CAS	Complex Adaptive System
CBI	Central Bank of Islamic Republic of Iran
CC	Consolidation Centre
CILT	Chartered Institute of Logistics and Transport of the UK
CM	Construction Management
CMAA	The Construction Management Association of America
CPM	Critical Path Method
CSCMP	The Council of Supply Chain Management Professionals
CSR	The Iranian Centre for Strategic Research
DSRC	The Iranian Defence Science and Research Centre
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IDRO	Industrial Development and Renovation Organisation of Iran
ILS	Iran Logistics Society
IME	Iran Mercantile Exchange
IMF	The International Monetary Fund
IRCEO	The Iranian Construction Engineering Organisation
ISIRI	The Institute of Standards and Industrial Research of Iran
ISNA	Iranian Student's News Agency
ISO	International Organisation for Standardisation
JIT	Just-In-Time
MHUD	Ministry of Housing and Urban Development in Iran
MSRT	The Iranian Ministry of Science, Research and Technology
PCU	Project Control Unit
PDF	Portable Document Format
PDSPC	President Deputy Strategic Planning and Control in Iran
PMBOK	The Project Management Body of Knowledge
PMI	The Project Management Institute
PSM	Per Square Metre
QDA	Qualitative Data Analysis
RFID	Radio Frequency Identification
RICS	The Royal Institution of Chartered Surveyors
RII	Relative Importance Index
Rls	The Rial (the Iranian currency)
SC	Supply Chain
SCI	Statistical Centre of Iran
SCM	Supply Chain Management
SFfC	The Strategic Forum for Construction

SFI	Santa Fe Institute
SMEs	Small and Medium size Enterprises
SPSS	Statistical Package for Social Sciences
TLC	Total Logistics Concept
WMS	Warehouse Management System

THESIS PATHWAY



Chapter *1*

INTRODUCTION

CHAPTER 1: INTRODUCTION

1. 1. Overview

This chapter provides a brief background about logistics management, construction logistics and the role of construction logistics in the Iranian construction industry. Justification for the research is also provided and the aim and objectives of the research are introduced. Furthermore, a concise description about what has been done and what has been achieved is provided. Finally, the research organisation and structure of the thesis is explained.

1. 2. Background

Logistics has been recognised as a major factor in industrial organisations for many years. Coming from the defence sector, logistics is the science of planning and carrying out the movement and maintenance of military forces (Merriam-Webster, 2010). Since twenty years ago, logistics has had a great effect on designing and forming the internal operation sequences of different industries and businesses (Christopher, 1998). Logistics, by clarifying the operation sequences, can enhance the productivity of the projects and provide competitive advantage over rivals by reducing the final cost and time of the production (Blanchard, 1998). Logistics management is a tool which ensures the efficiency of the logistics system. Its first role is to evaluate all facilities and issues which may have any impact on logistics cost and make the product conform to the customer's requirements (Simchi-Levi, Chen, & Bramel, 2005). As the second role, logistics management attempts to minimise cost and provide a cost-effective system across the whole process of production from transportation and distribution of raw materials to the inventories, work in process and finished products (Simchi-Levi, Chen, & Bramel, 2005). The Project Management Body of Knowledge guide (PMBOK) categorises logistics under the areas of 'expertise' and 'general management knowledge and skills' topics (PMI, 2004). It explains topics such as logistics, provides the foundation for building project management skills and is often essential for project managers.

In construction, logistics involves mobilising materials, equipment and information at the right time, in the right quantity, at the right quality, in the right place and at a right price. Some functions of construction logistics are: specifying supply sources, scheduling, purchasing, transportation, warehousing, handling, and site layout designing. Implementation of logistics management is rare in the construction industry. For instance, in the UK construction industry, as highlighted in the Egan report (1998) and Strategic Forum for Construction (SFfC) (2005), the advantages of adopting effective logistics are not recognised by many construction firms. This is owing to the specific nature of the construction industry with its single and matchless products, one-off and short-time projects, indirect employment, inaccurate information based on estimation, and low commitment in the supply chain. Some consequences of poor logistics management in construction projects are cost increase, poor quality construction, time increase and added risks to health and safety (Hill & Ballard, 2001).

1. 3. The Iranian Construction Industry

The construction industry plays a major role in the Iranian economy by generating employment and wealth. It accounts for about nine per cent of the gross domestic product (GDP) of Iran (CBI, 2009). There is a high demand in different sectors of the construction industry and specifically in the building sector, as reported by the Ministry of Housing and Urban Development (MHUD, Home, 2011). However, the process of construction is inefficient in Iran. One reason is that the civil engineers and architects, who construct buildings in Iran, do not have enough knowledge of project management and are not familiar with subjects such as logistics. Even those who attain the knowledge cannot apply it in practice. Generally, Iranian construction practitioners encounter two questions when applying project management knowledge in their projects:

1. How shall project management knowledge be applied in the context of Iran?
2. Is implementation of project management knowledge beneficial?

The first question implies that managers usually are not able to adopt the project management concepts in such a way that complies with the political, economic, technological, and sociological properties of the Iranian construction industry. The management concepts, as a part of the social sciences, should be contextualised in a specific environment and time. This is the point that usually is not considered by the Iranian construction managers when they try to apply project management techniques in their projects. One of the objectives of this research is to adapt the concept of construction logistics to the current condition of the construction industry in Iran. This will be discussed later.

The second question shows managers' concern about applying management concepts in practice. Even in western countries, such as the UK, projects managers often complain about the deadlines that were not met, targets that have slipped, vague strategic visions, and missions that are poorly communicated (Stacey, Griffin, & Shaw, 2000). The reason is that most managers practise a Newtonian style of management which believes prediction is possible by abstracting causal relations. Hence, they want to plan and control everything that will happen in the future. However, the real world is not predictable and the future is only recognisable when it comes. The complexity mindset, in contrast, offers an alternative that is based on uncertainty and unpredictability. This alternative is a new way of thinking about organisations and helps project managers to control their projects by using a holistic view and focusing on goals and directions rather than detailed planning. This research views construction logistics as a system and develops a model by considering the properties of complex systems.

1. 4. Rationale

Logistics management is chosen among other project management concepts as the topic of this research because it has the potential to help construction firms to attain cost advantages. Fairs (2002) explained that construction firms can cut 15 per cent from their materials and labour costs by making better use of basic logistics techniques. SFfC (2005) also believes that substantial savings in the range of ten to 30 per cent are achievable by implementing effective logistics management to the construction projects. However, in comparison with other project management topics such as scheduling, less research is conducted on construction logistics management. Although valuable efforts have been made by researchers such as Guffond and Leconte (2000), Hill and Ballard (2001), Fairs (2002), and Cox and Ireland (2006), none have studied construction logistics as a system and as a whole. This is the gap in knowledge that this study is going to fill by developing a holistic model for managing logistics in construction projects.

Another reason for choosing construction logistics as the topic of this research is that there is a lack of understanding about it among the Iranian construction practitioners

(Asnaashari, Hurst, & Knight, 2008). Lack of awareness about construction logistics causes problems such as late delivery, poor warehousing, large amounts of waste, and site chaos. Despite these problems, no research has been conducted in the field of logistics management in Iranian construction projects. Hence, this research aims to focus on the building sector of the industry to study and evaluate the current practice of logistics management. Based on the current practice, a model is created that is compatible with the characteristics of the construction industry in Iran.

The building sector, which includes construction of residential, commercial, health and educational facilities, is chosen as the focus of this research. The main reason is owed to the huge demand for buildings in Iran and the need to enhance the efficiency of the projects. Another reason is that the building sector impacts on every person in terms of where they live and work. Buildings' quality, cost and availability are crucial to individuals' quality of life. Quality houses, workplaces, hospitals, clinics and educational buildings are the foundation of a vibrant society.

1. 5. Research Aim and Objectives

The aim of this research is to develop a conceptual model based on the current practice of construction logistics in building projects which is adapted to economic, cultural, technological and environmental specifications of the construction industry in Iran. To build the model, how materials are estimated, selected, and acquired should be studied. How the packaging is specified, how the delivery schedule is designed, and how waste is managed should also be explored. Furthermore, how contractors plan materials use and how cultural matters affect the way contractors care for the materials provided should be investigated. To do so, three objectives can be explained for this research:

1. To distinguish social and technical factors which affect the process of construction logistics in building projects in Iran. These factors form the agents of the construction logistics system.
2. To identify how the above affecting factors are linked together. In other words, how do agents of the construction logistics system affect each other? These links and connections form the relationships of the construction logistics system.

3. To develop a holistic conceptual model that visualises the agents and relationships of the construction logistics system, while appreciating its properties as a complex system.

The two first objectives are converted into three general research questions:

a. To what extent are practitioners aware of logistics management in their projects?

b. What is the process of construction logistics? (What activities are included?)

c. What are the logistical problems and challenges that the Iranian construction experts experienced in their projects?

The objectives and research questions were considered as part of the process of developing the interview guide and questionnaire. This helped the research not to deviate from its objectives.

1. 6. The Research Process

The research was started by reviewing and evaluating the literature. The literature review focuses on five aspects: (a) general logistics, (b) construction logistics, (c) the Iranian building sector, (d) complexity theory, and (e) the methodology used in social sciences and specifically construction management. Reviewing the literature was not only limited to the beginning of the research project but continued even in the analysis stage. The literature review helped the author to attain a broader understanding of construction logistics. Specifically, the part that is dedicated to the valuable efforts of other researchers to create a model for construction logistics, or develop principles for successful construction logistic management, was important in setting the direction of this research and identifying the gap in the knowledge.

The literature review also helped to refine the philosophical assumptions and methodology of the research. The research has a constructivist ontology that sees reality in the management realm as a social construct and project management knowledge as individual and context dependant. The epistemological position of this research is interpretivism which focuses on the subjective meaning of social phenomena. The qualitative paradigm is utilised in this research as the main approach. However, quantitative data is also used through the complementarity approach that can be referred to as a mixed method approach. As a result of the literature review, and based on the philosophical position of the research, grounded theory was selected as the main methodology of the research.

In the next stage, twenty four in-depth open-ended interviews were conducted with construction experts in Iran. Interviews lasted around one hour and interviewees commented on the construction logistics process in their organisation and explained their beliefs, challenges, problems and solutions for a wide range of logistical affairs. Interviewing was continued up to the point that the desired level of data saturation was achieved. In parallel with interviews, over 200 photos were taken of different construction projects in Iran. These photos are used within the analysis to make it more visual.

Except for five, all the interviews were recorded and transcribed in Farsi. After transcription, the data was inputted into the qualitative data analysis software (NVivo) to be codified. The conventional template analysis was used where the researcher produces a list of codes representing themes identified in the textual data. From the first iteration of the qualitative data analysis (QDA), 41 codes (nodes) were identified. These codes were categorised, merged and restructured in the later stages of the QDA to form four main subsystems of the construction logistics system: Environmental Factors, Operational Factors, Commercial Factors, and Managerial Factors.

During the course of qualitative data analysis, it was noticed that some subjects needed to be investigated in more depth. To complement the result of the QDA, a questionnaire was designed to study and evaluate logistics knowledge, supply chain issues, logistics scheduling, contract methods, transportation, warehousing, logistics organisation, waste, and logistical problems. A total number of 135 responses were received from the questionnaire survey. Data gathered was analysed using descriptive analysis to support and complement the results of the QDA.

By going through the analysis, the agents and relationships of the construction logistics system were identified. These elements were integrated into a conceptual model, which is the final product of this research. The model is created based on the Iranian experts' views and, thus, is compatible with specifications of the Iranian building sector. Finally, the model was presented to three construction experts to obtain their feedback. The general attitude of the experts was positive and they offered some recommendations for improving the functionality of the model in the future.

1. 7. The Achievements of This Research

The results of this investigation enhance the understanding of construction logistics in Iran by describing the current practice of logistics management in building projects. The description is developed based on the experiences of practitioners who are expert in the building sector of the industry. Hence, there would be valuable lessons in the analysis chapters that can be used by researchers and other practitioners. The study reveals the logistical challenges and issues that practitioners may face during the course of the projects' execution. It also discusses the way experts deal with these challenges and introduces some solutions for managing logistics in construction projects. Sharing these experiences can improve construction logistics practice in the building sector.

This research also presents a new conceptual model for managing logistics in building projects. The conceptual model is grounded on the experience of interviewees and, thus, is compatible with the current conditions of the projects in Iran. The model, in addition to encompassing the conventional logistics functions, such as purchasing, transportation, and handling, covers marginal affecting factors such as culture, organisational structure, ICT, inflation, technology, project size and weather conditions. Furthermore, the model is aligned with the complexity mindset that appreciates change and uncertainty. Hence, it illustrates a holistic view of the construction logistics by giving value to both agents of the system and the relationship among those agents. The developed model can be implemented by all building firms; however, medium and large size organisations can make best use of the model. In fact, the larger the organisation, the more benefits can be achieved by adopting the construction logistics model in projects.

1. 8. Thesis Structure

This thesis consists of six parts: background, literature review, methodology, analysis, synthesis and conclusion. These parts are divided into twelve chapters. The background was explained in this chapter (Chapter one). Chapters two to five will cover the available literature. Chapter six will explore the methods used to conduct the research. In chapters seven to ten, the results of the qualitative and quantitative analysis will be presented. Chapter eleven will introduce the construction logistics model. Finally, chapter twelve will summarise what has been done and what has been achieved. A more detailed description of chapters is provided in the following:

1. *CHAPTER ONE: INTRODUCTION*

   This chapter provides a general background for the study. It outlines the aim and objectives of the research and explains why conducting research on construction logistics is important. It also briefly describes the utilised methodology and presents the organisation of the thesis.

2. *CHAPTER TWO: LITERATURE REVIEW - LOGISTICS MANAGEMENT*

   Firstly, this part will provide different definitions of logistics and supply chain management and also introduces some primary issues in these areas. Also, the concept of the supply chain and SCM will be clarified in this part. This chapter explains the process of the literature review, its importance, its aims, and structure of literature chapters. Also, it provides definitions of logistics and expresses the history of logistics development. Moreover, the two topics of logistics management and supply chain management are differentiated in this chapter and the focus of the research is clarified.

3. *CHAPTER THREE: LITERATURE REVIEW - CONSTRUCTION LOGISTICS*

   The second literature review chapter describes how logistics can be implemented in the construction industry. It evaluates different definitions for construction logistics. Also, this chapter describes the previous efforts in the area of construction logistics and clarifies logistics functions in construction projects.

4. *CHAPTER FOUR: LITERATURE REVIEW - THE IRANIAN BUILDING SECTOR*

   This chapter is mainly about the condition of the construction industry and building sector in Iran. Beside this, information about Iran’s history, economy and culture is provided. The chapter aims to describe the context of the research and put the topic of construction logistics management in context.

5. *CHAPTER FIVE: LITERATURE REVIEW – COMPLEXITY THEORY AND MANAGEMENT*

   This chapter covers issues of using the Newtonian mindset in management and offers the complexity mindset as an alternative. It is argued that construction logistics is a complex system and managers should take a holistic view of this system. The main discussion of the chapter is on the intrinsic properties of interactions and the relationships among parts of a complex system, such as construction logistics.

6. *CHAPTER SIX: RESEARCH METHODOLOGY*

   In this chapter, the philosophical position of the author is clarified and the strategy to achieve the objectives of the research is discussed. Furthermore, detailed information is provided on the data collection methods and the way the methods are integrated with each other to form a thesis is expressed.

7. *CHAPTER SEVEN: ANALYSIS – ENVIRONMENTAL FACTORS*

   The first chapter of data analysis describes the process of qualitative data analysis and how quantitative data complements QDA. It also explores environmental factors that affect construction logistics such as resource conservation, weather conditions, project location, and peak working seasons.

8. *CHAPTER EIGHT: ANALYSIS – OPERATIONAL FACTORS*

   In this chapter, issues related to technology, transportation and waste are interpreted. Descriptive statistics is used to make the qualitative interpretation more meaningful.

9. *CHAPTER NINE: ANALYSIS – COMMERCIAL FACTORS*

   This chapter focuses on the supply chain, material purchasing and finance. In chapter nine, the role of clients, consultants, and suppliers in construction logistics is explained. Moreover, the process of material purchasing, estimation, packaging and inspection is covered. The impact of economy condition and material price on construction logistics management is also studied in this chapter.

10. *CHAPTER TEN: ANALYSIS – MANAGERIAL FACTORS*

    This is the longest analysis chapter and presents the result of QDA in relation to logistics organisation, information management, scheduling and material management. In this chapter, there is a discussion about logistics personnel, logistics knowledge and the role of culture in construction logistics. Also, information is provided about material handling, the warehousing process and material protection. The qualitative analysis is supported by tables, charts, and respondents' comments. Beside these, a quantitative analysis conducted on logistics problems in projects is presented.

11. *CHAPTER ELEVEN: SYNTHESIS – CONSTRUCTION LOGISTICS MODEL*

    This chapter describes the process of how the construction logistics model is developed. It introduces the model's elements and expresses how it works. In this chapter, all subsystems of construction logistics systems are integrated together to form a holistic model. At the end, and to make the model credible, the views of three construction experts on the final construction logistics model are presented.

12. *CHAPTER TWELVE: CONCLUSION*

    The final chapter of the thesis presents the conclusions drawn from the research and states what has been done and what has been found. It summarises the achievements of the research and the way it contributes to knowledge. It also highlights directions for further work in construction logistics management and explains recommendations for future research.

Chapter 2

LOGISTICS MANAGEMENT

CHAPTER 2: LOGISTICS MANAGEMENT

2. 1. Overview

This chapter in the first stage, explains the process of the literature review, its importance, its aims, and structure of literature chapters. Then, the history of logistics and selected definitions of logistics and logistics management will be addressed. Moreover, the main functions of logistics will be expressed and the reason why a logistics system should be integrated will be discussed. In this chapter, also, the difference between logistics management and supply chain management will be pointed out and the focus of the research will be clarified.

2. 2. Introduction to the Literature Review

A literature review is an evaluation of the available body of knowledge on a topic, which forms a basis for investigating the topic and guides the research to identify a gap in the existing knowledge (Collis & Hussey, 2009). It is an important step in the research process because in the first stage, it enhances the researcher's understanding of different aspects of the topic and, in the second stage, it highlights arguments, strengths, weaknesses, and issues in previous works (Bryman & Bell, 2003). Generally, the goal of a literature review is to engage, understand and reflect on the relevant body of knowledge underpinning the research. Blaxter *et al.* (2006, p. 122) believed that the literature review aims "to locate the research project, to form its context or background, and to provide insights into previous work." Beside this, the literature review facilitates the researcher to refine the research methodology by becoming acquainted with various methods which have been used by other researchers (Bryman & Bell, 2003).

Considering the above definitions and goals, five objectives can be stated for the literature review in this research:

1. *To enhance understanding of logistics management knowledge by introducing relevant terminology.* It is believed that comprehensive definitions will lead to clear ideas and minimise the risk of ambiguity. Thus, in the first stage, the literature review intends to make the reader familiar with different concepts in the area of logistics and define and explain technical terms that are widely used in logistics related literature.

2. *To identify and describe the related research studies and relevant theories on logistics management, construction logistics, and complexity management.* To grow, the seed must be placed within an appropriate context - a pot and some soil. In the second stage, a literature review provides a context for the research.
3. *To study and investigate characteristics of the Iranian building industry.* This section expresses the conditions of the construction industry in Iran and considers the regulations, cultural matters, and economic issues in this country. The aim is to create a framework for the study and put the topic of construction logistics management in the context of the Iranian construction industry.
4. *To identify and evaluate methodologies adopted by different researchers in the area of construction logistics management.* This enables the researcher to adopt the most appropriate methods regarding the nature of the research.
5. *To identify and locate a gap in the previous research which needs to be filled.* This is an important stage because it justifies the necessity for conducting this research and introduces the potential contribution that this research will have to the body of knowledge.

To meet the objectives expressed above, the literature review of this research is divided into four chapters: (1) Logistics Management (Chapter two), (2) Construction Logistics Management (Chapter three), (3) The Iranian Building Industry (Chapter four), (4) Complexity and Management (Chapter five). In each literature review chapter, related terms will be defined and major issues and debates about the theme will be discussed.

To describe the organisation of the literature review, it is helpful to visualise its structure using some diagrams. Wellington *et al.* (2005, p. 82) illustrated four organisational patterns for reviewing literature: (1) zooming, (2) finding intersection, (3) patch working and (4) funnelling (Figure 1). A patch work can be used for the whole review, labelling each patch according to the different strands of the review. Other diagrams can be devised for each particular theme in the review to adopt a general to specific pattern moving from long shots to close ups.

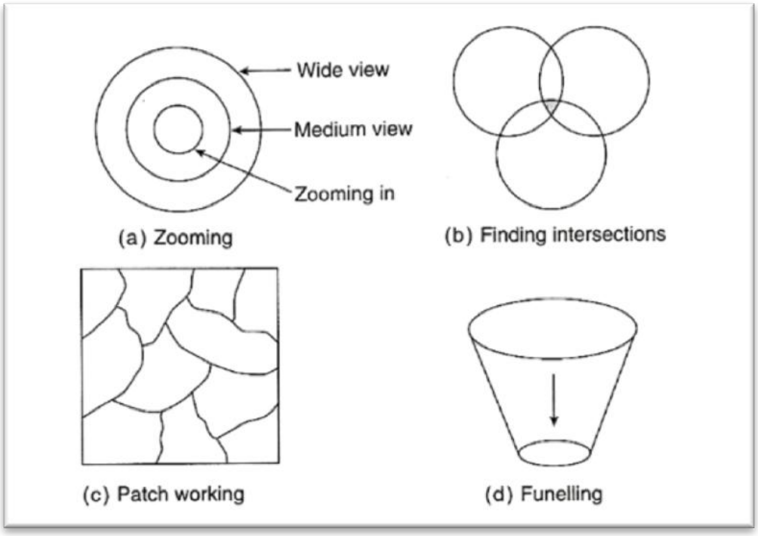


Figure 1: Organisational patterns for the literature review (Wellington, Bathmaker, Hunt, McCulloch, & Sikes, 2005, p. 82)

Figure 2 shows the way that the literature review is organised in this research. First, four different but interrelated themes of literature were studied to provide a strong basis for the research. This is illustrated as a jigsaw (or patch work) in Figure 2A. Then, for each theme a funnelling pattern is adopted (Figure 2B). It means that the review started wide with the overview and terminology and then narrowed down into a discussion of efforts that have been done so far and, finally, offered a conclusion.

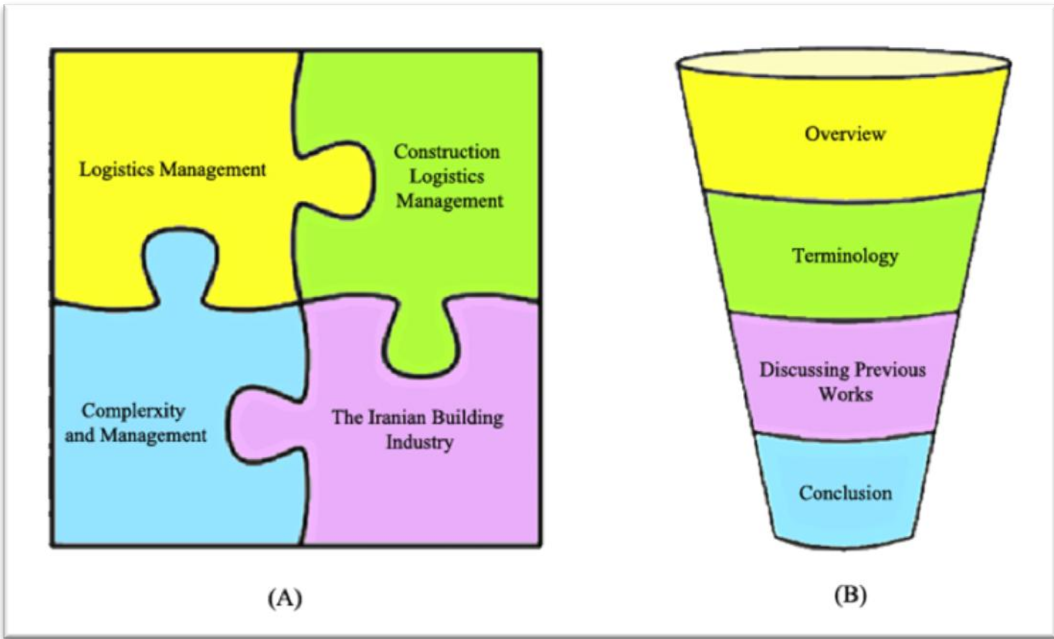


Figure 2: Structure of the literature review

2. 3. Definition and History of Logistics

Logistics is not a new term as it has been a human interest since items were moved from one location to another. The Cambridge Online English Dictionary defines logistics as “the careful organisation of a complicated activity so that it happens in a successful and effective way” (Cambridge-Online-Dictionary, logistics definition, 2010). The stress in this definition is put on ‘organisation’, ‘complication’ and ‘effectiveness’. Organisation means the planning of an activity or event. Complication means having a lot of different parts, in a way that is difficult to understand. Effectiveness is a measure of the quality of attainment in meeting intended objectives. Hence, so far, logistics can be defined as the act of planning to accomplish a task that has many not easily understandable parts, to reach objectives that are intended ahead. The Oxford Online English Dictionary also has a description for logistics (Oxford-Dictionaries, Logistics Definition, 2010): “the activity of organising the movement, equipment, and accommodation of troops.” This definition points out the nature of tasks that should be accomplished under the topic of logistics: moving, equipping and accommodating. Thus, the definition expressed above can be completed as: planning for all various activities that are included in moving, equipping and accommodating resources to attain objectives that are intended ahead. The Oxford Dictionary’s definition also reveals the origin of logistics, which is rooted in the military sector. The word ‘logistics’ is derived from the title of the Major General des Logis (translated in German as quartermaster), an officer who was responsible for lodging the troops, giving direction to the marches of the columns and locating them upon the ground (Scott, Rainey, & Hunt, 2000). Modern military logistics in different literature is described as the practical art of the supply, movement and maintenance of armed forces, including the tanks, armoured personnel carriers, artillery pieces, helicopters and aircraft (Scott, Rainey, & Hunt, 2000; Henderson, 2008; Thorpe, 2002).

From a thousand years ago, logistics, along with strategy and tactics, have been important in different wars, and the slighting of any one leads to failure on the battlefield (Scott, Rainey, & Hunt, 2000). There are many stories about leaders who won warfare by realising the importance of logistics. For instance, Alexander decided to increase the loads of his soldiers as much as possible instead of having carts that were slow (Scott, Rainey, & Hunt, 2000). This made his troops fast and mobile which terrified his opponents.

When wars began to be more complicated (e.g. without camps), the meaning of logistics was expanded owing to the importance of movement and mobilisation. Kim (1996) regarded logistics as the combat power multiplier and explained that the combat power of a military force can be worked out by multiplying weapons, manpower and logistics abilities (Kim, 1996). Hence, it is not surprising that logistics has attracted much attention in the military sector.

From the 1950s, logistics have come to be recognised as a vital function within the business environment (Rushton, Croucher, Baker, & Oxley, 2006). Through past decades, the field of logistics has grown significantly with emphasis on different but related areas. In addition to procurement and distribution functions, the realm of logistics has been expanded to include those activities pertaining to design and support, such as supply support, test and support equipment, personnel training, material handling, and information technology (Blanchard, 1998). It is necessary to define logistics in the business context to reveal the different functions that it may have in this sector. However, there is a lack of a unique and comprehensive definition for logistics management that embraces all aspects and branches of this concept in different industries. The reason is the variety of businesses, products, materials, systems and legislations which may affect the function of logistics management. Thus, several definitions of logistics management are available that are aligned with the nature of each particular industry. Rushton *et al.* (2006, p.4) defined logistics as the following: "Logistics = Supply + Material Management + Distribution". In this definition, supply means procuring raw materials, components, parts and packaging items. Material management includes the storage and flow of supplied items into and through the production process, encompassing packaging, unitisation and finished good warehousing. Distribution represents the storage and flow of the final product from the production point to the customer. The Chartered Institute of Logistics and Transport of the UK (CILT) explained logistics as "the positioning of resources at the right time, in the right place, at the right cost, at the right quality" (CILT, 2005). This definition is concerned with both ‘doing the right thing’ and ‘doing things right’. To be aligned with this definition, there is a need for a tool that ensures the efficiency and effectiveness of the logistics system. This tool is labelled ‘logistics management’.

2. 4. Logistics Management

After exploring the logistics concept from different perspectives, the meaning of logistics management should be clarified. But, first, it should be explained why logistics management is important. Attention to logistics has been increased in different industries during recent years. This is owing to (1) the high price of logistics tasks which represents a huge amount of cost to the industries and (2) potential competitive advantages reachable via distribution networks and customer services (Rushton, Croucher, Baker, & Oxley, 2006). Christopher (1998) emphasised that logistics management has a great potential to help organisations to achieve both cost and value advantages. He expressed that it is essential for each business to understand the nature of logistics costs and try to keep these costs to a minimum (Christopher, 1998). Rushton *et al.* (2006) categorised the major factors that affect total logistics costs as transportation, warehousing, and logistics management. They claimed that logistics management has the most effect on logistics costs saving, in spite of consuming the lowest proportion of total logistics costs (Rushton, Croucher, Baker, & Oxley, 2006). Beside its costly nature, logistics faults may also cause loss of reputation and customer satisfaction which are hard to regain once lost (Langford J. , 2007). Thus, proper designing, planning and control are required to manage a logistics system. The Project Management Body of Knowledge guide (PMBOK) also recognises the importance of logistics management and categorises it under the area of 'expertise' and 'general management knowledge and skills' topics (PMBOK guide, 2004). It explains that general management concepts, such as logistics, provide the foundation for building project management skills and are often essential for project managers.

2.4.1. Logistics Management Definition

Through the past few decades, the field of logistics management has grown significantly with an emphasis on several different but related areas. In addition to the procurement and distribution functions, the realm of logistics management has been expanded to include those activities pertaining to design and support. Today, logistics management is an umbrella term that may include supply support, equipment testing, transportation, material handling, storage and asset tracking (Blanchard, 1998).

There is no comprehensive definition that covers all aspects of logistics management in different industries. Available definitions usually focus on the limited functions of logistics management and ignore others. Generally, logistics management is a tool which ensures the efficiency of the logistics system. Its first role is to evaluate all facilities and issues which may have any impact on logistics cost and make the product conform to the customer's requirements (Simchi-Levi, Chen, & Bramel, 2005). As the second role, logistics management tries to minimise cost and provide a cost-effective system across the whole process of production from transportation and distribution of raw materials to the inventories, work in process and finished products (Simchi-Levi, Chen, & Bramel, 2005).

Christopher (1998, p. 13) defined logistics management as “the means whereby the needs of customers are satisfied through the co-ordination of the materials and information flows that extend from the marketplace, through the firm and its operations and beyond that to suppliers”. Christopher’s idea is visualised in Figure 3. This definition expresses the span of logistics management and emphasises the importance of material and information flow in logistics management. However, terms like ‘co-ordination’ and ‘operation’ are vague and need clarification.

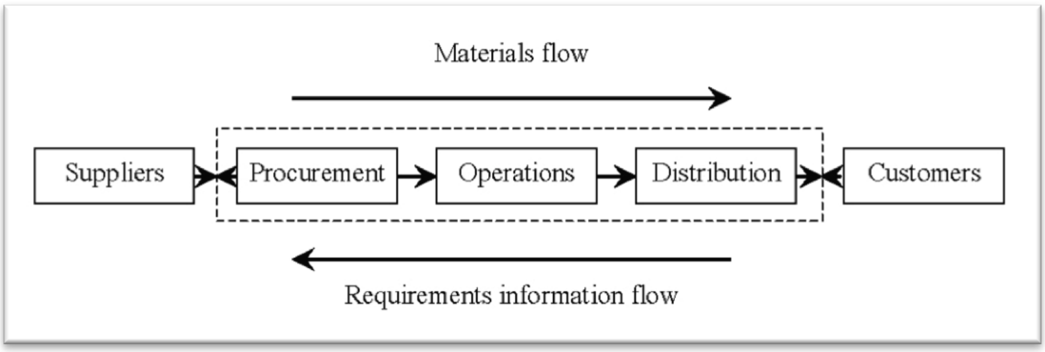


Figure 3: Logistics management process (Christopher, 1998)

Another simple definition for logistics management was explained by Rushton *et al.* (2006, p. 6) as “The efficient transfer of goods from the source of supply through the place of manufacture to the point of consumption in a cost-effective way whilst providing an acceptable service to the customer”. The stress in this definition is on transfer, sourcing, cost effectiveness and acceptable service. This definition is also too general to reflect issues, such as planning, information flow and reverse logistics.

Simchi-Levi *et al.* (2005), described logistics management in three areas:

1. In logistics management, all facilities which may have any impact on logistics cost and make the product conform to the customer's requirements should be evaluated. This task covers all issues from the early stage of supplier and manufacturing facilities through warehouses and depots to retailers and end customers.
2. Across the entire logistics system from transportation and distribution of raw materials to the inventories, work in process and finished product, logistics management tries to enhance cost effectiveness.
3. The main role of logistics management is planning and controlling the logistics network. Planning should be considered in strategic, operational and tactical levels.

The Council of Supply Chain Management Professionals (CSCMP) defined logistics management as a "part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements" (CSCMP, 2007). It seems that this definition is the most comprehensive definition for logistics, although it needs some modification when applied in different industries.

Considering the definitions cited above, material flow and information flow are the focal point of logistics management. In fact, all activities in logistics management aim to lubricate the process of material and information flow in an organisation. These two terms will be discussed in more detail in the next sections.

2.4.2. Material Flow

Generally, the main aim of logistics management is to maintain prompted and continuous materials flowing from the source to the end customer. Harrison and Hoek expressed that "flow measures the quantity of materials that passes through a given network per unit of time" (Harrison & Hoek, 2005, p. 11). As shown in Figure 3, the direction of material flow is from left to right. It starts from the supplier and goes through the production process and, finally, will be stopped at the customer point. Knill (1992) believed that effective material flow in a supply chain should have two characteristics: continuity and synchronisation. Continuity includes elimination of interruption, unnecessary accumulations and bottle-neck points. Synchronisation means on-time and sequential delivery of materials exactly to the point they are needed.

2.4.3. Information Flow

Information is critical in logistics management. Harrison and Hoek (2005) believed that information acts as the 'glue' in a supply chain that binds all the elements together. As made clear in Figure 3, the direction of information flow is the reverse of material flow. The reason is that customers signal the whole supply chain based on their demands. These signals are referred to as information. Accurate, detailed and timely information has the potential to enhance the efficiency and productivity of the material flow (Langford J. , 2007). Beech (1998) used a circle to illustrate the information flow instead of a direct line (Figure 4). He emphasised that information passes through each element of the supply chain twice: first, demand signals start from the customer and flow through the supply chain in the opposite direction to material flow and, second, demand fulfilment information goes through the chain from the supply side towards the customer in parallel with material flow. Information and communication technology (ICT) has the potential to enhance the quality and quantity of information flow in a supply chain (Rushton, Croucher, Baker, & Oxley, 2006).

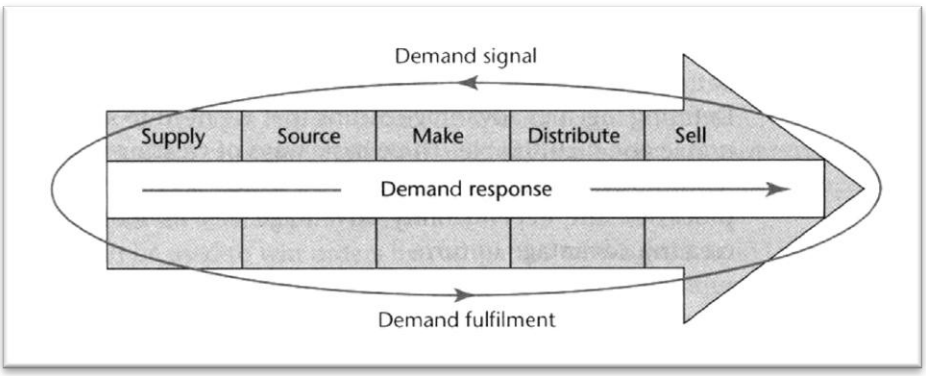


Figure 4: Integrating the demand and supply chain (Beech, 1998, p. 95)

2.4.4. Logistics Functions

Logistics management functions typically include inbound and outbound activities (Wood, Barone, Murphy, & Wardlow, 2002; CSCMP, 2007). The main functions are logistics network designing, supply and demand planning, transportation management, fleet management, material handling planning, warehousing management, inventory management, administrating third party logistics services providers, and order fulfilment (CSCMP, 2007). In some cases, the functions of logistics may expand and encompass sourcing and procurement, production scheduling, labelling, packaging, and customer service (Wood, Barone, Murphy, & Wardlow, 2002; Rushton, Croucher, Baker, & Oxley, 2006).

Rushton *et al.* (2006) developed a diagram (Figure 5) that illustrates some functions of logistics. In Figure 5, the flow of materials and information is shown using arrows with different patterns. From the left, raw materials enter the system and go through the production process. After assembling and packaging, the product is sent to distribution centres for delivering to the customers. An important point in Figure 5 is that a small white arrow shows the reverse logistics which involves dealing with a returned item.

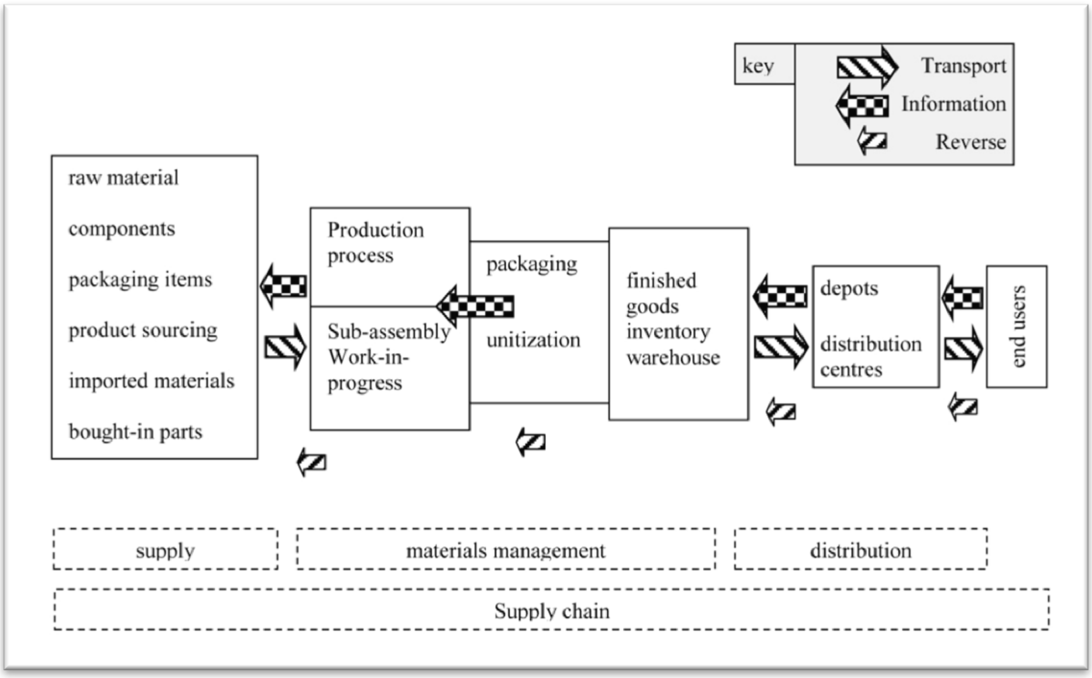


Figure 5: The configuration of key components of logistics, Adapted from: (Rushton, Croucher, Baker, & Oxley, 2006, p. 5)

Another point in Figure 5 is the integration of logistics functions. CSCMP (2007) expressed "logistics management is an integrating function which coordinates and optimises all logistics activities, as well as integrates logistics activities with other functions, including marketing, sales, manufacturing, finance, and information technology". To be integrated into the whole production system, logistics should be considered in all planning, operational, and tactical levels. This will be explained in the next section.

2.4.5. Logistics Integration

Several researchers pointed out the importance of logistics integration. For instance, Gimenez (2006) studied the logistics integration process and divided it into two types:

1. *Internal integration:* the coordination, collaboration and integration of logistics with other functional areas in the company, such as logistics-marketing and logistics-production.
2. *External integration:* integration of a firm's logistics activities with customers and suppliers.

Rushton *et al.* (2006) discussed the total logistics concept (TLC) and expressed its role as an integrated system which encompasses different elements that come under the logistics topic as a single entity. They emphasised that the interrelationships between different elements of a logistics system should be considered within a broader context. In the other words, individual elements of a logistics system should not be studied in isolation and the whole system should be considered for managing logistics.

2.4.6. Trade-off Analysis

Integration of a logistics system provides a ground for conducting a trade-off analysis and adding value to the supply chain members. Trade-off means "some parts of an operation may sacrifice efficiency to the greater good of the operation as a whole" (Rushton, Croucher, Baker, & Oxley, 2006, p. 21). For example, a company may conduct a cost trade-off analysis and distinguish that, although spending money on quality packaging increases the cost of the product, it may save costs through efficiency improvement in the warehousing process. Kim (1996) stated trade-off analysis is widely used as a tool in different industries for managing logistics. It should be clarified that, as confirmed by Kim (1996), to conduct a trade-off analysis, an individual should have a clear understanding of the elements of the logistics system and also the nature of the relationships which exist among those elements. In fact, a trade-off analysis requires taking a holistic approach toward the logistics system. That is why this research aims to develop a holistic model for managing construction logistics in projects. The holistic approach will be addressed in more detail in Chapter five of the thesis.

2. 5. The Supply Chain (SC) and Logistics

In the previous section, logistics management was defined. In this section, the supply chain (SC) and supply chain management (SCM) will be defined and their distinction from logistics management will be clarified.

2.5.1. Supply Chain Definition

The supply chain is "the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer" (Mangan, Lalwani, & Butcher, 2008). The word 'network' is widely used instead of "chain" in the literature (Christopher, 1998; Harrison & Hoek, 2005; Rushton, Croucher, Baker, & Oxley, 2006) for two reasons: (a) there are multiple suppliers and multiple customers (suppliers' suppliers and customers' customer) and (b) links, relationships and interactions between the various entities can be better understood in this way. In the network approach, the organisation is located in the centre and linked to different suppliers and customers (Figure 6).

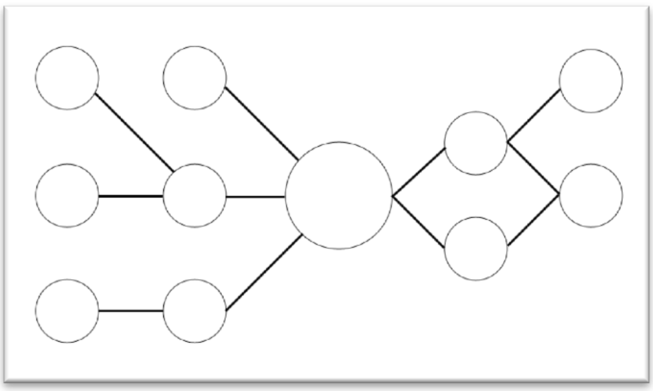


Figure 6: Primary supply chain

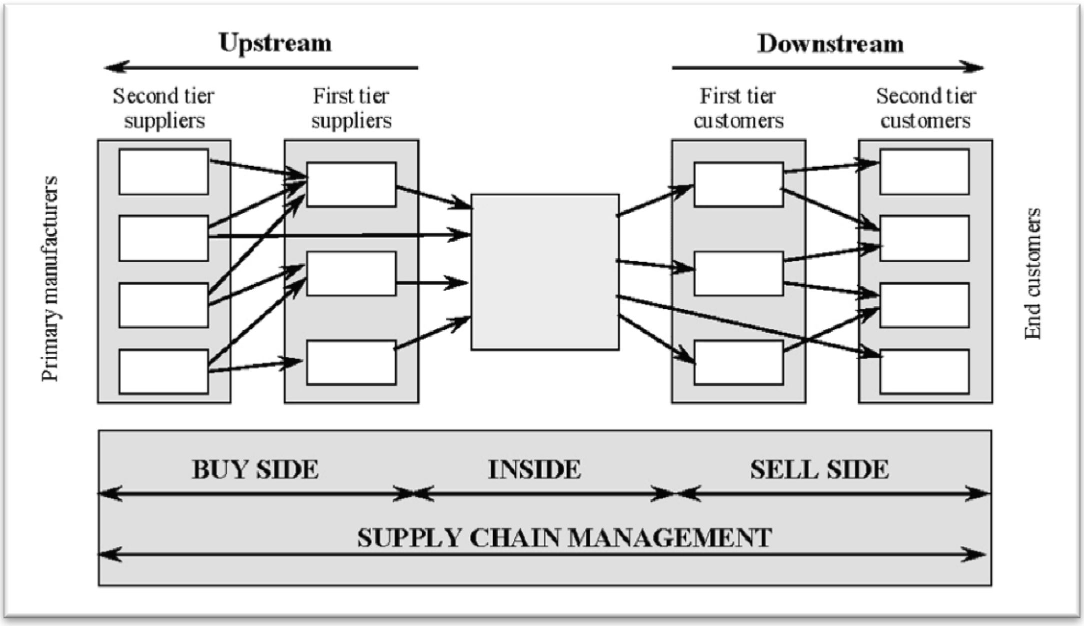


Figure 7: Relationships in the supply chain (Harrison & Hoek, 2005, p. 9)

A more realistic model for a supply network that illustrates nodes (SC members) and their relationships is developed by Harrison and Hoek (2005) (Figure 7). In this model, the organisation is positioned at the centre and a network of suppliers and customers are linked to it using arrows that show material flow. The whole supply chain is divided into three sections of buy side, inside, and sell side.

2.5.2. Supply Chain Management

Supply chain management (SCM) is about managing a network of organisations in which buyers and suppliers are linked together to serve the end customer (Harrison & Hoek, 2005). Christopher defined SCM as “The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole” (Christopher, 1998). The process of SCM includes procurement, production scheduling, order processing, inventory management, transport, storage, customer service and information management (Morledge, Knight, & Grada, 2009). To manage the supply network, an organisation should make decisions in five areas (ILS, 2007): (1) location, (2) production, (3) inventory, (4) transportation, and (5) information (how to gather, process, and share information).

2.5.3. Differentiating Logistics and Supply Chain Management

Logistics and supply chain management are close subjects and, in some cases, have been used interchangeably (Rushton, Croucher, Baker, & Oxley, 2006). This is owing to vague conceptual boundaries, definitional similarities and overlapping functions. However, there are areas that differentiate these two topics. While reviewing logistics and SCM literature, Larson and Halldorsson (2004) identified four perspectives on SCM versus logistics: traditionalist, re-labelling, unionist and inter-sectionist (Figure 8).

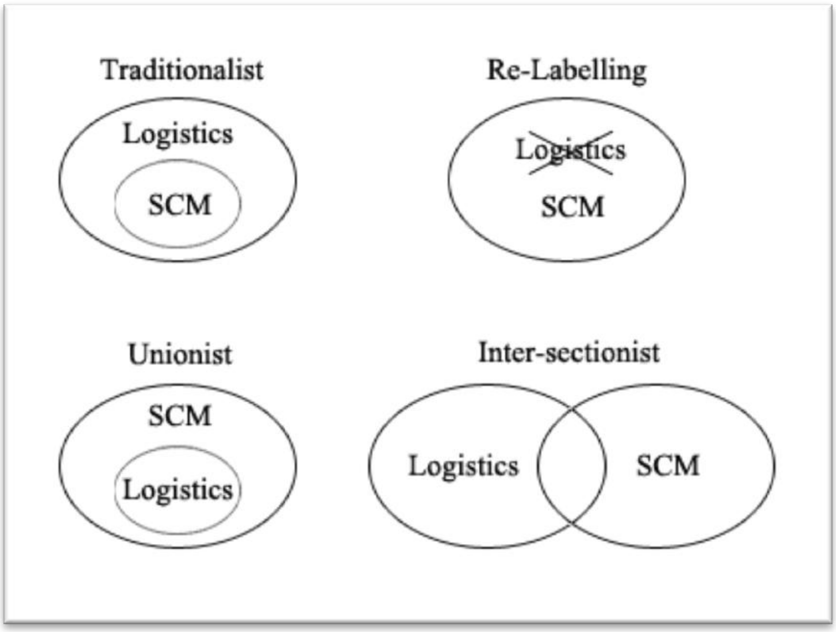


Figure 8: Perspectives on logistics versus supply chain (Larson & Halldorsson, 2004, p. 19)

Traditionalists regard SCM as a subset of logistics which has been evolved from logistics. The re-labelling view expresses that logistics has been re-labelled by the newer term SCM. The unionist view sees logistics as part of the wider context of SCM. The inter-sectionist view appreciates the overlap between parts of both logistics and SCM, but confirms that each topic has its parts that are separate and distinct. The approach of this research is to adopt the unionist view which assumes SCM as an umbrella term that covers logistics. In fact, as Christopher (1998) explained, logistics management aims to optimise flows and integrate internal functions (internal integration) while SCM extends internal integration to the suppliers and customers (external integration) (Figure 9). Mangan *et al.* (2008) also confirmed this idea and stated that SCM is a wider, inter-company, boundary-spanning concept in comparison to logistics. In other words, SCM, in addition to logistical affairs, includes managing relationships with the suppliers, sharing information in the supply network and dealing with customers' enquiries (Lummus, Krumwiede, & Vokurka, 2001). It can be concluded that the focus of logistics is on a specific organisation, business or project, while SCM aims to deal with the whole network, which may encompass several independent firms.

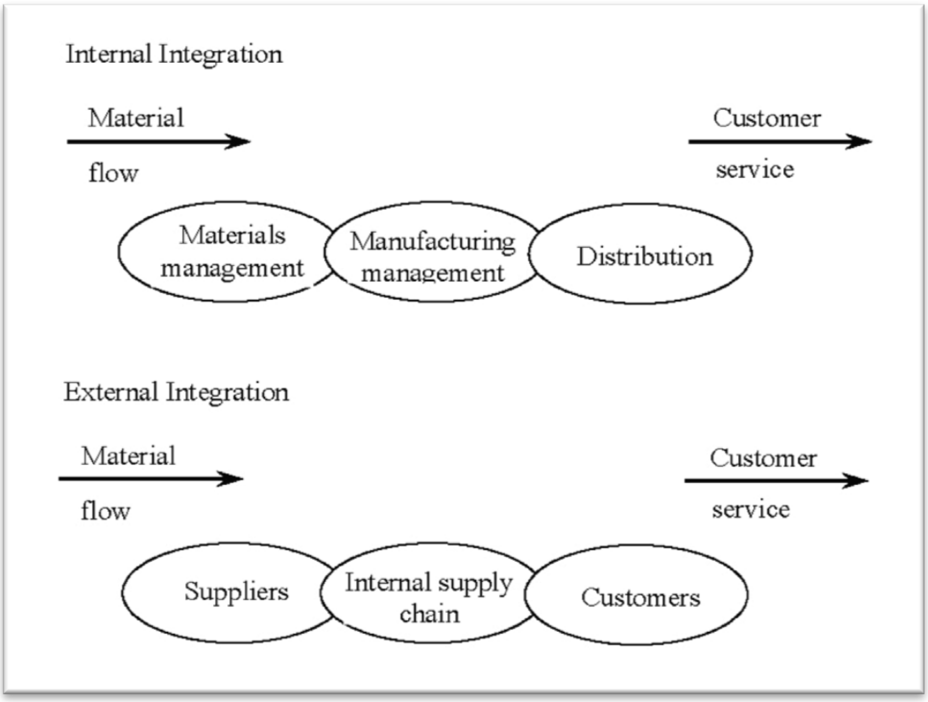


Figure 9: Internal and external integration, Adapted from (Christopher, 1998, p. 17)

2. 6. Conclusion

This chapter described the process of a literature review and introduced its structure. Five objectives of reviewing literature in this research are (a) becoming familiar with the logistics terminology, (b) describing and evaluating literature on logistics, construction logistics, and complexity, (c) studying the Iranian building sector, (d) reviewing methodologies used in construction management research, and (e) identifying the gap in the existing body of knowledge. .

This chapter also introduced the logistics management concept by providing some definitions. In summary, logistics is about delivering items accurately, efficiently and in a timely manner to the place required. Material and information flow as two critical points were also addressed. Moreover, the different functions of logistics were explained in this chapter. Furthermore, it was explained that logistics should be seen as an integrated system and a single entity. By taking a holistic view towards logistics, benefits can be achieved using trade-off analysis. In this chapter, the supply chain and supply network were also defined. It was expressed that the research adopts the unionist view which assume logistics as a part of SCM. It can be stated that logistics involves internal integration and SCM involves external integration of a logistics system.

Chapter 3

CONSTRUCTION LOGISTICS

CHAPTER 3: CONSTRUCTION LOGISTICS

3. 1. Overview

This chapter describes the logistics concept in the construction industry. The first part of the chapter is descriptive and provides different definitions of construction logistics and lists functions that are associated with this term. The aim is to make the reader familiar with different branches of construction logistics. The distinction between site logistics and supply logistics is explained and the focus of the research is clarified. Five important functions of construction logistics are also described in detail and the available literature for each function is reviewed briefly. The second part evaluates the previous efforts by referring to the researchers who attempted to manipulate models or guidelines for construction logistics. At the end of this chapter, the gap which is identified in the body of knowledge is highlighted.

3. 2. Logistics Management in Construction

Logistics management has rarely been applied in the construction industry. One reason may be that logistics management researchers are often specialised in business, distribution, transportation, and general supply chain management. Hence, they automatically carried out research based on the basic assumptions of industries, such as manufacturing, food or retail, that are mass production, product standardisation, heavy customer service and automation. However, in construction, owing to the nature of this industry, some of these concepts are not applicable or should be modified to be used. For instance, Ibn-Homaid (2002) compared the materials management process in manufacturing and construction and concluded that there are differences at the various levels of detail.

Many authors have described the special characteristics of the construction industry. The Strategic Forum for Construction (SFfC) (2005), Cox *et al.* (2006), Morledge *et al.* (2009) and Sullivan *et al.* (2010) pointed out the following specifications for the construction industry:

- Uniqueness in design
- Design and production separation
- Single product
- One-off and matchless project
- Temporary location
- Short-time projects

- Temporary organisation
- Indirect employment
- Adversarial relationships among parties
- Fragmented supply chain
- Site production
- Inaccurate information based on estimation

Owing to the above differences between the construction industry and manufacturing, it is almost impossible to replicate the manufacturing methods in construction (Sullivan, Barthorpe, & Robb, 2010). Hence, a logistics model that is designed for other industries cannot be properly applied in construction and a new framework should be developed for logistics management that understands and respects the characteristics of the construction industry. Construction researchers' attempts to achieve such a framework will be presented in the last section of this chapter.

3. 3. Construction Logistics Management

In construction projects, logistics management includes mobilising the various resources (man, material, and machine), ensuring that resources are in the right place in the right quantity and at the right time, and providing a condition that enhances quality, safety and efficiency in the project. The span of logistics management is illustrated in Figure 10. Based on several definitions and explanations that are provided in the literature for construction logistics (Guffond & Leconte, 2000; Hill & Ballard, 2001; Jang, Russell, & Yi, 2003; Cox, Ireland, & Townsend, 2006; Sullivan, Barthorpe, & Robb, 2010), ten functions of logistics management in construction projects can be explicated as the following:

1. Specifying supply sources
2. Acquisition of resources
3. Logistics planning and scheduling
4. Site layout designing
5. Transportation
6. Material inspection
7. Warehousing
8. Handling
9. Waste management
10. Security

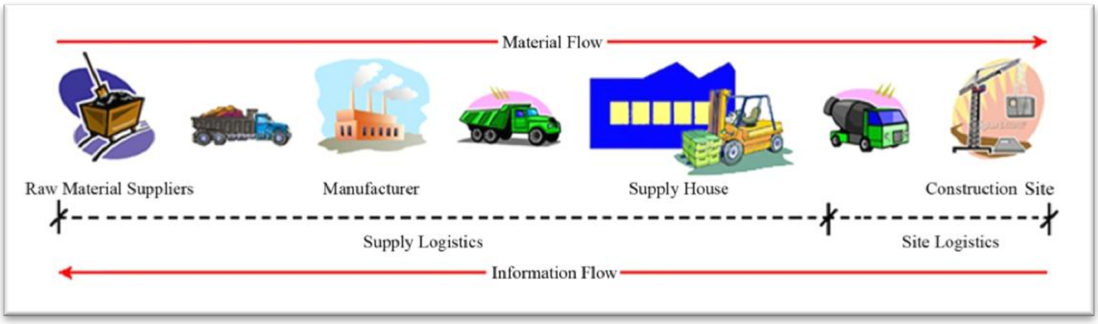


Figure 10: The span of construction logistics, Adapted from (Jang, Russell, & Yi, 2003, p. 1134)

3. 4. Site Logistics and Supply Logistics

Some researchers, such as Da silva and Cardo (1999) and Thomas *et al.* (Thomas, Riley, & Messner, 2005), divided construction logistics into two parts: (a) supply logistics, and (b) site logistics (Figure 10). Figure 11 shows the divisions of supply logistics and site logistics. Some functions, such as transportation, are in the overlap area because they can be member of both groups. Although the focus of this research is on site logistics, a brief description of supply logistics is provided in the next section.

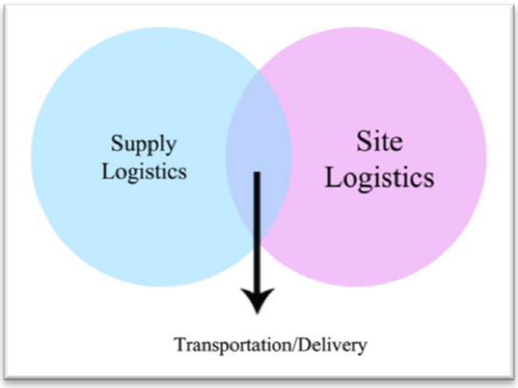


Figure 11: Construction logistics divisions

3.4.1. Supply Logistics

Supply logistics can be assumed as an equal term to supply chain management which includes managing suppliers, supply planning, acquisition of resources, transportation and delivery (Da Silva & Cardo, 1999). The final form of a supply chain in the construction industry is a system of multiple supply chains delivering all raw materials, human resources and required information to bring success to the project (Westling, 1991). Different researchers (Fryer, Fryer, Egbu, & Ellis, 2004; Cox, Ireland, & Townsend, 2006) identified strategies for improving construction supply chain management that can be summarised as:

- Establishing a stable partnership
- Modular outsourcing of components
- Design for suitability for manufacturing
- Evolution of the supply chain with the product life cycle
- Information sharing

3.4.2. Site Logistics

Site logistics, which is the main focus of this research, encompasses material delivery, handling, storage, health and safety, site layout designing, and scheduling (Da Silva & Cardo, 1999; Thomas, Riley, & Messner, 2005). Considering ten functions of construction logistics, site logistics can be expanded to five areas as: (a) logistics planning, (b) purchasing, (c) material management, (d) information management, and (e) waste management. Each of these topics will be covered in the following sections.

3. 5. Logistics Planning and Scheduling

Planning is necessary for managing logistics of projects to ensure that the right materials arrive at the right time to the site. Logistics planning involves developing a material procurement schedule which includes the materials list, the suppliers, and lead times (CITB-Construction-Skills, 2006). The schedule helps "to create a regular heartbeat, with regular and consistent arrivals" (Sullivan, Barthorpe, & Robb, 2010, p. 70). To plan properly, a logistics manager should attain a thorough understanding of the local area, drawings, type of building, construction method, material specifications, the construction programme, constraints (e.g. working hours, allowed delivery time, and site location), and facilities and staff requirements for handling (Sullivan, Barthorpe, & Robb, 2010). CITB-Construction-Skills (2006) introduced five scheduling strategies:

1. *Maintaining buffer stocks on site:* commonly used materials (e.g. insulation) with short lead times.

2. *Match the pace of work:* a delivery schedule is agreed between the project and the supplier to deliver the materials (e.g. bricks) in a sequence aligned with the work progress.
3. *Just-in-time ordering:* no buffer time allowed in placing order (consequence of poor planning or unpredicted events).
4. *Just-in-time (JIT) delivery*: materials arrive just in time for incorporation into the building. JIT works for steel sections, yet there are factors that make JIT delivery impossible such as buying in bulk to get a discount or suppliers' low commitment and inconsistency.
5. *Programming the procurement process*: for materials (e.g. windows) that have lengthy design and manufacturing process.

There are factors that endanger the logistics plan and should be avoided by the construction firms. A short list of these factors is provided in the following (CITB-Construction-Skills, 2006):

- Long lead time (e.g. lifts)
- Material unavailability
- Unavailability of labour
- Lack of information about material specifications
- Changes to specification or design
- Incomplete order
- Incorrect quantity estimation

3. 6. Site Layout Designing

Designing the site layout encompasses assigning access, egress and traffic routes, providing enough and suitable storage spaces, positioning administration buildings welfare facilities and equipments, and considering the services locations and site boundaries (Mawdesley, Al-jibouri, & Yang, 2002; Thomas, Riley, & Messner, 2005). Most site layout researchers have used algorithms to find optimal solutions for site layout. The most common method is the genetic algorithm which was used by Li and Love (2000), Mawdesley *et al.* (2002), and Lam *et al.* (2009). These studies developed valuable models for optimising cost or transportation flows. However, the problem is that there are many factors affecting site layout, such as schedule, operational sequences, topographical aspects, and project size, that are not considered in those models and this makes the applicability of these models suspicious. The site is dynamic and changes according to the construction progress. Hence, an optimum solution for the first month could be unsuitable for the second month. Thomas *et al.* (2005) believed a heuristic method is more satisfactory because it allows the planner to use his/her experience and knowledge to address the uniqueness of each site.

Another approach to site layout research is using computer-aided design (CAD). Sadeghpour *et al.* (2004) proposed a CAD-based model that allows the configuration of physical objects and their attributes to suit the unique demands of each project. This model is more practical compared with the algorithms because it utilises the user's experience and considers different criteria and site conditions. However, the issue of optimisation is still questionable.

3. 7. Purchasing

Purchasing is the starting point of the logistics process and incurs much cost to construction firms. Normally, in the purchasing stage, the buyer selects a supplier among competent firms (Cox, Ireland, & Townsend, 2006). There is often a supply manager who attempts to obtain the highest-quality materials at the lowest possible price for their organisations (Benton & McHenry, 2010). The supply managers should be experts on the materials and undertake the following tasks (Benton & McHenry, 2010):

- Select the most suitable bulk materials, commodities, or services
- Choose the suppliers
- Negotiate the lowest price
- Award contracts
- Make sure the correct amount of the material is received at the appropriate time
- Conduct background checks on suppliers
- Establish long-term relationships with suppliers

Selecting a suitable supplier is an important stage in the purchasing process that should have a logical process (Pryke, 2009). The literature emphasised that supplier selection should be based on the value-added capabilities and not purely on the prices (Dubois & Gadde, 2000; Pryke, 2009; Virhoef & Koskela, 2000). The supplier selection is based on quality, price, service support, and reliability (Benton & McHenry, 2010).

The current trend in materials purchasing is to reduce the numbers of suppliers and establish a long-term relationship with them (Virhoef & Koskela, 2000; Cox, Ireland, & Townsend, 2006). Benton and McHenry (2010) expressed that in today's economic conditions, with rising prices and scarce resources, a strong and long-term relationship is required between construction organisations and suppliers. However, establishing a long-term relationship between parties that pursue their own economic interests is not easily achievable. Furthermore, because construction firms take on projects in different locations, having long-term relationships with suppliers that often work locally is not possible. A construction firm that has a project in the UK may build a facility in the Middle East in the future and cannot purchase materials from suppliers in the UK. Other common problems that may occur in the purchasing period are: incapability of identifying the proficiency of suppliers, economic fluctuation, low commitment, standards misunderstanding, and poor estimation on volume of required materials (Pryke, 2009).

3. 8. Material Management

Material management means the preparation and flow of different items in a construction site. It is an important topic, because materials account for 5-60 per cent of project cost and control 80 per cent of the schedule (Ibn-Homaid, 2002). Material management deficiencies, such as running out of materials, improper storage, double handling, out of sequence deliveries, and poor housekeeping, frequently cause disruption to the construction process (Thomas, Riley, & Messner, 2005). In the following sections, material management will be divided into three topics of material delivery, warehousing, and handling.

3.8.1. Delivery

Getting materials to the site and delivering them to the right place at the right time is the key for successful material management (Hill & Ballard, 2001). The project location, delivery capacity, allowed delivery hours, and delivery slots are issues that should be addressed in this stage (Sullivan, Barthorpe, & Robb, 2010). The daily site meeting takes place to ensure all parties will get the items they need for the next day (Sullivan, Barthorpe, & Robb, 2010).

Transportation and delivery channels should be determined before the construction stage. Issues that should be considered for efficient transportation are access to the site, capacity utilisation of vehicle, travel distance, and waiting times for unloading (CITB-Construction-Skills, 2006). SFfC (2005) explained that there is non-quantified evidence that shows the inadequacy of transportation in construction sites, such as lorries moving around the roads either empty or with part-loads and lorries having to wait for a long time to be loaded or unloaded.

Hill and Ballard (2001) developed a diagram for different delivery channels of construction projects (Figure 12). Choosing a reasonable and logical selection of delivery channels should be done in a way that the desired service level is achieved at minimum cost (Hill & Ballard, 2001). The significant information in Figure12 is that the shortest route (from manufacturer to the point of use) is not always the best choice. In many cases, buffers are required by having different types of storage areas to manage unpredicted events onsite.

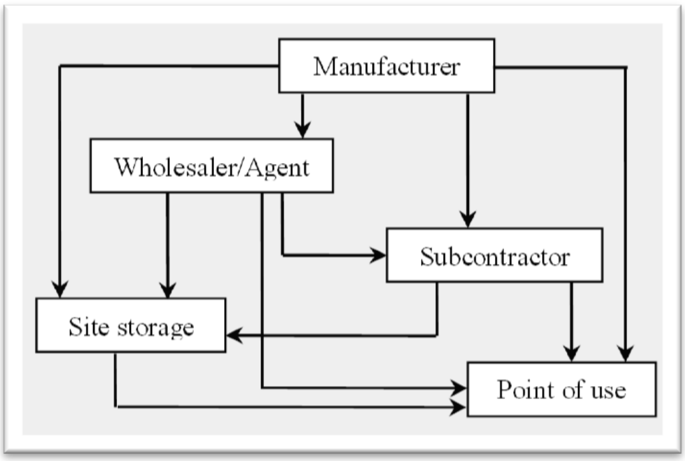


Figure 12: Construction material delivery channels (Hill & Ballard, 2001, p. 5)

There is research that attempted to use new methods to solve delivery issues. For instance, Ala-Risku and Kärkkäinen (Ala-Risku & Kärkkäinen, 2006), recommended creating short-term schedules, based on a constraint analysis of resources, for different project tasks to overcome the challenges of the materials delivery process.

They insisted on transparency in the material inventory yet they did not address how transparency can be achieved. Other researchers use technologies such as RFID and Gate-Sensor to monitor inventory information and delivery status (Song, Haas, Caldasa, Ergenb, & Akincib, 2006; Lee, Song, Kwon, Chin, Choi, & Kim, 2008). Automated data acquisition brings accuracy and reduces the risk of mistakes but, in most research, the results are limited to specific material types. Issues such as frequency interference between two tags, or between tags and materials, are also not addressed properly.

3.8.1.1. Consolidation Centre (CC)

To reduce the number of problems which occur in the material delivery process, Hill and Ballard (2001) recommended a consolidation facility. The Consolidation Centre (CC) is a place to consolidate loads to maximise vehicle fill, and reduce transport costs. Sullivan *et al.* (2010, p. 91) provided an analogy between CC and pouring water into a bottle: “If you fill it straight from the tap, water usually splashes everywhere, however careful you are to try to control the rate of supply. If you use a funnel, on the other hand, the task becomes infinitely easier”.

The CC was used in the Heathrow Airport Terminal 5 project successfully. In that project, two consolidation centres provided a buffer for raw materials, reducing the storage time, and precisely matching deliveries with demands onsite (Doherty, 2008). In CCs, materials assembled into work packages and reinforcement cages are prefabricated in a safe environment (Doherty, 2008). The achievements include cutting the number of HGVs moving around the site and reducing congestion.

However, the CC can be criticised from three angles:

1. Finding a suitable location for a consolidation centre which is large enough and close to the site is difficult.
2. It is built around a system of double-handling and double-transportation that may increase the total cost of deliveries.
3. Although a CC is not a warehouse (Constructing-Excellence, 2006), some warehousing tasks, such as identification, storage and retrieval, should be carried out in a CC and this incurs extra cost to the project.

3.8.2. Warehousing

Warehousing is a critical component of construction logistics which ensures the punctual availability of materials. The aim of warehousing is to make sure that a sufficient stock of materials is available onsite to protect the construction process against variability in both delivery dates and the use of materials. Generally, there are two major material storage philosophies (Tompkins & Jerry, 1998):

1. *Fixed location storage:* each item is stored in a specific location, and no other items may be stored in that location, even though that location may be empty.
2. *Random location storage:* any item may be assigned to any available storage location. An item that is stored in location A in the first month might be stored in location B in the next month.

It seems that, due to having various kinds of materials and limited space in construction sites, the random location storage philosophy is more appropriate for projects, although fixed location storage might be used for small size items that have high value.

Thomas *et al.* (2005) explained that a construction site should be divided into three storage areas which have different uses:

1. *Semi-permanent storage:* materials are stored for an extended period of time before being used. Materials should be clearly marked and segregated to be distinguishable. They should be placed on pallets to prevent damage from damp and mud and stored in a way that allows easy access by lifting and transporting equipment.
2. *Staging area (next to the exterior of the building):* materials are off loaded in this area and then lifted into the building (poly handling may be required).
3. *Workface:* some materials should be stored inside the building. The amount stored should be kept to a minimum and good housekeeping practice should be implemented.

CITB-Construction-Skills (2006) also introduced three stockholding scenarios (Figure 13) as: (a) ancillary storage (open and accessible by crane but vulnerable to damage), (b) secure storage (lockable space for high value materials), and (c) site operation (materials positioned close to the point of use).

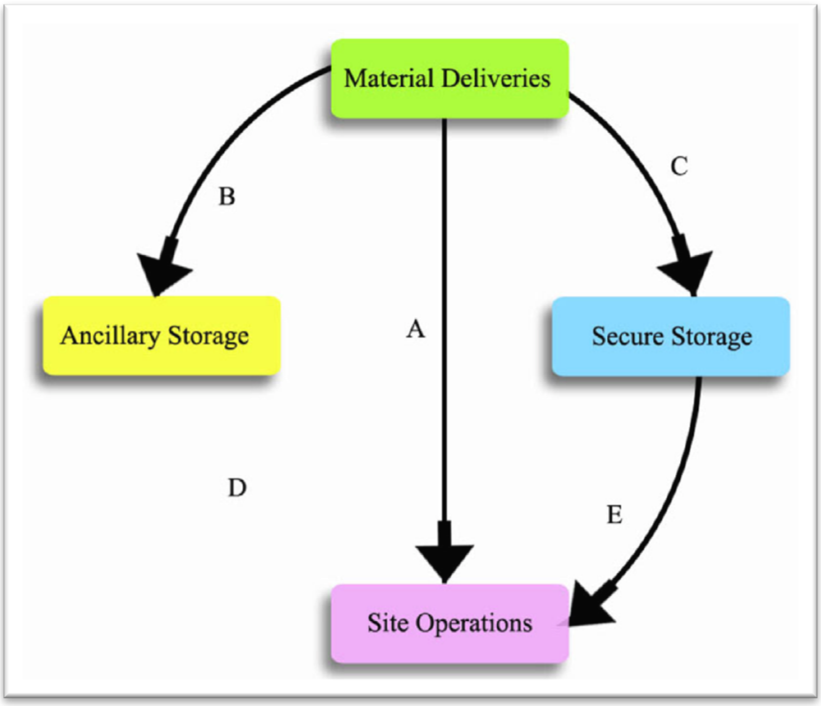


Figure 13: The stockholding scenarios, Adapted from (CITB-Construction-Skills, 2006)

After allocating a suitable area for storage, a policy should be established that deals with the product arrivals, receiving, storage, space allocation, retrieval operations and sequencing of order picking (Van den Berg & Zijm, 1999). The principles that should be considered for successful warehousing policy are (Gopalakrishnan, 2010):

1. Easy identification
2. Close to the work area
3. Ease of handling
4. Proper container
5. Safety
6. Security
7. Tidiness

The length of time that materials are stored onsite is an important issue. SFfC (2005) stated that materials are often stored onsite for long periods of time. CITB-Construction-Skills (2006) expressed most of these materials are left from the full load. The factors affecting the storage duration are material nature, its handling characteristics, procurement issues, and storage options (CITB-Construction-Skills, 2006).

To avoid unnecessary stock inventory, a system is needed to monitor the performance of the warehouse. A warehouse management system (WMS) is required to manage information such as: material type, quantity, owner details, handling details (the time and location the materials are needed), and any health and safety information (Sullivan, Barthorpe, & Robb, 2010). It can be a basic system to record the flow of materials through the warehouse, or an advanced one that can optimise storage spaces and allocate storage zone to the consignments. A WMS creates a means for processing deliveries (tracing the consignment) and offers a standard product description among parties involved in the project (Sullivan, Barthorpe, & Robb, 2010). To identify, control and monitor the inventory, three tagging system can be used:

1. *Paper based:* each consignment is tagged with a unique identification number and the corresponding information is stored on a spreadsheet. This system is slow and mistakes are more likely to happen when dealing with spreadsheets.
2. *Barcode technology:* a printed machine-readable symbol is used to encode product information. Pick accuracy, rapid stock check, and reduced warehouse worker hours are the advantages of using barcodes, as explained by Sullivan *et al.* (2010). The problem of barcodes is that they may get dirty onsite and become unreadable.
3. *Radio Frequency Identification (RFID):* an electronic tagging system consisting of a microchip for storing information and an antenna for wireless data transfer. Differences between barcodes and RFID are summarised in Table 1. Frequency interference and high cost are the disadvantages of RFID. Moreover, this system is not suitable for loose materials or items without packaging.

Table 1: Differences between Barcode and RFID technology

Barcode	RFID
Must be on the surface of the item	Can be placed inside of the packaging
Line of sight is required	No line of sight is required
Carry limited information (20 characters)	Can carry large amounts of data
Items need to be scanned one by one	Multiple items can be scanned

3.8.3. Handling

Selecting suitable material handling methods has a great influence on the productivity of construction sites (Tommelein, 1994). Material characteristics, such as size, weight, bulkiness, and packaging, impose handling requirements. The number of lifting machines and staff to load and unload materials should be determined for each stage of the construction process (Sullivan, Barthorpe, & Robb, 2010).

The crucial issue related to handling is that the majority of materials are handled more than once onsite, which is the result of poor logistics planning (CITB-Construction-Skills, 2006). The double-handling and poly-handling increases the likelihood of damaged materials while it wastes the working time of skilled labours (Sullivan, Barthorpe, & Robb, 2010).

Unloading and moving by hand is problematic because the rod may be obstructed (Sullivan, Barthorpe, & Robb, 2010). Hence, machines, such as forklift, hiab, crane, and beam winch, are used for lifting materials. Factors that should be considered when selecting a suitable machine (or a combination of them) include: working surface, lifting capacity, loading platform (street, first floor or the roof), project location, street condition, circulation area, and street traffic (Sullivan, Barthorpe, & Robb, 2010).

There is research about material handling methods. For instance, Proverbs *et al.* (1999) compared the use of concrete pumps with other methods of pouring concrete in high-rise construction. They explained the advantages of using concrete pumps as: time saving, cost saving, lower labour cost, and better concrete work quality in adverse weather.

3. 9. Waste Control

The construction industry generates between two and five times the quantity of household waste in European countries (Nowak, Stcincr, & Wicgcl, 2009). The wastage rate within the industry is 10-15 per cent (McGrath & Anderson, 2000).

Sullivan *et al.* (2010) stated the main reason for waste production in construction project is that there are many parties on site and most of them are cutting and fixing materials that will be discarded immediately. Dainty and Brooke (2004) reviewed the literature about wastage in construction and concluded that the sources of waste relate to design changes, leftover materials, waste from packaging and non-reclaimable consumables, design/detailing errors, poor storage and handling of materials, and insufficient protection of the completed works.

Apart from physical waste, there is also invisible waste in construction projects. Hill and Ballard (2001) expressed that much waste in construction is related to time and non-value-added activities. Although invisible waste is critical, the focus of this section is on physical waste.

There are two ways in which wastage can be reduced in construction projects: (a) minimising waste generation and (b) improving waste management practice onsite (McDonald & Smithers, 1998). CITB-Construction-Skills (2006) expressed that the use of quality packaging is a way to minimise waste specifically in the handling stage. However, packaging increases the amount of waste and needs effective housekeeping to remove and dispose of packaging waste. To find solutions for minimising wastage, Dainty and Brooke (2004) interviewed key stakeholders of five large construction projects and distributed 45 questionnaires. The outcome of this valuable research provided an extensive list of waste minimisation policies that can be utilised in different construction projects. The policies below are ranked based on importance (Dainty & Brooke, 2004):

1. Supply chain alliances with suppliers/recycling companies
2. Increased off-site prefabrication to control waste
3. Standardisation of design to improve buildability and reduce the quantity of off-cuts
4. Stock control measures to avoid the over ordering of materials
5. Improved education of the workforce
6. Provision of waste skips for specific materials
7. Just-in-time delivery strategy
8. Dedicated specialist sub-contract package for on-site waste management
9. Contractual clauses to penalise poor waste performance
10. Design management to prevent the over specification of materials
11. Additional tender premiums where waste initiatives are to be implemented
12. Waste auditing to monitor and record environmental performance on-site
13. On-site waste compactors for skips
14. Educate clients about measures to reduce waste levels
15. Supplier flexibility in providing smaller quantities of materials
16. Environmental impact assessments of the scheme during the design phase

3. 10. Moving Towards a Model for Managing Construction Logistics

So far, the main functions of logistics in construction projects have been explored. In this section, the valuable efforts of different researchers in the construction logistics realm are cited. The stress is on research that attempted to create a model for construction logistics or develop principles for successful construction logistic management.

Agapiou *et al.* (1998) conducted research to examine material logistics and how it may benefit the construction industry. They developed a logistics model (Table 2) and applied it to a Danish house building project. Agapiou *et al.* (1998) stated that a total saving of 5 per cent was achieved by utilising the logistics model. However, there are three problems with their model. First, they did not made clear how the model was developed; so, whether it is based on literature or the result of any qualitative research remains unknown. Second, many functions of logistics, such as site layout designing and the purchasing process, were missed in their model. Third issue is that the process of suppliers' involvement was not described clearly. In other words Agapiou *et al.* (1998) did not explain how they convinced the suppliers to implement concepts such as JIT and unit specification.

Table 2: Components of a logistics management model (Agapiou, Clausen, Flanagan, Norman, & Notman, 1998, p. 134)

Logistics management tool	Description
Materials coordinator	Responsible for managing the logistics model during the construction process.
Supply plan	The supply plan indicates the proposed delivery dates of units for the whole project.
Unloading plans	These plans indicated where daily supplies (units) would be delivered on site.
Unit specification	A unit is a package of materials required for one working operation within one craft at one location on the construction site.

Muya (1999) developed a decision-support supplier management model for improving construction materials logistics. The model is presented as a flow chart which has three phases: (a) development of the database of preferred suppliers, (b) selection of suppliers from the database, and (c) performance monitoring of the suppliers. The interesting part of Muya's work is the identification of the performance indicators against which the performance of suppliers can be evaluated. The proposed model by Muya is relatively user-friendly and functional. However, the model is only focused on supplier selection rather than the logistics model. In other words, Muya addressed overall supplier management issues but ignored topics such as storage, handling and transportation.

Hill and Ballard (2001) introduced ten principles for successful logistics management:

1. *Design for production:* anticipating the supply chain issues in the designing stage and choosing a suitable construction method, such as off-site prefabrication.
2. *Rationalise the supply side:* choosing suppliers based on their willingness to collaborate and the value that they can add to the system, and establishing long-term relationship with a few suppliers.
3. *Manage processes, not functions:* looking at the supply chain as an entity and integrated system.
4. *Establish standard processes for construction logistics*
5. *Define supplier standards:* defining standards such as delivery time, method of delivery, packaging, waste disposal, etc.
6. *Measure performance:* establishing indicators and assessing members of the supply chain based on these.
7. *Continuous improvement*
8. *Reduce the component count*
9. *Share information*
10. *Throughput, not storage*

Hill and Ballard's (2001) research is a clear pathway for applying effective logistics management to obtain time, cost and value advantages. However, they failed to provide a whole picture of the construction logistics concept. In fact, all logistics aspects are not covered and the relationships among the different functions of construction logistics and how they can affect each other were not addressed.

However, Hill and Ballard's work forms a cornerstone for utilising effective construction logistics in real projects.

Strategic Forum for Construction (Strategic-Forum-for-Construction, 2005) identified that a substantial amount of waste is incurred in the construction industry because of poor logistics management. Hence, a task group was set up to find out what needed to be done. Their main aim was to develop an Action Plan that shows what should be done by different parties involved in projects to improve construction logistics. The action plan has two axes:

1. *Support for other initiatives that will contribute towards improving logistics*: includes developing an integrated project team and supply chain, and using off-site manufacture and modern methods of construction.
2. *Programme for improving logistics:* explains the contribution that clients, design professionals, contractors, manufacturers, suppliers, and distributors can make to improve logistics. It also contains recommendations on more utilisation of IT, sharing successful case studies, and learning from other industries.

In addition to the Action Plan, another strength of the SFfC (2005) research is that they attempted to address what prevents the construction industry applying effective logistics. Yet, they did not express how these barriers should be removed. Furthermore, there is no evidence that shows the Action Plan can work in real situations. The Action Plan was developed based on the brainstorming of the group members and discussion of the topic in a workshop of 30 people from the industry. Adequate information about the people participating in the workshop is not provided. Hence, whether they are true representative of the industry is questionable. Although the Action Plan provides a valuable insight into construction logistics, its recommendations are too general and, in some cases, they contradict each other. For instance, while the report recommends JIT, it emphasised that lorries should arrive to the site with a full load.

There are researchers who approach construction logistics from mathematical point of view. For example, Sobotka (2000) developed two models based on information gathered from the Polish construction industry to minimise logistics costs. However, Sobotka's models only optimise the delivery cost and not the total logistics cost.

Other research that utilised simulation and optimisation methods was conducted by Fang and Ng (2008). Their aim was to model the logistics process under a dynamic environment. Fang and Ng (2008) created a useful diagram to explain the general procedure for construction logistics that includes the total cost of all logistics related activities or sub-activities (Figure 14). They used the genetic algorithm for simulation and considered the work start time, delivery frequency and quantity as variables. Although Fang and Ng's research is a commendable example of taking a mathematical approach towards logistics, it has some limitations. The first issue is that storage is not included in the variables while it constitutes a large proportion of logistics costs. They also have two arguable assumptions for developing the model: (a) the model is based on JIT where no offsite warehouse exists, and (b) change in the work schedule does not impact on the overall construction period. These assumptions may deviate the model outputs from reality. However, Fang and Ng (2008) explained that, in the future model, they will consider more variables and reduce the numbers of assumptions.

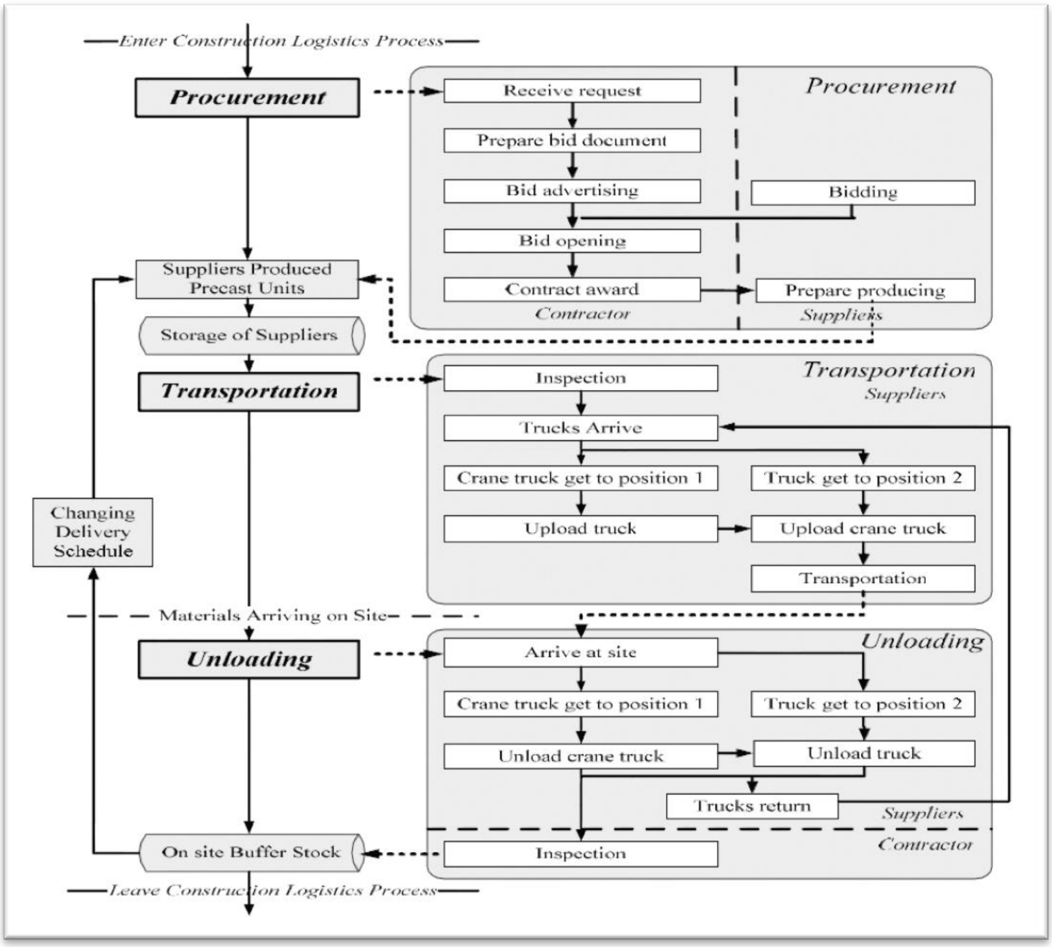


Figure 14: Construction material logistics process (Fang & Ng, 2008, p. 393)

It can be seen that most studies about creating a logistics model have focused on a single or a few aspects of logistics and did not approach the topic holistically. These works reduce the construction logistics system into its parts and then attempt to provide solutions to enhance productivity or optimise time and cost. The point that is missed is the relationships between the different functions of the construction logistics system. This is the gap in the knowledge of construction logistics that needs to be addressed. This research aims to fill the gap by introducing a holistic conceptual model that considers most construction logistics functions and provides the big picture of the whole system.

3. 11. Conclusion

This chapter first focused on defining the concept of construction logistics and then evaluated the existing body of knowledge about construction logistics models and frameworks. Construction logistics can be explained as the efficient mobilisation of resources in a project. It is divided into two parts: (a) site logistics and (b) supply logistics. This research focuses on site logistics, which includes planning, site layout designing, purchasing, material management and waste control. There are two types of research in the area of construction logistics: (1) the works that aims to develop principles and guidelines, which are usually qualitative and use case studies or focus groups, and (2) the studies that attempt to model logistics by employing various simulation techniques or optimise the cost and time using different sorts of algorithms. There is a need to develop a holistic view towards construction logistics. The relationship between the different parts of the construction logistics system, and the factors that may affect these parts, should be understood. This is the gap in the knowledge that this research aims to fill.

Chapter 4

THE IRANIAN BUILDING SECTOR

CHAPTER 4: THE IRANIAN BUILDING SECTOR

4. 1. Overview

This chapter is mainly about the condition of the construction industry and building sector in Iran. The aim is to describe different aspects of the industry concisely. Important information about the construction activities in Iran, the building sector strategies, regulatory institutions, codes, productivity issues, delay and construction related education are provided.

Before exploring the Iranian construction industry, a short review of the present Iran, its history, its economy and Iranian culture, is provided. It is essential to know Iran and the Iranian character properly to put the topic, construction logistics management, in context. More stress is put on describing the Iranian culture because it is believed that culture shapes the values, behaviours, standards and principles of a society. Hence, studying the Iranian culture will help to enhance understanding of why Iranians react to a specific social phenomenon in a special way. This will be critical later in this research when the conceptual model is formed. In that stage, the model will be designed in a way that appreciates the Iranian cultural specifications.

As there is little research about the social aspects of the Iranian construction industry specifically in the English language, information in this chapter has been mostly gathered from the Iranian governmental institutions which are available through annual reports, statistics, pamphlets, newsletters and websites. These are the most accurate materials about Iran that are collected from reliable sources such as the Ministry of Housing and Urban Development, Islamic Parliament of Iran, Central Bank of Iran, President Deputy of Strategic Planning and Control, and Centre for Strategic Research of the Expediency Council. Moreover, some reports about Iran that were crafted by the governments of other countries are covered. Beside these, the researcher's general knowledge of Iranian society, based on his birth, upbringing and education in the country, is utilised. To keep himself updated and informed, the researcher studied the Iranian construction news on a weekly basis for a period of three years, mainly from two famous Iranian news agents: Iranian Student’s News Agency (ISNA) and Fars News Agency. Although in a constructivist investigation like this, the researcher is a part of the research, reference to the researcher’s experience, and even news agents, was kept to a minimum to avoid bias.

4. 2. Introducing Iran

Iran, which was known as Persia until 1935, is an ancient country with over 8000 years of civilisation (Bakhīt, 2000), a proud history and strong national identity (Jones, Allen, Townsend, Bolton, & Taylor, 2009). This country lies in the Middle East on the north coast of the Persian Gulf and south cost of the Caspian Sea (Figure 15). The total area of Iran is 1,648,195 sq km (land: 1,531,595 sq km and water: 116,600 sq km) (CIA-World-Factbook, 2011). The climate is mostly semi-arid, but there are subtropical regions along the Caspian Sea and the Persian Gulf coasts. Iran’s natural hazards include periodic droughts, floods, dust storms, sandstorms and earthquakes (CIA-World-Factbook, 2011). The most important cities are Tehran (the capital), Mashhad, Esfahan, Karaj, Tabriz and Shiraz.

Figure 15: Map of Iran (Britannica, 2011)

Iran’s population is around 77,891,220 (July 2011) with an urban population ratio of 71 per cent. It is a young country, as 70.9 per cent of its population are between 15 to

64 years of age. Iran's official language is Persian or Farsi (Parsi), as 58 per cent of the population speaks this language, while Azeri accounts for 26 per cent, Kurdish nine per cent, Luri two per cent, Balochi one per cent, Arabic one per cent, Turkish one per cent, and other languages two per cent (CIA-World-Factbook, 2011). Islam is the official religion of the country and 98 per cent of the population are Muslims, the majority of whom are Shi'a (a branch of Islam). The Iranian calendar (Jalali) is one the most accurate calendars in the world and the New Year (Norouz) begins on the day of the vernal equinox, the first day of spring (20-21st March) (Abdollahi, 1996).

Iran's natural resources include petroleum, natural gas, coal, chromium, copper, iron ore, lead, manganese, zinc, and sulphur (Jones, Allen, Townsend, Bolton, & Taylor, 2009). The country has around 10 per cent of the world's oil reserves and the second largest reserves of natural gas, after Russia (Jones, Allen, Townsend, Bolton, & Taylor, 2009). Thanks to this, Iran's population has a respectable standard of living, low infant mortality, reasonable longevity, high literacy and college enrolment, access to electricity, piped water, and modern transportation and communication technology (Jones, Allen, Townsend, Bolton, & Taylor, 2009). The currency of the country is called the Rial (Rls) and 1 US Dollar is approximately equal to 10000 Rials.

The political system of Iran is unique and complex. The Islamic regime is a mix of theocratic and democratic government. At the top of the political hierarchy, there is a Supreme Leader with ultimate authority, elected for his life-time by conservative clerical forces (Ilias, 2008). There is also a president and members of the Islamic parliament elected directly by the public for a four-year period who work independently, but under the Supreme Leader's authority. The current governmental structure is based on the constitution written in 1979 and amended in 1989 (Ilias, 2008).

4. 3. History of Iran

Iran means the land of 'Aryans', a branch of Indo-European people who appeared around 2000 B.C. (Daniel, 2001). Their domain ranged at times from the Tigris to the Oxus and beyond (Daniel, 2001). During several thousand years of history, Iran has experienced several periods of glory and fragility. Although there is many archaeological evidence that shows there was a civilisation in Iran dating back to 8000 years ago (Briant & Daniels, 2006), the first great development of ancient Iran took place under the Achaemenid dynasty (559 B.C.), which is known as the Persian Empire (Alizadeh, Pahlavani, & Sadrnia, 2003). Their land extended from the Indus River in the east to Libya and Thrace in the west, and from the Persian Gulf in the south to the Caucasus and the Jaxartes River in the north (Alizadeh, Pahlavani, & Sadrnia, 2003) (Figure 16). In 636 A.D., after the advent of Islam, Arabs conquered Iran after several battles (Alizadeh, Pahlavani, & Sadrnia, 2003). Although Iran was invaded by Alexander, Arabs and Mongols, Iranian traditions, language and arts still survive, and they were influential even on the invaders (Alizadeh, Pahlavani, & Sadrnia, 2003).

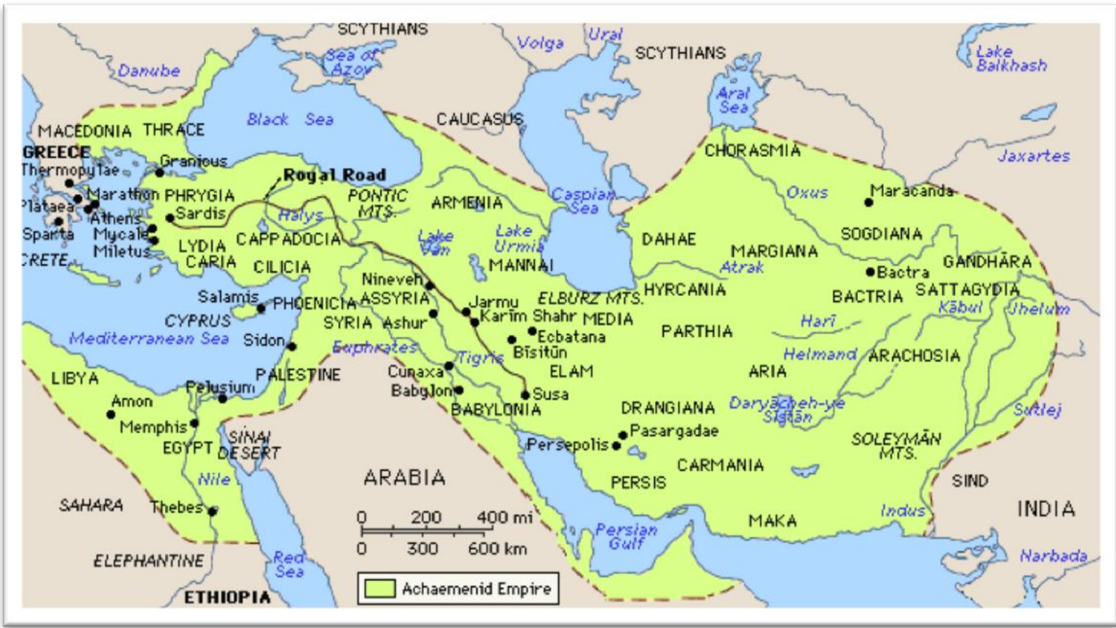


Figure 16: Achaemenid Dynasty (550-330 BC) (CAIS, 2010)

Iran became an Islamic republic in 1979 after 2500 years of monarchy (Jones, Allen, Townsend, Bolton, & Taylor, 2009). This happened after the Islamic revolution led by Ayatolah Khomeini. From 1980 to 1988, Iran fought with Iraq (CIA-World-Factbook, 2011), usually regarded as an imposed war. Currently, Mahmoud Ahmadinejad is the president of Islamic Republic of Iran (since August 2005) and he works under the power of the Supreme Leader, Ayatolah Khamene (since June 1989).

4. 4. The Iranian Culture

Culture has been defined in many ways. Hofstede (1984, p. 21) explained culture as "the collective programming of the mind which distinguishes the members of one human group from another". The Iranian Centre for Strategic Research (CSR-R71, 2008) defined culture as an integrated source of beliefs, knowledge, thoughts, values, attitudes and behaviours that members of a society show in various situations and circumstances of social life. Understanding the dimensions of the Iranian cultural system is necessary to develop a construction logistics framework that complies with the current conditions of the Iranian society.

The Iranian culture is well-known for its famous poets such as Hafiz, Saadi and Rumi, its magnificent architecture masterpieces in Esfahan and Shiraz and for people's hospitality and Persian food. Yet, this section aims to provide a deeper understanding of contemporary Iranian culture by highlighting its strengths and weaknesses. The reason that the strengths and weaknesses of the Iranian culture are explained here is not to compare it with other cultures (e.g. Western or Eastern cultures) and to conclude which one is better. In fact, cultural differences are inevitable and each nation has its own values, norms and beliefs. The goal is to provide an unbiased critique to distinguish and study the positive and negative cultural factors that may affect the construction logistics model. In other words, this section aims to study and understand cultural factors affecting the construction logistics model and make it compatible with these factors.

In the following sections, five strengths and weaknesses of the Iranian culture are expressed. Again, it should be emphasised that highlighting the weak points of the Iranian culture does not mean that these do not exist in other cultures. Also, it does not mean that these characteristics can be generalised to all Iranian people. These are common aspects that have been seen in the Iranian society during the past years and Naraghi (2001) has studied, explained and categorised them. Some of these are also confirmed by the results of a report published by CSR (CSR-R62, 2008). Although weaknesses can be considered as cultural crisis, as CSR (CSR-R71, 2008) stated, crisis is a necessity for a developing country as it motivates society to undertake serious efforts to find solutions for emerging problems and achieve new patterns that may push the boundaries of traditional norms.

4.4.1. Strengths of the Iranian Culture

1. *Collectivism and Family*

   The Iranian culture has shown a level of collectivism. Although this level is not so high, as in Japanese or Chinese culture, Iranians are eager to be a part of a strong and well-known community or group (Naraghi, 2001). In fact the family, the community and the group that a person belongs to forms a part of his/her identity. One advantage is that if an Iranian likes the group that he/she belongs to, he/she will be committed and loyal to it and will do his/her best to make it successful. Another advantage of the collectivist nature of the Iranian culture is the support that an individual receives from his/her family during their entire life. The primary unit of the Iranian society which has fundamental importance is the family (Daniel, 2001). Usually the family supports its members in difficult situations and the members should support the family when needed.

2. *Excitement and Joy*

   Although Iranian people experience high levels of stress in life, they have a notable ability to produce joy and excitement. There are many events full of traditions, rituals and symbols that are celebrated during a year which bring joy and happiness for Iranians (CSR-R17, 2006). The most important events that have been celebrated for several thousand years are Norouz (the New Year), Mehragan (the Autumn Festival), Yalda (the longest night of the year), and Chaharshanbe-Suri (Wednesday Feast or the Fire Festival). In addition to these events, Iranian people are generally extrovert and are usually in close communication and interaction with family, friends and relatives. Thus, the level of loneliness and seclusion is relatively low in the society.

3. *Flexibility and Adaptability*

   Being flexible and adaptable are qualities that help Iranians to move easier through the twists and turns of life. The fact that, after thousands of years, Iran as an independent country still exists can demonstrate the ability of its citizens to be flexible and adaptable to problems like invasion (Abolhasani, 2009). On the whole, Iranian people are good at extracting and acquiring from other cultures. Whether it is a new fashion, a piece of technology, or even a life-style, Iranians are keen to attain the best of the best. Since ancient times, the Iranian culture has affected, and was affected by, other cultures (Solasi, 2000)

4. *Positive Attitude towards Education*

   A high level of education has always been valued by Iranians. Each year, around 1.5 million youths participate in the Iranian University Entry Exam (Sanjesh, 2010). Meanwhile, over 75,000 Iranian students are studying (mostly at Master and PhD level) abroad (The Iranian Ministry of Science, Research and Technology (MSRT), 2011). In 2010, Iran showed the fastest scientific growth of any country, eleven times faster than the world average (The-UK-Department-of-Trade-and-Industry, 2005). Interest in education is not a new phenomenon as there were many Iranian scientists, such as Avicenna (Medicine), Khwarizmi (Mathematics) and Zakariya al-Razi, who contributed to world knowledge in different fields.

5. *Self-esteem and self-sufficiency*

   In contrast with the factors expressed above, this is a new ability that has strengthened in the last 30 years. After the 1979 Islamic Revolution in Iran, because of some political issues, the country encountered intensive international economic sanctions which limited or prohibited import of sensitive products and engineering services to Iran. To survive (specifically during the war with Iraq), Iranian manufacturers and engineers had to design products and meet the country's needs, ranging from food to weapons (DSRC, 2010). This approach, which has been highly supported and encouraged by the Government, enhanced the confidence of Iranians and proved that they can achieve what they want even without the help of other countries. With the exception of a few fields in the oil and gas sector and power industry, which a limited number of foreign contractors utilised, indigenous consultants and contractors have executed projects and met all the construction demands of the country (Yisa, Holt, & Zakeri, 2000).

4.4.2. Weaknesses of the Iranian Culture

1. *Team-working Inability*

   Although Iranian people join together for joy and happiness, they prefer to work individually. The reason is that they are more interested in their own benefits rather than the public benefit (CSR-R62, 2008). Thus, instead of collaboration, competition is encouraged. This is also noticeable in the performance of Iranian athletes, who are successful in individual sports but not good in team sports (Naraghi, 2001).

2. *Law Aversion*

   Law never has the opportunity to be established in the Iranian culture properly (CSR-R62, 2008). This is mainly due to the legitimacy crisis of the state. Owing to thousands of years of monarchy and dictatorship, people do not believe in the state. Furthermore, issues such as political corruption amplify the legitimacy crisis (CSR-R82, 2008). Therefore, established laws, whether they are logical or irrational, are not accepted by the public (Naraghi, 2001). Other reasons for law aversion can be summarised as: economic issues, poverty, inefficient judiciary system, unawareness, and law deficiency (Naraghi, 2001).

3. *Hypocrisy, Secrecy and Affectation*

   Iranian people used to hide their beliefs, opinions, and thoughts. In some cases, this is a sign of politeness and considered as a value which is usually beneficial (Naraghi, 2001). This is rooted in the political system of the country which had been a dictatorship until 30 years ago and had punished people because of their dissenting opinions (CSR-R82, 2008). For example, employees do not have the courage to express their opinion about a person or a topic in front of their boss and they usually appreciate the boss's performance. Yet, when the boss leaves, the room they criticise him/her harshly. Hypocrisy and secrecy lead to distrust among members of the society (CSR-R62, 2008). Another problem is that Iranian people regret to say 'no' or 'I do not know' to a request or a question (Naraghi, 2001). The problem is that when somebody pretends he/she knows about a subject, he/she does not look for a proper consultation.

4. *Criticism and Jealousy*

   Generally, Iranians are very harsh in criticising each other. At first glance, this may be seen as an advantage, but the issue is that this criticism does not aim to rectify the problem and improve the situation (Naraghi, 2001). The aim is to eliminate a person, a group or a belief which is normally rooted in jealousy (Naraghi, 2001). In brief, rejection of opposite voices, jealousy and lack of logical discussion are critical issues in the Iranian culture.

5. *Lack of Planning and Irresponsibility*

   Lack of long or even medium term plans is a common issue in the life of Iranians. Even the Government has not been successful in meeting its five-year plan (CSR-R62, 2008). High levels of economic and political uncertainties prevent Iranian people from planning. Beside this, many Iranians are not aware of different planning methods because they have not received enough education. Another issue is that Iranians do not accept responsibility, because they do not want to be accountable (Naraghi, 2001). In fact, the fear of making mistakes and being judged by others prevents people taking responsibility. Even if they accept responsibility, if a mistake happens, first they try to hide the error and then deny their role.

4. 5. Economy of Iran

In 2007, Iran was the 29th largest economy in the world with a value of $286 billion, which is larger than the economy of South Africa and smaller than Denmark (Jones, Allen, Townsend, Bolton, & Taylor, 2009). The country's rate of economic growth is considerable and, according to the International Monetary Fund (IMF), Iran will have the 25th largest economy by 2014. Iran's rank is higher than this in terms of Gross Domestic Product (GDP) on the purchasing power parity basis (the sum value of all goods and services produced in the country valued at prices prevailing in the United States). Valued at $863.5 billion, Iran had the 19th largest economy in the world on this measure in 2010 (CIA-World-Factbook, 2011). Figure 17 illustrates the annual percentage change of Iran's GDP. However, the country rank of GDP per capita is 100 ($11,200 in 2010), mostly because of high rate of population growth during the past 30 years (CIA-World-Factbook, 2011).

Iran's economy is dominated by an inefficient state sector and is highly reliant on oil (CIA-World-Factbook, 2011), which accounts for around 80 per cent of export earnings and 50 per cent of government revenue (Jones, Allen, Townsend, Bolton, & Taylor, 2009). The oil has caused a phenomenon called the resource curse, which means a valuable natural resource like oil stops the country improving its economy. The private sector is mostly involved in small-scale workshops, farming, and services (CIA-World-Factbook, 2011). Issues such price controls by the Government and subsidies decline the potential for private-sector-led growth (CIA-World-

Factbook, 2011). The Government has attempted to give more opportunity to the private sector through privatisation schemes and reducing subsidies in the recent years (Ilias, 2008). The most extensive economic reforms during the past ten years are gasoline (petrol) rationing in 2008 and subsidies reduction, particularly on food and energy (CIA-World-Factbook, 2011).

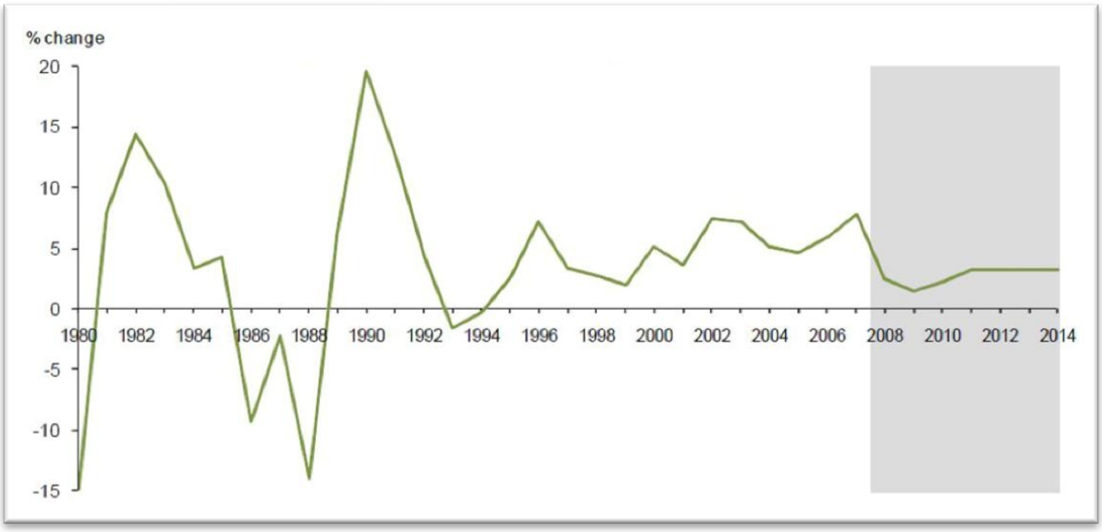


Figure 17: Iran Real GDP, annual % change (forecasts in grey area) (Jones, Allen, Townsend, Bolton, & Taylor, 2009)

Iran's economy has encountered different challenges in recent years. The Central Bank of Iran explained that, as many countries, Iran was affected by the difficult conditions of global financial markets and the credit crunch (CBI, 2009). Discussion about the extent of these negative impacts is controversial, as some Iranian analysts assessed the impact of the financial crisis as negligible because Iran's economy has been almost isolated from the global economy for 30 years (CBI, 2009). However, the crisis does have a serious impact on Iran's economy, specifically in the oil sector in terms of changes in the main items of the external balance of payments of Iran (CBI, 2009).

The high rate of inflation (11.8 per cent in 2010) is another challenge (CBI, 2009). Iran has suffered from double-digit inflation since 1990 (Figure 18). Factors contributing to the rise in inflation are expansionary government economic policies, growing consumption demands, international sanctions and rising international food and energy prices (Ilias, 2008). The unemployment rate is also high, reaching 14.6 per cent in 2010 (CIA-World-Factbook, 2011). The main reason is the young population of the country, which puts pressure on the Government to generate new jobs. The worst consequence of the high unemployment rate is that Iran had the highest 'brain drain' rate in the world in 2010 (Ilias, 2008).

Beside these, economic sanctions are serious issues. The United States has tried to limit Iran's nuclear program by putting Iran in financial isolation (Ilias, 2008). Sanctions aim to obstruct Iran's development of its oil and gas sectors, impede manufacturing activities and isolate the Iranian banks from the financial world (Ilias, 2008). However, rising oil prices in the world in the past years have increased Iran's oil export revenue which has eased the financial impact of sanctions (CIA-World-Factbook, 2011). Despite these challenges, most analysts believe that the economy is not in an immediate crisis, because of the continued highs in oil prices (Ilias, 2008).

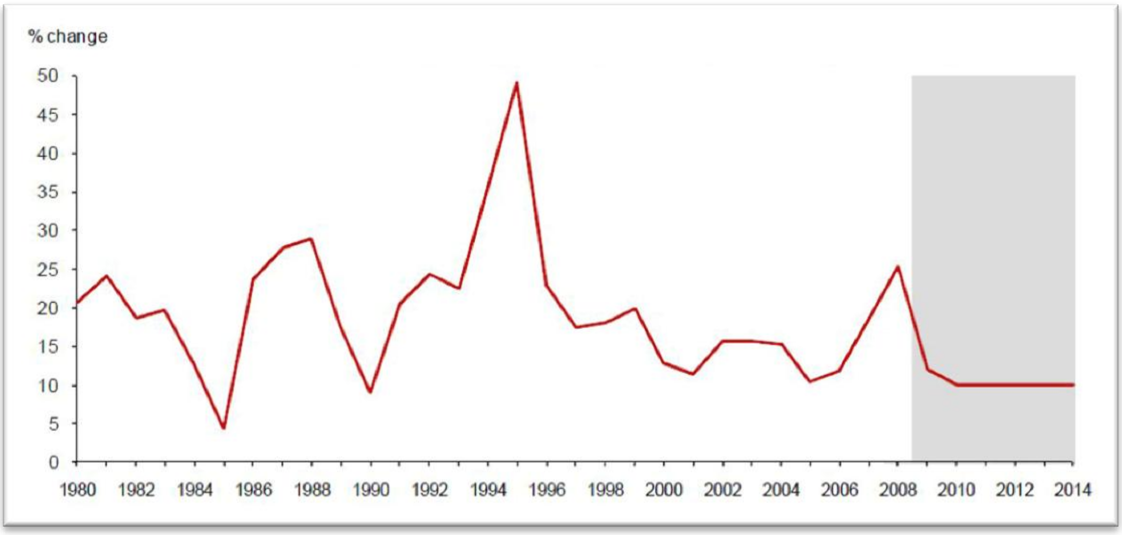


Figure 18: Consumer price inflation, annual % change (forecasts in grey area) (Jones, Allen, Townsend, Bolton, & Taylor, 2009)

4. 6. Business in Iran

Regardless of cultural, political and economic challenges in Iran, the private sector can still achieve financial success. Ghafarian and Alami-Milani (2008) conducted a qualitative study to identify the common factors that make private firms successful in the Iranian business environment. They introduced a conceptual model (Figure 19) for running a business in Iran.

Their study revealed that effective leadership, continued improvement of business ability within the firm, enhancing the knowledge and understanding of the business environment, choosing a proper business pattern, value creation, and risk management are important subjects that should be considered by the private sector to attain financial success in Iran. They also concluded that international academic literature is valid to be applied in the business conditions of Iran, but some modifications are required.

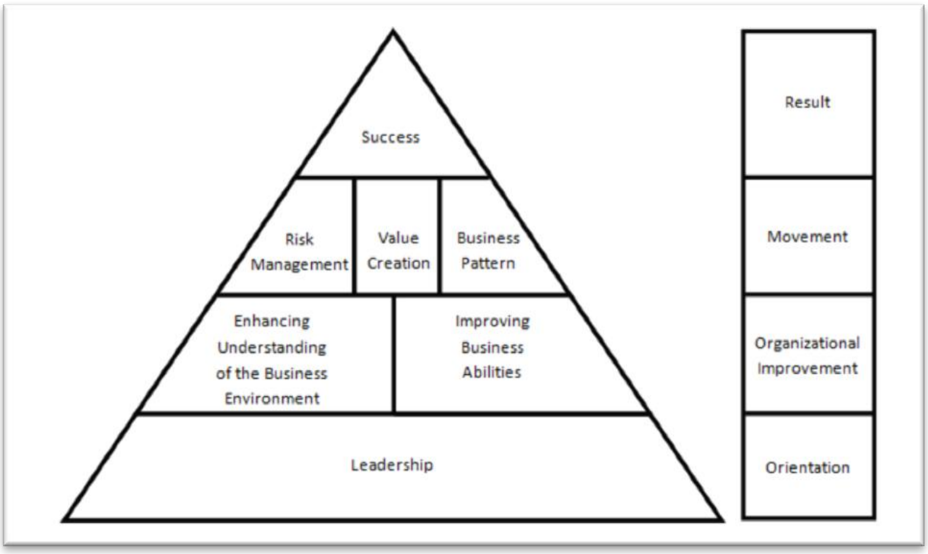


Figure 19: Conceptual model for a successful business in Iran (Ghafarian & Alami-Milani, 2008)

The problem with Ghafarian and Alami-Milani's research is that they did not define the term 'success' properly. Throughout the research, it is unclear whether they considered success in terms of revenue, product development, or market development. Moreover, they did not address political matters, which are an important factor that affects the business performance in countries like Iran. However, their study provided a ground for further study on business performance in Iran.

4. 7. Construction Industry in Iran

The Iranian construction industry has an important position in the nation's economy and accounts for about nine per cent of the gross domestic product (GDP) of Iran (CBI, 2009). There is a huge demand in different sectors of this industry in Iran, specifically in building and civil sectors. For example, in transportation sector, many infrastructures, such as roads, airports and railways, are under construction. Only in road building, more than 1000 kilometres of roads were constructed in 2007 (FarsNews, 2008).

There are also several projects in the water, oil and gas, industrial, petrochemical and commercial sectors that are under construction or in the design stage. For instance, the South Pars project in the Persian Gulf (Photo 1), which is the biggest gas field in the world, started in 2001/02 and has attracted over 30 billion US Dollars of national and international investment so far (NISOC, 2009; MoP, 2010). The project was divided into 28 phases and phases one to ten were brought to production by the end of 2009 (SPGC, 2011; Petropars, 2010). It is estimated that the 18 remaining phases need more than 170 billion US Dollars to be completed (NISOC, 2009; MoP, 2010).

Photo 1: South Pars phases six, seven and eight (JamejamNews, 2008)

4.7.1. Construction Related Education

Civil Engineering and Architecture are courses offered in many Iranian universities at undergraduate, postgraduate and PhD levels. There are no Construction Management or Project Management courses at undergraduate level in the Iranian universities. Yet, a few universities have established these courses at Master (MSc) level since ten years ago. Hence, civil engineers and architects are often responsible for executing construction projects and should undertake the roles of quantity surveyors, construction managers, project managers and facility managers. Although they usually have enough knowledge about design aspects and construction methods, most of them are not familiar with management subjects. Zakeri *et al.* (1996) expressed that the Iranian site managers usually have little knowledge of new management styles and, even if a manager is aware of modern management techniques, it is generally felt that such techniques are not applicable to the construction industry in Iran. Sobhie *et al.* (1997) also confirmed that poor expertise in project management tools and techniques causes problems for the projects and can lead to the failure of state programmes. Therefore, much effort is needed to set a strategy for acquiring, developing and exploiting project management knowledge and techniques in Iran. It should also be considered that these tools and techniques need to become adapted to and compatible with the cultural, economic, political and technological characteristics of the Iranian construction industry.

4.7.2. Regulatory Institutions and Codes

Generally, four main institutions regulate the construction industry in Iran:

1) *Ministry of Housing and Urban Development (MHUD)* is the most influential institution in the building sector. Some of its responsibilities are regulating the housing market, designing, executing and supervising urban development/redevelopment schemes, establishing general strategies in building sector, preparing required regulations, codes and standards associated with buildings, and supporting housing schemes in rural areas (MHUD, Home, 2011). The Building and Housing Research Centre, which works under the Ministry’s authority, conducts research in different aspects of building science. Moreover, this centre formulates the National Building Codes that must be observed in building construction to provide safety and comfort for inhabitants. These codes have been published in 20 volumes, each with a building related topic, such as concrete structure design, steel structure design, seismic design, energy conservation, gas supply plumbing, etc (BHRC, 2010).
2) *President Deputy Strategic Planning and Control (PDSPC)-Technical Affairs Office* is responsible for the preparation of rules, regulations and technical codes for all engineering subjects, including civil engineering. More

importantly, this office groups and ranks construction consulting and contracting companies in five grades based on the companies' abilities, such as previous experience, expertise and the personnel's qualifications (Technical-Affairs-Office, 2011). Grade one is the highest grade a company can achieve which enables it to be involved in large and complex projects. No company can participate in public projects without the required grade. Companies may achieve a grade in one or several specialised areas, such as building, petrochemical, industrial, water-structure and road construction. Another important role of the office is to prepare and publish price indices for construction materials and services (Technical-Affairs-Office, 2011).

3) *Municipalities* are responsible for managing different affairs in cities and preparing master-plans for urban development and regeneration. Their most important role in the building sector is to issue building permits. Considering the total land area, the land location and width of the street, they decide on the number of floors, the proportion of the land that can be built on, and total built area in square metres (Tehran-Municipality, 2010). They also supervise construction projects so that they do not violate regulations. Moreover, all architectural and structural drawing should be confirmed by municipalities (Tehran-Municipality, 2010). Owing to the complicated rules and intensive bureaucracy, dealing with municipalities in urban areas is a time consuming task.
4) *The Iranian Construction Engineering Organisation (IRCEO)* is a non-governmental organisation which acts as a consultant for MHUD and PDSPC to establish rules and codes. It also attempts to enhance the image of the industry by providing technical education for members through courses and publications. The most important role of the IRCEO is to accredit construction related graduates by assessing their abilities through a set of examinations. Meanwhile, this institute aims to enhance productivity and the quality of building construction by recommending standards and independent reviews. It is also considered as the voice of the building sector in the Government and Parliament committees (IRCEO, 2010).

4.7.3. Productivity and Delay in the Iranian Construction Industry

Sobhie *et al.* (1997) claimed that paying inadequate attention to the cost and time of the project is still a common practice in Iran. The reason is that, based on the grading system which was explained above, the Iranian companies are assessed on the number of major works completed and not on the efficiency and effectiveness of resource utilisation (Sobhiyah, Seymour, & Perry, 1997). Hence, in a competitive environment, contractors underestimate time and cost to win a project. After the contract is awarded, and during execution, they will claim for extra bills and price escalation. This is a common practice that is also accepted by the clients (Sobhiyah, Seymour, & Perry, 1997).

Zakeri *et al.* (1996) expressed that the construction industry in Iran suffers from poor productivity and increasing construction costs. They pointed out the most problematic constraints to construction productivity in Iran are: shortage of materials, weather and site conditions, equipment breakdown, design deficiency, lack of proper tools and equipment, lack of inspection, absenteeism, accidents, improper plans of work, repeating work, changing crew size and labour turnover (Zakeri, Olomolaiye, & Holt, 1996). Yisa *et al.* (2000) identified factors that make the Iranian projects more productive, such as employing skilled people, increasing motivation, availability of materials, tools and equipment, and proper supervision (Yisa, Holt, & Zakeri, 2000).

In addition to low productivity, delay is one of the most reoccurring problems in the Iranian construction industry and has a negative impact on project success in terms of time, cost, quality and safety. Some practitioners believed that acquisition of capital is the main cause of delay in Iran (Sobhiyah, Seymour, & Perry, 1997). However, after a while it became clear that insufficient socio-economic institutional development and low capacity of them is the main issue (Sobhiyah, Seymour, & Perry, 1997). In fact, the problem was attributed to the poor performance of the Iranian economic, financial, banking, foreign trade and customs systems.

Although the role of socio-economic institutions in causing delay is undeniable, it cannot be the only reason. The question is, then, what is the role of other stakeholders, such as clients, consultants and contractors? To answer this question, Asnaashari *et al.* (2009) carried out qualitative research to identify and interpret the causes of delay in Iranian construction projects. They interviewed eleven experienced construction managers and practitioners in an open manner. They classified causes of delay under seven categories: (1) Stakeholders; (2) Economy; (3) Politics; (4) Project Management; (5) Logistics; (6) Technology; and (7) Environment (Figure 20).

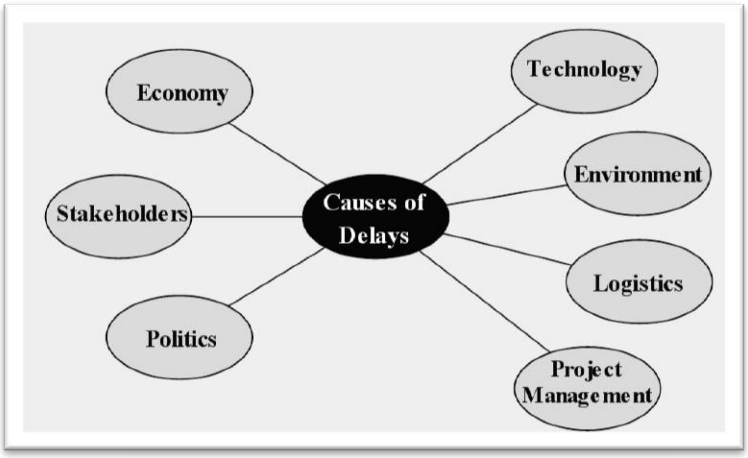


Figure 20: Categorising causes of delay in the Iranian construction projects (Asnaashari, Shahrabi Farahani, Hoseini, Knight, & Hurst, 2009)

Asnaashari *et al.* (2009) stated that the main causes of delay in the Iranian construction industry include: clients' lack of knowledge about construction legislation and processes, slow decision making by clients, changes in drawings, unrealistic cost estimation by contractors, traditional management styles, poor scheduling, using old technology, disputes in the supply chain, low level of commitment among supply chain members, shortage of materials/labour, high rate of inflation, the Government liabilities to contractors, old-fashioned construction legislation, delay in payments, cash constraints, and adverse weather conditions. As some delays may be rooted in logistical issues, associated causes to logistics should be considered in the conceptual model.

4.7.4. Information and Communication Technology (ICT)

As the role of information flow in a logistics system is critical, attention should be paid to the ways ICT can be utilised in a logistics system. In terms of Information and Communication Technology (ICT) utilisation (access, use and skills), Iran is ranked at 64 in the ICT Development Index in 2009 (International-

Telecommunication-Union, 2009). This shows improvement considering the country's rank of 92 in 2002 (Gerami, 2010).

There is no statistical evidence that describes ICT penetration in the Iranian construction industry. However, Rajaee *et al.* (2009) claimed that, although the level of ICT utilisation in construction industry varies depending on size of the organisations and projects, most managers are aware about its importance in projects and the impacts that it may have on improving the efficiency and effectiveness of firms. Rad *et al.* (2010) carried out qualitative research to study the trends and patterns of ICT utilisation in the construction industry in Iran. They conducted twelve semi-structured interviews with experienced construction practitioners and construction related software developers in Iran. They stated that the main incentives which motivate the Iranian construction firms to apply ICT are cost saving, time saving, and high level of functionality. They also explained that the virtual environment, wireless networks, information integration, remote access and visual inter-organisational communication are features that the Iranian construction firms expect to have in the near future. In their study, Rad *et al.* (2010) also identified obstacles that block the Iranian construction firms from utilising ICT, including low speed connection, expensive high speed internet connection, lack of an integrated online payment system, lack of construction ICT standards and costly hardware. Considering the importance of information flow in a logistics system, the conceptual construction logistics model developed in this study should take into account the capacity and barriers of ICT utilisation in the Iranian construction industry.

4. 8. The Residential Sector in Iran

In the housing and residential sector, the Iranian Government is facing three challenges: the sharp rate of population growth, the risk of earthquake, and the turbulent building economy. From March 2004 to March 2005, Iranian households numbered 15.1 million but the total number of dwelling units was 13.5 million (SCI, 2006). This reveals a significant difference between demand and supply in the residential sector. Moreover, according to the Ministry of Housing and Urban Development (MHUD) (2009), there is a need for 800,000 additional units every year as young couples embark on married life. However, in 2010/11, only 440,000 units were built (MHUD, 2011). Meanwhile, Iran's geographical position over the seismic belt necessitates the reinforcement and renovation of old buildings in this country (Pourezzat, Nejati, & Mollaee, 2010). In addition, the current economic environment of Iran poses uncertainty and risk for construction contractors, owing to the high inflation rate, sanctions and the construction materials market instability (Yisa, Holt, & Zakeri, 2000). Sharp rises in the price of land and construction services cause a dilemma for people with middle and low incomes who cannot afford to buy a house at the present prices (AftabNews, 2006; Chegini, 2007). Table 3 shows the average cost per square metre (PSM) of building construction in Iran. In a three-year period, PSM cost increased around 113 per cent from Rls 1,412,000 in 2005/06 to Rls 3,006,000 in 2008/09.

Table 3: Average cost of one square metre of building construction (Rials) (MHUD, 2010)

Year	Urban Areas
2005/06	1,412,000
2006/07	1,666,700
2007/08	2,248,300
2008/09	3,006,000

These challenges have put so much pressure on the Iranian Government that it has declared that the Iranian building sector must improve its productivity and efficiency to meet the huge demand in the market (ISNA, 2008). To cope with these challenges, the Government, through MHUD, has set six main strategies: 1) Maskan-e-Mehr Scheme, 2) Public-rent Housing Scheme, 3) Mass-produced Housing, 4) supporting new methods of building (e.g. industrialised building), 5) renovating old buildings (reinforcing against earthquake), and 6) Rural Housing Development Scheme (MHUD, 2011). In the following sections, first, the economy of the residential sector in Iran will be described and, then, the two most important strategies expressed above will be explained (the Maskan-e-Mehr Scheme and industrialised building).

4.8.1. The Economy of the Residential Sector

The Iranian residential sector is currently in recession and no sign of improvement is visible. However, this sector has faced several rises and falls in recent years and it is expected that the situation will be improved by the end of 2012 (CBI, 2009). Regardless of economic issues, during the past years, managers have learned that they should initiate the work and not stop because of the numerous uncertainties and risks (Sobhiyah, Seymour, & Perry, 1997). The reason is that, traditionally, the Iranian private sector is eager to invest in building construction as it is seen as a safe way of investment with a good return.

In the Annual Report 2008/09 of the Central Bank of Islamic Republic of Iran (CBI), which was published in 2009, the most recent condition of the residential sector was described from an economic point of view. It was explained that this sector had experienced a boom, starting in 2006/07, which continued to 2008/09. However, in early 2009, construction activities declined because of the recession in housing market. The total number of residential buildings constructed (by the private sector) in urban areas in 2008/09 was 601.9 thousand with a total floor space of 73.6 million square metres (Figure 21). Compared to 2007/2008, this shows a 22.5 per cent growth in number and a 20.8 per cent rise in floor space. However, the number of construction permits issued by municipalities declined by 15.4 per cent, which indicates a recession in the sector.

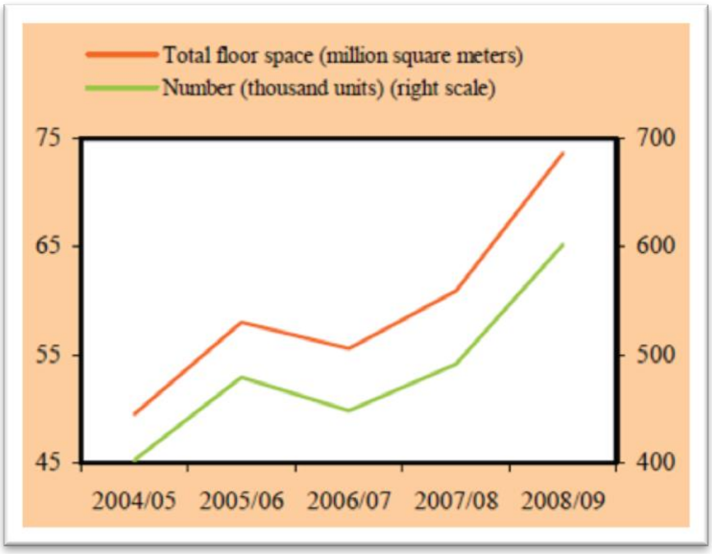


Figure 21: Residential buildings constructed by the private sector in urban areas

In 2008/09, the Government allocated a sum of Rls. 19.3 trillion in the country’s budget to be used for the acquisition of non-financial national assets for the housing sector, urban and rural development, and support programs. Yet, only 66.2 per cent of this figure was realised at the value of Rls. 12.8 trillion. Banking facilities to the non-public housing sector increased by 17.2 per cent in 2008/09 compared to 2007/08. In 2008/09, the land price index and construction services price index rose by 42.4 per cent and 34.7 per cent respectively. Moreover, the price index of metallic and non-metallic construction materials increased by 16.2 per cent and 51.6 per cent respectively in the same year (CBI, 2009).

A bubble in the housing market is also an issue. The term ‘bubble’ is defined by Case and Shiller (2003) as “a situation in which excessive public expectations of future price increases cause prices to be temporarily elevated”. The Government has provoked the housing market in two ways that caused a bubble (Nazari & Soori, 2009):

1) Decreasing banks’ interest rate which directed the capital into the building sector and increased the number of investments in the housing market. This reduced the risk of investment in the sector and amplified demand in the market.
2) Increasing banking facilities (mortgage) led to even more demand for houses.

Although the price of a house, as with other goods, is determined based on supply and demand, the housing market does not respond to the Government’s short term solution quickly. The main reason is slow production which leads to a slow supply of houses. Thus, setting strategies for the housing market should be differentiated from other markets. In fact, injecting cash into the market to make the buyer able to buy a house may make the situation worse.

4.8.2. Maskan-e-Mehr, the Biggest Housing Scheme in Iran

In 2007, the Government introduced the Maskan-e-Mehr Scheme to be involved in the residential sector and meet demands. This scheme targets meeting the residential needs of low income people by constructing affordable buildings (Jahani, 2008). The aim is to produce low cost buildings by eliminating the price of land (MHUD, 2011; Hemati, 2008). In fact, the Government transferred its land ownership for a 99-year period to housing cooperatives (clients) to build affordable residential complexes (MHUD, 2011; Hemati, 2008). A housing cooperative is an institution with members who do not have enough capital to build houses individually and, thus, they form a cooperation to prepare the required capital by aggregating members’ small-sum money and using banking facilities (MoC, 2007). Hemati (2008) expressed the three advantages of the Maskan-e-Mehr Scheme as:

1) increasing supply in the residential sector
2) focusing end-users' cash on building production rather than buying land
3) eliminating the role of dealers

Although this scheme has increased the rate of building production considerably, it has had some problems. Some critiques consider it a hasty scheme which has not been successful at all (EbtekarNews, 2009; IranEconomist, 2010). The weaknesses of this scheme are noted by several researchers, practitioners and authorities as:

1) Clients have had problems in receiving banking facilities (EbtekarNews, 2009)
2) The housing cooperatives do not have the expertise to be a client and have performed weakly in making contracts and supervising contractors (Hemati, 2008)
3) Although the price of land makes up a large proportion (80%) of building construction cost in big cities, such as Tehran, in medium or small cities, such as Kerman, this figure is low (e.g. 16%). Hence, in medium or small cities, this scheme has had a weak effect on housing prices and cannot solve the issue (Heidari, 2008).
4) Lands allocated to this scheme are usually far from the city centre (Heidari, 2008).
5) In most cases, the cost of land preparation is very high because majority of lands allocated to this scheme are located in very high or very low areas with hilly terrains and land reliefs (Heidari, 2008).

4.8.3. Industrialised Building

In July 2008, the Iranian President, Mahmoud Ahmadinejad, announced that his government was looking for different ways to reduce the time and costs of construction, especially in residential projects, by insisting on industrialising building construction (ISNA, 2008). Before this announcement, the government spokesman had publicised that 30 prefabricated building factories would be opened by April 2009 (FarsNews, 2008). Nozari (2008) emphasised that industrialised methods have the potential to reduce waste of resources, materials, time and energy in the Iranian building sector. However, there are some obstacles in the way of industrialising building construction in Iran, such as: inflexibility in design, tedium in forms, lack of technical knowledge, low quality assembly, old-fashioned design, heavy weight, shortage of specialised workforce, transportation issues, and inadaptability with the cultural and geographical specifications of the country (Nozari, 2008). Regardless of these obstacles, industrialised building remains an important part of MHUD strategy to deal with the large housing demand. To remove the obstacles, Abdi and Mehdizadegan (2008) recommended some solutions, such as supporting producers, establishing required codes, educating the workforce, enhancing public awareness, and using localised technology.

4. 9. Logistics in Iran

The word ‘logistics’ is not a familiar term in Iran and most people associate it with military actions. Although the concept of logistics is known by most industrial engineers, people who are educated in management fields and those who work in transportation sectors, not enough attention has been paid to it in different industries so far. According to Iran Logistics Society (ILS, 2007), a large proportion of the final price of Iranian products often is due to surplus logistics expenses. Furthermore, on the macro economy scale, logistics costs represent 14 per cent of the Iranian GDP (ILS, 2007). Factors affecting logistics cost in Iran are: (a) total area of the country, (b) population, (c) the length of railway, (d) water boundaries, (e) volume of import and export, (f) inflation rate and (g) the rate of energy consumption (ILS, 2007).

There has been little research about logistics management in Iran. However, after establishment of the Iran Logistics Society in 2004, the numbers of investigations and studies with topics related to logistics and supply chain have increased considerably. Three national conferences about logistics which were held in recent years by ILS illustrated that both researchers and practitioners understand the importance of logistics and supply chain management and are interested to work on this topic.

The Iranian construction industry does not take advantage of effective logistics management. Asnaashari *et al.* (2008) evaluated logistics knowledge among Iranian construction practitioners and concluded that respondents perceive logistics as equivalent to supplying, procurement or transportation. The authors explained that, although practitioners were aware of the general meaning of logistics management to some extent, none of them could explain an inclusive definition (Asnaashari, Hurst, & Knight, 2008). Asnaashari *et al.* (2008) expressed two reasons for this: (1) lack of an official translation for 'logistics' in Farsi which can project and clarify all the different aspects of this term and (2) lack of training and education about logistics among personnel. Asnaashari *et al.* (2008) also stated that the Iranian construction companies often suffer from logistical problems, such as early/late delivery of materials, slow material handling methods, lack of an inspection system, poor warehousing, shortage of construction materials, transportation, heavy traffic, bad weather conditions and cash constraints.

A comprehensive search was conducted to find other literature around the topic of construction logistics management in Iran through academic journals, periodicals, and national and international databases, but no research was found. This is one of the reasons that this research focuses on construction logistics management in Iran.

4. 10. Conclusion

This chapter introduced Iran from historical, political, cultural and economic perspectives. The aim was to make the reader familiar with the current conditions of the country. This will help later in this thesis to form a conceptual model which appreciates the characteristics of Iran. Furthermore, information was provided about the construction industry in Iran, and specifically the building sector. The aim was to form a context for this research. Indeed, it has enhanced the readers' knowledge about the construction economy, national projects, regulatory bodies, education and the Iranian Government's strategies towards housing.

Chapter 5

COMPLEXITY AND MANAGEMENT

CHAPTER 5: COMPLEXITY AND MANAGEMENT

5. 1. Overview

Management is difficult, because managers have to deal with people who are more complex to understand than machines. Although the traditional role of managers in organisations is to control the performance of the organisations, sometimes they find the organisation out of control. There is no guarantee that, if a manager just plans harder and in more detail, the organisation works properly. In fact, forcing reality to stick to the plan is impossible. This chapter aims to discuss this issue by exploring two management mindsets: the Newtonian style and the Complexity approach. This chapter will challenge the Newtonian style of thinking and argue that organisations are complex systems which exert special properties, such as nonlinearity, unpredictability, instability, and self-organising. It will explain that complexity science has the potential to help managers in today's world with a high rate of uncertainty to manage their organisation more effectively by utilising a holistic view instead of a reductionist view. The complexity mindset provides a number of sophisticated tools for managers. Some of these tools are computer based, for describing and simulating systems, and some of them are analytical, for studying these systems deeper. Yet, the most important tools that complexity offers for managers are concepts that help them think about a complex system. This chapter does not aim to explain the use of simulation or other analytical approaches but to introduce a new way of thinking about organisations as complex systems. It will be explained later, that the construction logistics system is a complex adaptive system (CAS). Understanding the properties of a CAS will help to create a qualitative model which is more adaptable to the current situation of the construction industry in Iran.

5. 2. Describing the Problem

One of a manager's concerns is keeping the project under control. In Oxford Online Dictionary (2009), management is defined as "the control and organisation of something". Encarta Encyclopaedia (2009) defines management as "the techniques and expertise of efficient organisation, planning, direction, and control of the operation of a business". As is clear, 'control' is a common term in both of the above definitions, and many other definitions that are used for management. In fact, managers are the people who are in charge to control the performance of a business, a project or a process. To do so, many tools and techniques can help managers to keep their business affairs under control. Despite great development in management concepts and techniques, controlling organisations is a tough job that sometimes cannot be done as it is expected. Usually, managers complain about the deadlines that were not met, targets that have slipped, vague strategic visions, and missions that are poorly communicated (Stacey, Griffin, & Shaw, 2000). These issues may take organisations' control from managers' hands. It is stressful for managers to be the ones who are in charge, but who find that they are not in control.

By looking at different planning tools, such as the Critical Path Method (CPM), it can be concluded that they are designed based on a simple assumption: the future is predictable. It will be argued that this assumption is the main reason that managers fail to control their organisations. Although managers can guess some up-coming circumstances by analysing available data and previous experience, the future is still recognisable only when it arrives. Hence, managers need to think about a new way to look at the future and the way that organisations can be managed and controlled.

5. 3. Newtonian Organisations

Organisations, as social entities which control themselves and pursue a specific goal, are one of the important parts of management and business studies. Much effort has been made to investigate how people act within an organisation and how an organisation should be managed to meet its goals.

The current dominant notion about managing organisations has roots in a Newtonian style of thinking, with universal laws of a linear type, such as gravity (Darwin, 1996; Stacey, Griffin, & Shaw, 2000). The Newtonian style of thinking explains that a phenomenon consists of discrete and objective elements that can be studied by separating the whole phenomenon into its parts or elements (Tsoukas, 2005). This is called the reductionist approach. Newtonian thinkers also believe that there is a law-like association among the elements of a phenomenon that should be identified by finding a linear causal relationship. Based on these laws, a mechanistic model will be constructed to predict the future and take control of the phenomenon (Tsoukas, 2005).

Newtonian-style thinking has been quite successful in applied sciences and engineering. Based on this noted reputation, many attempts were made to bring the Newtonian view to management studies. Frederick Winslow Taylor (1856–1915), an American mechanical engineer, was one of the first people who brought Newtonian thinking from engineering to management by developing scientific management principles. To make working processes stable and predictable, and eliminate human variability, Taylor removed all responsibility from the workers, leaving them only with their particular tasks. He believed that workers do not need to think, and should act as a machine and repeat the same job. Taylor also thought that the only incentive that can motivate workers is money (Pettinger, 1994). It means that the more a worker works, the more he earns, and vice versa.

Taylor's approach was absolutely based on the Newtonian style of thinking by using a reductionist approach towards activities: identifying laws (the best practice), using a linear causality in terms of the incentive system, and predicting the outcome by promoting objectivism. Taylor's scientific management, and the Newtonian view, are still the current dominant approach towards managing organisations. This notion encompasses (1) predicting the future, (2) choosing proper strategies, (3) preparing detailed planning, (4) motivating human resources, (5) measuring progress, and (6) controlling the organisation.

Although in many situations of everyday life, Newton's mechanics work well, in the organisations and management field, it has proved much less successful (Darwin, 1996). The reason is that the world of organisations is different to pure science realms. The Newtonian view might work well under conditions of low speed, low change and high predictability. However, in today's fast-paced world of organisations with high rates of uncertainty, this traditional approach no longer works. Today's organisations are characterised by high technology, high speed, high change, high unpredictability and high stress (DeCarlo, 2004). They work in turbulent business conditions and a competitive market. They have complex structures with multiple departments, making them politically sensitive.

There is an alternative to the Newtonian style of managing organisation that enables organisations to compete in volatile business environments and dynamic workplaces. This new mindset, in contrast with the Newtonian mindset that is based on stability, is derived from the assumption that accepts change, uncertainty and unpredictability as norms in today's life of organisations (DeCarlo, 2004). This new mind set is offered by the science of complexity and will be explained more in the following section.

5. 4. Complexity Theory

Complexity is a new paradigm that intends to discover the laws governing systems that are made up of a large number of interacting agents, whether those systems are a national economy, an ecosystem, or an organisation (Belgian Federal Centre for Complexity and Exobiology, 2009). This theory was founded on researchers' attempts to rationalise the behaviour of complex systems, believing the usual laws of nature cannot describe them. Complexity is a context-dependent concept, as there are several complexity theories that arise from different disciplines, such as biology, mathematics, physics, chemistry, computer and social sciences (Mitleton-Kelly, 1997). However, the principle of complexity theory is that there is a hidden order to the behaviour of complex systems. To study this hidden order, complexity focuses on the parts, relationships and the environment of complex systems.

Complexity theory can help us to reform our understanding about organisations that we have been studying (Lewin, 2002). It informs us how to think about the evolutionary process. To study a complex system, a researcher should be aware about three points: (1) the causality relationship among agents of a complex system is nonlinear; (2) the future is unpredictable; and (3) explaining complex systems is only possible by taking a holistic view instead of a reductionist view.

5. 5. Complex Adaptive System (CAS)

A CAS is a complex system that includes planner units, i.e., units that are goal-directed and that attempt to exert some degree of control over their environment to facilitate achievement of these goals (SFI, 2008). In a CAS, the parts, which are usually called agents, are connected to each other and have a degree of freedom in responding to changes. These responses can be highly nonlinear. A CAS may learn from previous experiments and adapt itself to the new conditions and environment. Hence, they are known as adaptive systems.

The term complex adaptive systems (CAS) was put forward by John H. Holland (1992), who looked at the immune system as a CAS, which consists of antibodies that continually repel antigens. As there are almost infinite varieties of antigens, the immune system must adapt its antibodies as new antigens appear. Thus, the immune system is adaptive. This system has the ability to change its constitution and is also able to influence its current and future survival (Holland, 1992; McCarthy, 2003). The immune system must also distinguish legitimate parts of the bodies from antigens. This is a difficult task because there are the tens of thousands of differing types of cells in a body that the immune system needs to recognise. Therefore, the immune system is complex because there are many parts with varying individual criteria involved in the system (Holland, 1992).

Generally, a CAS has three properties: (1) evolution and self-organisation; (2) aggregate behaviour; and (3) non-determinism and dynamic structure (Holland, 1992; Mitleton-Kelly, 1997; McCarthy, 2003). Evolution happens in a Darwinian fashion. The system changes as its environment changes. Yet, when the system changes, it will also affect its environment because the system is a part of the environment. When the environment is changed again, the systems should also change to adapt itself with the environment. This continual cycle of feedback usually happens in complex systems (Holland, 1992; McCarthy, 2003). Aggregate behaviour emerges from the interaction of agents and is not necessarily derived from the actions of them (Holland, 1992). Non-determinism means that it is impossible to anticipate precisely the behaviour of such systems, even if we completely know the function of its constituents. Hence, by reducing a complex system into its parts we cannot discover its future performance. In fact, the dynamic structure of complex systems limits functional decomposability. The reason is that the system has a permanent interaction with its environment and its property of self-organisation allows it to restructure itself (Pavard & Dugdale, 2007).

To make these issues more understandable, firstly, a system should be defined clearly. A system consists of elements which are bonded together to produce a whole in which the attributes of the elements contribute to the behaviour of the whole (Jones W. , 2003). The elements and the components of a system are the agents of that system which interact with each other. An agent can be an ant in a colony, an electron in an atom, or a worker in an organisation. In a CAS, agents can combine into meta-agents. Also, a CAS can be an agent of a mega system. Each agent has an individual set of rules which can be adaptive. These rules consist of action rules and also rules for change (Tilebein, 2006; Nilsson, 2006). The agents of a CAS are connected to each other and have a degree of freedom in responding to changes. These responses can be highly nonlinear. These systems adapt themselves with their new condition and environment (e.g. ant colonies). The aggregate behaviour of a CAS is usually far from optimal because the agents are continually changing. If temporarily a CAS remains on a optimal or equilibrium point, they die (Holland, 1992; Mitleton-Kelly, 1997; Tilebein, 2006). It should be expressed that CAS is a way of thinking about the world; not a model for predicting what will happen and reaching optimal points. Knowing and understanding the properties of the CAS will give us a more accurate insight into the complex phenomena of the world. Schultz (2002, p. 19) summarised the key points about CAS in the following:

- The system consists of individual agents, who are able to make decisions against changes.
- Agents can have their own or shared mental models within which learning and adaptation are possible.
- Agents are interconnected and systems are embedded within systems.
- The behaviour of the system emerges from the interactions of agents. The behaviour may be novel.
- Action by one agent changes the context for others.
- The system is nonlinear; small inputs can lead to major outcome swings.

5. 6. Complexity and Organisations

Today’s business is characterised with a high level of uncertainty that comes from the fast pace of changes. Change in organisations is an important issue as it can be both constructive and destructive. A manager’s major concern is how an organisation becomes stable and how stability leads to a novel situation. In fact, an organisation of any kind can be seen as the interplay of stability and change. For a better understanding of change and stability, the source of these two concepts should be studied. Stacey *et al.* (2000) believe that identifying the source of both change and stability has to do with causality. The reason is that to make the organisation stable, managers should predict the future. The possibility of prediction and control depends upon the manager's ability to identify causal links (Stacey, Griffin, & Shaw, 2000). What causes organisations to become what they are and what causes them to be stable or instable is at the focal point of this discussion. Stacey *et al.* (2000) expressed that there is a causality spectrum which shows the way people think about change and stability. The Newtonian mindset is on one side of the spectrum that emphasises stability and the predictable nature of change. The other side belongs to the complexity mindset that emphasises change and its unpredictable nature. The differences between the Newtonian mindset and the complexity mindset are illustrated in Table 4, which is developed based on the DeCarlo (2004) book.

Table 4: Differences between the Newtonian mindset and complexity mindset

Newtonian mindset	Complexity mindset
Stability is the norm	Chaos is the norm
The world is linear and waterfall-like	The world is intricate and spider web-like
A good plan is a prediction	Uncertainties; we cannot predict
Minimise change	Welcome change

To elucidate the causality spectrum, two concepts of mechanism and organism that were developed by Immanuel Kant (1724–1804) should be described. A mechanism is a functional unity in which the parts exist for one another in the performance of a function (Goodwin, 1994). An organism is a functional and a structural unity moving to a mature form and this form is unique in a particular context (Webster & Goodwin, 1996). To make a mechanism (e.g. a clock), a finished notion of the whole should exist. In the clock example, the final function, which is recording the passing time, exists. Based on this function, different parts should be designed and assembled to meet the aim of the mechanism, that is keeping time. However, for an organism, like a plant, parts (roots, stems, leaves and flowers) are not first designed and then assembled. Actually, the parts emerge from interaction within the plant and the environment (Stacey, Griffin, & Shaw, 2000). It means that, in contrast with a clock, parts of a plant do not exist before the whole plant. The differences between mechanism and organism are summarised in Table 5 (developed based on the thoughts of Stacey *et al.* (2000)).

Table 5: Differences between mechanism and organism

	Mechanism	Organism
First Idea	needed	not needed
Parts	parts exists before the whole and should be designed and made	parts do not exist before the whole and arise from interactions within the developing organism
Planning	Goal directed	Not goal directed
Interaction	not important	very important
Future	Predictable	Unpredictable

Managers' belief in mechanism or organism reflects how they manage their organisations. Sherman and Schultz (1998) also confirm that complexity theory "…is about how our ideas shape our behaviours. If our ideas about the world in which we operate are machine-like and mechanical, our behaviours will be very different than if our ideas are based on that of complex adaptive systems, which are more evolutionary and organic". Based on this idea, a manager with a Newtonian mindset may have serious problems to manage an organisation that is working in a complex world. Hence, the manager is likely to feel frustrated and under stress most of the time, because his or her actions are in conflict with reality (DeCarlo, 2004). Therefore, there is a need to change the way of thinking about organisations and take an organic view towards them, to address issues related to uncertainty, unpredictability and complexity.

5. 7. Three Lessons for Managers

It is believed that complexity science can present a holistic perspective to organisation in which the whole is more than just the sum of the parts. Organisations are living systems which consist of several parts. Parts interact in a nonlinear style and form organisation systems. Organisations interact with each other as well to form mega-systems, such as industries and economies. The main differences between the two mindsets explained above is that organisations cannot simply be divided into the parts to be understandable without consideration of interactions among parts, irregular patterns and nonlinear behaviours. Other distinctions between the

Newtonian approach and complexity approach to management are explained by DeCarlo (2004). His explanations are summarised and tabulated in Table 6.

Table 6: Differences between Newtonian style and complexity style of management

Newtonian Style	Complexity Style
Deliver on the planned result	Discover the desired result
Use the plan to drive results	Use results to drive planning
Aim, aim, fire	Fire. Then, redirect the bullet
Establish stronger procedures and policies	Agree on guidelines, principles and values
Keep tight control on the process	Keep the process loose
Be a task master	Be a relationship manager

Complexity mindset offers many lessons for managers. Three lessons will be expressed in this section. The first lesson is that in an uncertain world the future is not predictable, and that successful strategies emerge from complex and continuing interactions between people in a self-organising system (Rosenhead & Mingers, 2001). Letting an organisation self-organise does not contradict the need for strategy. Rather, it means that organisational strategy should evolve based on feedback and change as it occurs. Therefore, a high level of agility to become adaptable to changes is a requirement for the longer-term success of organisations.

Another lesson is that an organisation should place itself in the region of bounded instability, to seek the edge of chaos, rather than trying to consolidate stable equilibrium (Rosenhead & Mingers, 2001). In fact, seeking a stable equilibrium will lead to failure in the relationships between the organisation and its environment. Working on the edge of chaos, instead of a perfectly planned schedule, will release creativity and will lead to an organisation which continuously reinvents itself (Rosenhead & Mingers, 2001).

Complexity theory also changes the role of managers. This notion defines the job of managers as people who prepare a clear vision for the company, provide effective leadership, express and encourage organisational values, and provide a basis for open communication instead of becoming involved in planning for an unknowable future, detailed decision-making, and controlling people (Rosenhead & Mingers, 2001).

5. 8. Sources of Complexity in Construction

Construction is generally seen as an ordered and linear process that can be organised, planned and managed top down (Bertelsen, 2003). Project managers divide the process in to activities and work packages to be executed in a sequence based on detailed plans (Bertelsen, 2003). However, the frequent failures to complete construction projects on time and schedule show that construction is one of the most complex and risky businesses undertaken (Wood & Ashton, 2009). In fact, construction is a nonlinear, complex and dynamic process (Bertelsen, 2003). Gidado (1996) attempted to identify the sources of complexity in construction by interviewing practitioners. A summary of his results is as follows:

- Construction has a large number of different systems that need to be put together. Each of these systems has a large numbers of interactions between its agents.
- In construction projects, several trades have to work closely in a confined site at the same time.
- Planning to bring numerous parts of work together.
- Technical complexities of executing hard details.
- Efficient coordinating, control and monitoring are required from start to finish.
- Encountering a series of revisions and change during construction

In addition to this list, factors such as the emergence of the new technologies, economic fluctuations, competitive markets, new regulations imposed by the governments, dwindling resources, risky workplaces and globalised markets can be regarded as sources of complexity in construction (Mills, 2001). All of these imply that a construction project as a phenomenon should be approached in a different way. What complexity mindset offers is an alternative way to think about a construction project and understand how it forms, moves, changes, responds to the environment and influences its environment. In the next section, the discussion will be continued about the complexity of logistics management.

5. 9. Complexity and Construction Logistics Management

Logistics management is about movement, inter-relations and interaction among agents of the logistics system, such as material management, transportation, purchasing, etc. In this research, logistics will be studied as a system. The aim, as Rushton *et al.* (2006) emphasised, is to treat the many different elements that come under the broad category of logistics as one single integrated system. This view will help us to interpret the interrelationship among the different elements of a logistics system and identify cost trade-offs to add value to the whole logistics network.

At the early stage of the research, a diagram was developed to have a general idea of a construction logistics model and how it looks (Figure 22).

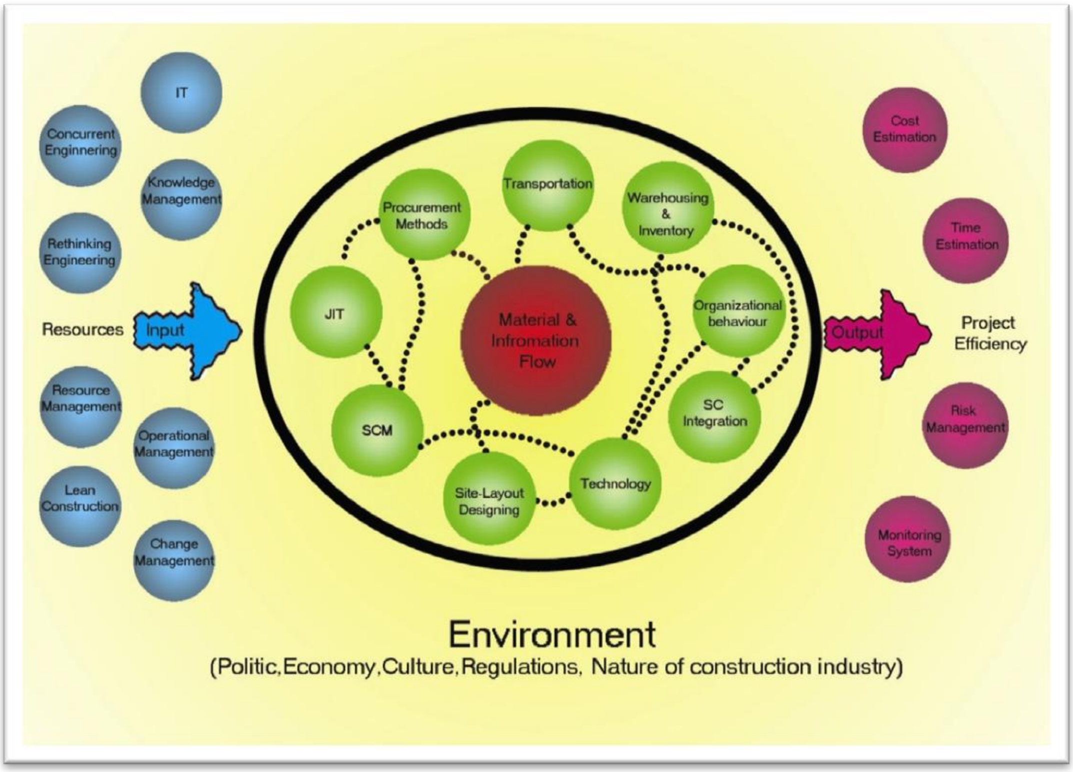


Figure 22: Basic construction logistics diagram

This diagram shows a system which is located in an environment. Within the system, there are subsystems or agents that are somehow linked together and separated from the environment with a boundary (the black oval in Figure 22). The basic system also has some inputs and outputs. The inputs are resources and tools that are required to make the system work, such as IT and operational management techniques. The outputs are the system goals that should be achieved, such as time and cost efficiency. It should be explained that the system illustrated in Figure 22 is quite basic, and the agents, relationships and environmental factors are not real. The diagram was developed based on early thoughts of the researcher to apply system thinking in the research project.

Construction logistics is a complex system for four reasons: (1) a construction logistics system is more than its agents. The inter-relationship and interaction among the agents of the logistics system is critical. (2) The agents of the logistics system have a degree of freedom to respond to changes. (3) The whole system can learn from the environment and adapt itself to the changes. (4) A logistics system is a part of a construction project that is a complex environment, as explained above. The characteristics of a logistics system can be explained as:

- A logistics system consists of many subsystems that should be identified.
- Logistics subsystems have significant impact on the performance of the whole system. They are inter-related, manageable and changeable.
- Subsystems of logistics system are free to choose strategy and emerges novel behaviour.
- The logistics system is a part of an environment (a typical project). The environment itself is a system that has interactions with its environment (construction industry) as well as the logistics system.
- A logistics system is an integrated entity. This means that this system cannot be understood by dividing it into its parts, because the interrelationships between different elements of logistics system are important.

Considering these characteristics, the logistics system can be assumed to be a Complex Adaptive System (CAS). A logistics system is a network of autonomous agents that behave based on regularities extracted from their environment. Some agents of a logistics system are material management, earthmoving, waste, machinery, security, personnel, and storage and warehousing.

Complexity is helpful in studying construction logistics as it is a theory based on relationships, emergence, patterns, and iterations. Complexity theory is able to offer a new way of thinking which gives us an insight to study the complex phenomena of the world. The complexity mindset states that a holistic view should be taken towards the logistics system. Looking from the top, managers should attempt to recognise emerging patterns and business trends and adjust their strategies to changes. In fact, the firm's strategy should evolve based on change as it occurs (Rosenhead & Mingers, 2001). In other words, a high level of agility to become adaptable to changes is a requirement for the longer-term success of construction organisations in today's conditions of the industry. Moreover, the complexity mindset modifies the role of managers. It defines the job of managers as people who prepare a clear vision for the company, provide effective leadership, express and encourage organisational values, and provide a basis for open communication, instead of becoming involved in planning for an unknowable future, detailed decision-making, and controlling people (Rosenhead & Mingers, 2001).

5. 10. How Does Complexity Help This Research?

In the previous sections, a brief description of the complexity mindset, the sources of complexity in construction projects and logistics systems were explained. This section explicates how complexity helps this research. Generally, the complexity mindset contributes to this research in the following three ways.

The first contribution is that the agents of logistics systems cannot be studied in isolation. There are relationships among agents (internal relationships). In fact, agents are linked together and interact with each other during the course of the project. This means that change in one agent may affect several agents and change their behaviour. For instance, one may save money by reducing the packaging quality of a product, but this action may incur extra cost in handling and transportation which increase the total cost of the product. Moreover, there are relationships between agents and their environment (external relationships). The external factors, such as economic conditions, may have a strong impact on some agents and change their behaviour. Meanwhile, in some cases, the agents may also cause change in the environment. Both internal and external relationships form the behaviour of the system, which is referred to as an aggregate behaviour. Hence, a logistics system is a web like phenomenon and investigating this system is not possible without considering the aggregate behaviour of the system. This means that studying and focusing on the function of each agent is not enough and the researcher should consider the aggregate behaviour of the system by giving credit to internal and external relationships.

The complexity mindset also helps to look at the logistics system holistically. This means seeing the big picture, instead of focusing on each agent. All agents, relationships and environmental factors should be seen in one big picture to identify potential sources of improvement in the system. The holistic view allows managers to understand complex causal relationships by visualising them in the form of a model.

The third contribution is about the role of the environment in managing logistics systems. The connection and interaction of the system and the environment have been expressed above. The question is, ‘what are the environmental factors?’ Complexity implies that environmental factors, such as culture and economy, should be considered when the system is under study. In other words, the importance of the environment and its impact on the system should not be neglected.

To utilise these contributions, complexity science offers making models. Models provide a dialog that can promote deeper and richer understanding of a phenomenon (Lissack, 2002). Models are strong tools that allow the leaders and managers to demonstrate their ideas and beliefs in a meaningful way to other people. Conger (1991, p. 44) emphasised this and stated that, "It is important that business leaders see their role as meaning makers. They must pick and choose from the rough materials of reality to construct pictures of great possibilities ... In the choice of words, values, and beliefs, you as a leader craft reality". In fact, a leader should be able to transfer the meaning of what his/her group is doing to the group members to enhance their understanding about the process. This is the point where a model can help. Lissack (2002, p. 273) noted “if leaders can put such understanding into a model, then the meaning of what the group is doing becomes a social fact. The group can now communicate about the meaning of their behaviour”. Lissack (2002) also expressed that transfering meaning through ilustrative models is not the role of leaders or managers only and researchers studying management should also focus on making models.

In this research, a model is a visual representation of a phenomenon that highlights important connections in a real world system. This type of model is usually referred to as a qualitative or conceptual model. In contrast to the quantitative models which are based on mathematical facts, the qualitative model is developed based on qualitative data. Gammelgaard (2004) indicated that qualitative methods in system studies can be used to approach a problem solution conceptually. Lissack (2002) explained that both the qualitative and the quantitative modelling have much to contribute to each other in management studies.

The final product of this research is a qualitative model for managing logistics in construction projects. The model uses boxes or circles to indicate subsystems and agents of the logistics system. It uses arrows and lines to indicate relationships, flows, and exchanges. The model is designed based on qualitative data analysis which is conducted on information gathered from interviewing construction practitioners in Iran. This model will be shown in the analysis chapters. However, to express the thinking evolution of the researcher, another diagram should be described. Figure 23 is a basic diagram developed at an early stage of the research. After reviewing the literature about construction logistics, Figure 23 was designed.

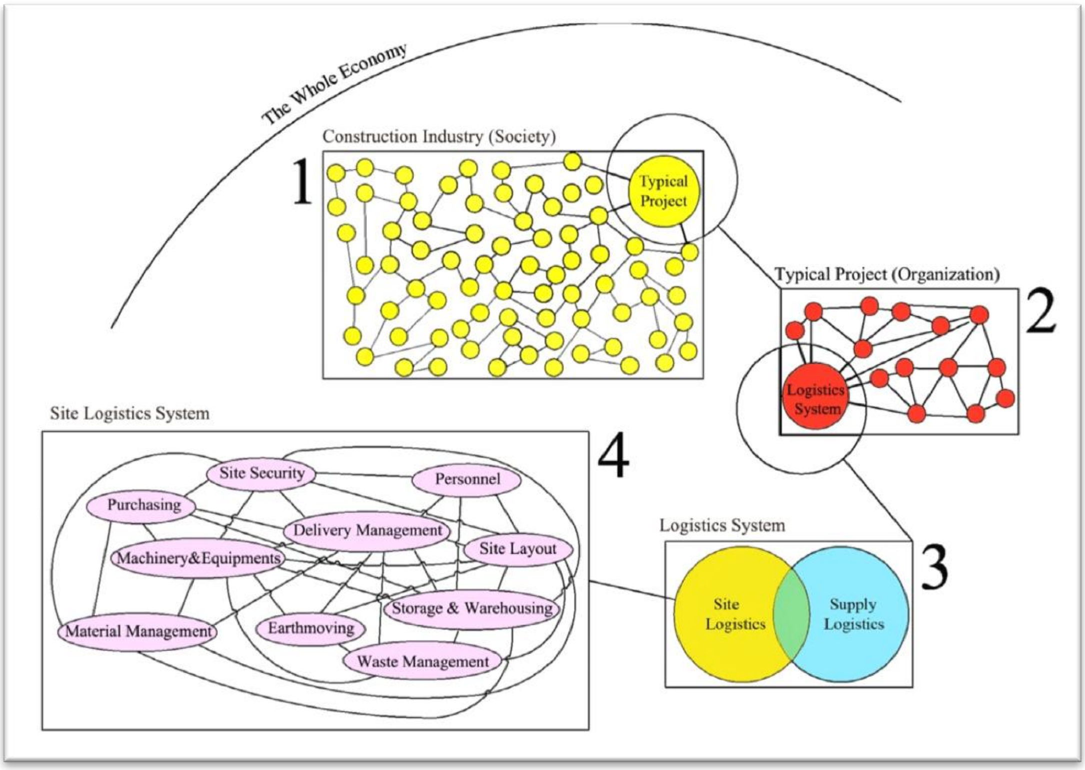


Figure 23: Road map of the construction logistics system

This diagram illustrates four focus stages. First, the construction industry is showed as a large subsystem which is embedded in the whole economy as the environment. The subsystems in the construction industry are illustrated using small circles which are connected to each other. Second, a typical construction project with several agents is showed as a subsystem of the construction industry. Third, the logistics system as an agent of a typical project is displayed which is divided into two sections: site logistics and supply logistics. Fourth, the site logistics system, which is the focal point of this research, is illustrated. The system consists of agents, such as material management and earthmoving, that were identified in the literature. The relationships between agents are logical but they do not have an empirical basis. Stage four in Figure 23 gives a better look of the final construction logistics model.

5. 11. Conclusion

The Newtonian style of thinking, which promotes predictability, linear cause-and-effect relationships and detailed planning in management, has attracted criticism recently. The mechanistic notion in management, with linear laws and regular patterns, led to the premise that managers can predict the future, choose strategies, measure activities and control them. This cannot address today's characteristics of businesses with the unstable situation of the economy, shortage of resources and credit crises.

The construction industry is a complex environment which requires managers to tackle a diverse range of problems. Simple solutions no longer work and a paradigm shift is required to address the complexities of construction projects. The complexity mindset is a way of thinking about the complex world. Complexity explains that intrinsic properties of interactions and relationships among parts of a complex system would be the cause of emergent coherence, which is unpredictable. The new paradigm recommends managers to take a holistic view towards organisations and deal with them as complex systems instead of machines. The complexity notion asserts that managers should attempt to recognise emerging organisational patterns and business trends and adjust organisational strategies to them. A clear vision, leadership, corporate values and open communication are critical subjects that managers should take into account to implement the complexity mindset in their organisations.

Complex problems are difficult to solve because they are often hard to understand. In these problems, the causes and effects are not obviously related. Making models is a way that helps us to visualise complex problems, have a holistic approach towards them, and understand their behaviour. Qualitative models, by using boxes and lines, enhance the understanding of construction logistics systems by conceptualising qualitative data and transferring meanings to users.

Chapter 6

METHODOLOGY

CHAPTER 6: METHODOLOGY

6. 1. Overview

The research methodology is an important decision made by the researcher because it forms the orientation of the research. Research is "a process of systematic enquiry or investigation into a specific problem or issue that leads to new or improved knowledge" (Burns & Burns, 2008, p. 5). The systematic process of conducting research is regarded as methodology. Fellows and Liu (2003) described methodology as the overall strategy to achieve the objectives of the research project. Methodological approaches range from pure scientific and objective experiments, such as chemical studies, to interpretive and subjective studies, such as humanistic investigations. This range can be expressed as a spectrum. A researcher should position him or herself somewhere in this spectrum (Figure 24). To do this, first, the researcher should have a clear philosophical understanding about the assumptions, foundations, methods and implications of science. These emerge from the researcher's view towards the world, truth and knowledge. Based on the philosophical assumptions, the suitable paradigm and, consequently, proper methods can be chosen to address the aims of the research.

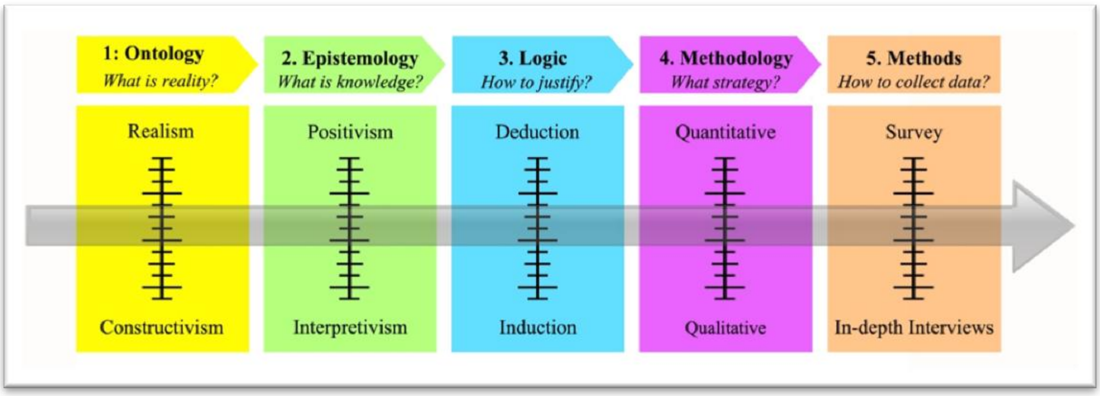


Figure 24: Research spectrum

In this chapter, the philosophical position, research strategy and the methods used to conduct this research will be described. Figure 25 illustrates the process of the research from inception to completion. The process had five levels: (1) inception, (2) conception, (3) empirical works, (4) thinking and (5) creation. Each level will be expressed in detail in this chapter. Before this, an overview of the debates on methodologies that are adopted in the field of construction management will be explained briefly in the following section.

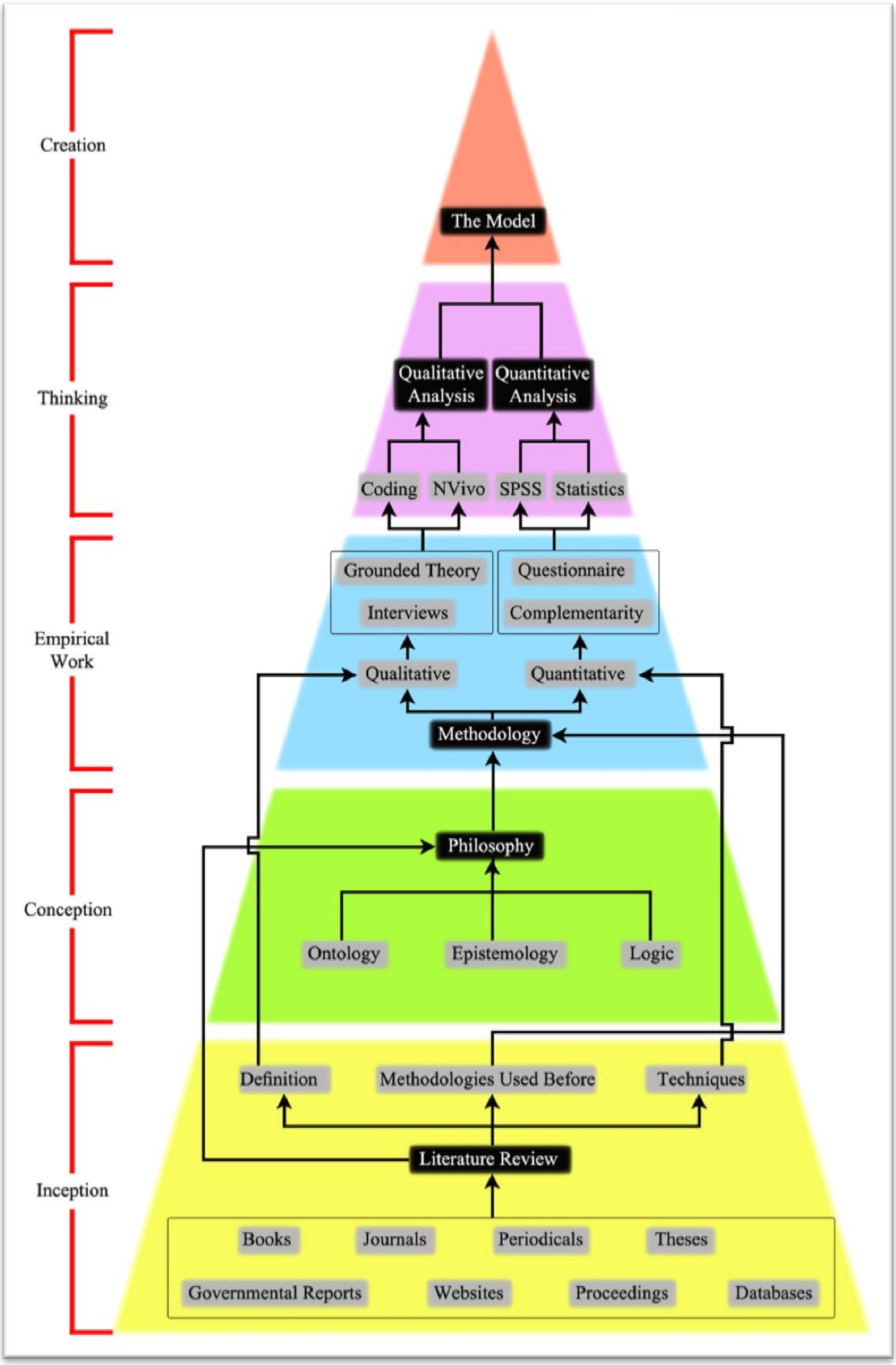


Figure 25: The process of conducting this research

6. 2. Methodological Debates in Construction Management Research

Construction Management (CM) is an interdisciplinary field that provides a link between the technical knowledge of construction and management science. The Construction Management Association of America (CMAA) (2002) defined CM as "a professional management practice consisting of an array of services applied to construction projects and programs through the planning, design, construction and post construction phases for the purpose of achieving project objectives including the management of quality, cost, time and scope". The history of construction is dated back to the period of the Egyptians and the Persian Empire. However, the period of post World War II (1945 onwards) is assumed as the earliest time that the CM discipline was found (Langford D. , 2009). In this period, a housing crisis, which was the consequence of war, led to technical and managerial advances, such as prefabrication, planning techniques and innovative construction methods (Langford D. , 2009). After over 60 years, the question is: can CM be considered as a strong academic discipline?

Langford (2009) believed that CM is a discipline because (a) it codifies what it knows, (b) the positivist paradigm is widely accepted in the field, (c) there is consensus about theory and methods among academics, (d) it has a degree of practical application, and (e) it is involved with living organisations. Among the five criteria introduced by Langford, (b) and (c) can be argued. The weakness in these criteria was even recognised by Langford, but not addressed properly. In fact, there is a controversial discussion about methodological issues (paradigm, theory and methods) in CM.

In general, positivism and use of quantitative methods is predominent in CM research (Dainty A. , 2008). However, the use of interpretevism and qualitative methods, as an alternative paradigm, has increased in recent years (Amaratunga, Baldry, Sarshar, & Newton, 2002). The work of Seymour and Rooke (1995) is assumed as the starting point of the discussion about methodological approaches in CM. In 'the culture of the industry and culture of research', they criticised the dominant realist paradigm in CM research. They believed empirical investigation into the nature of CM should take place instead of the dominant realist paradigm. Seymour *et al.* (1997) also ignited a debate about 'the role of theory in construction management'. They explained that, for CM to be a rigorous discipline, it should not be dominated by positivism as a unique epistemology and the quantitative approach as a unique method in the field. Runeson (1997), in response to Seymour *et al.* (1997), expressed that positivism offers the best way to reduce subjectivity and to discipline undisciplined researchers. He emphasised that there is no need for an alternative paradigm which is less useful. Runeson (1997) also believed that the Seymour *et al.* approach would lead to antiscientific attitudes. He explained that a good researcher should be objective and develop or test a theory. Thus, it does not matter if data comes from a survey or in-depth interviews. Although he appreciated the importance of interpretive research, he indicated that the use of the qualitative paradigm should be limited to primary theory building or where quantitative data is unavailable or unreliable. There is also another side in this debate that believes qualitative and quantitative paradigms focus on the different dimensions of the same phenomenon and may be collected together as complementary approaches. Researchers on this side recommend using a mix of qualitative and quantitative methods, which is called triangulation. Raftery, McGeore, and Walters (1997), in response to Seymour and Rooke (1995), expressed that the methodological monopolies in CM research should be broken up. They indicated that qualitative and quantitative paradigms are not mutually exclusive and there is no need to restrict ourselves to one paradigm.

In conclusion, it can be expressed that, in contrast to natural sciences, CM research is characterised by a level of disagreement on the appropriate paradigm and methods for inquiry. The author believes that both qualitative and quantitative paradigms have added value to CM research. Hence, it is not useful to give priority to one over the other. The qualitative paradigm helps the researcher to study human behaviour, while a quantitative approach is useful for establishing causal relationships of variables. The most important point is that using each of these approaches should be based on the well-grounded ontological and epistemological position of the researcher. Hence, in the next section, the philosophy of this research will be described.

6. 3. Philosophical Assumptions of the Research

Research methodology is not only about the methods adopted in a particular research, but also includes the philosophical assumptions that underlie a particular study (Dainty A. , 2008). In other words, selection of the research methods for collecting and analysing data should be based on the ontological and epistemological position of the researcher. However, finding a strong philosophical position is a challenging task. Selecting a suitable paradigm for research needs understanding of available ontological and epistemological directions and this requires much effort. Yet, the main problem arises when a researcher attempts to somehow merge two different paradigms with each other to achieve better results. This section addresses these issues and gives a short and general overview of the dimensions of the philosophy of science. Figure 24, which is referred to several times in the following sections, visualises the process of the philosophical positions of this research.

6.3.1. Ontology

Ontology is concerned with the question of existence. In other words, ontological assumptions show the perception of the researcher towards reality: whether social phenomena are objective realities or the constructions of social actors (Dainty A. , 2008). As shown in Figure 24, ontological positions range from realism to constructivism. Realism assumes that social phenomena are external facts beyond the observer's influence (Bryman & Bell, 2003). The principles of realistic ontology are:

1. There is a single reality and single answer.
2. The observer is external to reality.
3. Reality can be studied through reductionism (a complex phenomenon is not more than its parts).
4. Facts are the main concerns.
5. Reality should be defined and manipulated.

Constructivism, in contrast, asserts that social phenomena are constructed by the actors through interaction and a constant state of change (Bryman & Bell, 2003). The principles of constructivism can be expressed as:

1. There are multiple realities and multiple interpretations.
2. The observer is not external to reality.
3. Reality can be studied through holism (complex phenomenon is more than its parts and should be seen as whole).
4. Meaning is the main concern.
5. Reality should be understood and appreciated.

The ontological position of this research is neither pure realist nor pure constructivist, but somewhere between these two extremes. From the point of view of this research, managing construction logistics as an organism is context dependent and is the result of social interactions. The notion of having a pre-given organisation that can be managed using a single solution, as promoted by a realist ontology, is hard to believe. Moreover, reducing a complex system into its parts, as was expressed in the previous chapter, does not give us a detailed understanding of the whole system. However, this does not mean that there are no facts about managing logistics in projects. What should be respected is that, although social phenomena are often affected by the way they are constructed, there are realities that are not affected by how the observer constructs them. For instance, materials specifications are objective realties. In conclusion, in a construction logistics system, we are facing both socially constructed reality and independent reality. In fact, there is no contradiction between these two modes and realism and constructivism should be used to study different realities in a complementary way. In Figure 24, the position of this research is shown with a grey arrow between the two conventional extremes.

6.3.2. Epistemology

Basically, epistemology is the theory of knowledge. It concerns what should be regarded as acceptable knowledge in a field (Bryman & Bell, 2003). The epistemological position of the research is important because without understanding the meaning of knowledge and the way it can be attained, the contribution to knowledge cannot be defended strongly (Knight & Turnbull, 2008). There are two general epistemological standpoints: positivism and interpretivism (Figure 24). Positivism asserts that "there are observable facts which can be observed and measured by an observer, who remains uninfluenced by the observation and measurement" (Fellows & Liu, 2003, p. 18). Thus, the role of a positivist researcher is to stick to what he/she can observe and measure. Positivism is aligned with a realistic ontology and focuses on fundamental laws, causal relationships, and reductionism. The five principles of positivism are (Bryman & Bell, 2003):

1. The real knowledge is the one which is confirmed by the senses.
2. The role of theory is generating hypotheses that should be tested to amend the theory.

3. Knowledge is produced by gathering facts that are independent to us as observers.
4. Science must be objective.
5. We obtain knowledge through science.

Although the principles of positivism are applied in natural sciences with high confidence, assumptions like pure objectivism have been challenged by social scientists. Interpretivism is regarded as opposite to positivism and rooted in a constructivist ontology. It emphasises the differences between the subject of study in natural sciences (natural laws) and social sciences (people) (Fellows & Liu, 2003). Interpretivism focuses on understanding the subjective meaning of social actions (Bryman & Bell, 2003). It refers to knowledge as a constructed reality with human components which depend on time and place (Fellows & Liu, 2003). Hence, the aim of an interpretivist researcher is to understand and explain a social phenomenon. The principles of an interpretivist epistemology are:

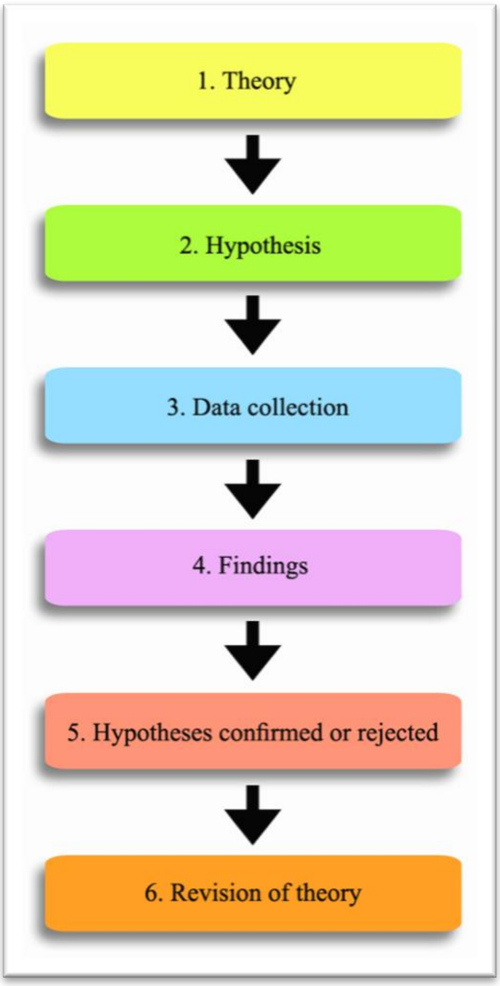
1. Knowledge is a social construct.
2. Knowledge is subjective and context dependent.
3. Knowledge is produced by empirical works.
4. The research is primarily concerned with meaning rather than causality.

This research avoids dualism between positivism and interpretivism (grey arrow in Figure 24). The importance and contribution of positivism is clear, but it does not mean that this approach is foolproof. The role of humans in managing construction projects is significant and, because humans are reflective, they may exert a novel behaviour which did not exist before. This behaviour can be interpreted by the researcher to reveal patterns and norms. This research believes that research in construction management can be pragmatic and takes the two epistemological viewpoints in different circumstances. In other words, to study social phenomena, the researcher can draw on both positivist and interpretivist approaches.

6.3.3. Logic: Deduction vs. Induction

Logic concerns the valid method of reasoning. It is defined as a “particular way of thinking, especially one which is reasonable and based on good judgment” (Cambridge-Online-Dictionary, logic definition, 2010). From a philosophical point of view, logic can be divided into two groups: deductive reasoning and inductive reasoning. The deductive argument consists of a minimum of two propositions where a conclusion is necessarily drawn from them. The truth of the propositions leads to the truth of the conclusion. In research, the deductive approach encompasses developing a hypothesis from a theory, designing a strategy to test the hypotheses, collecting data, confirming or rejecting the hypothesis, and amending or developing the theory (Saunders, Lewis, & Thornhill, 2009). The process of deduction is shown in Figure 27. Deduction owes more to positivism and realism as it concerns theory and the testable knowledge. The important characteristics of deduction can be expressed as (Saunders, Lewis, & Thornhill, 2009):

1. Explaining causal relationships between variables
2. Following reductionist approach
3. Measuring facts quantitatively
4. Generalising results



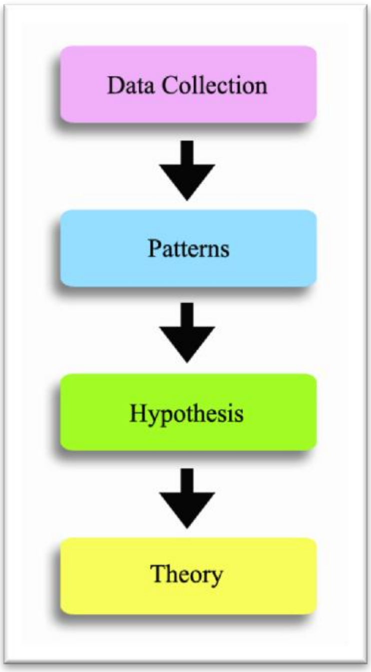


Figure 26: The process of induction

Figure 27: The process of deduction (Bryman & Bell, 2003)

Induction, on the other hand (Figure 26), is an alternative to deduction and is used for theory building. Inductive logic means that, if the propositions are true, then the conclusion is probably true (we are not 100% sure). In inductive research, theory would follow data, rather than vice versa as with deduction (Saunders, Lewis, & Thornhill, 2009). In other words, in an inductive approach, theory is the outcome of research (Bryman & Bell, 2003) (Figure 26). The strength of induction over deduction in social sciences is that it gives more flexibility to the researcher to focus on interpreting meanings. The other characteristics of induction are:

1. Following a holistic approach
2. Interpreting qualitative data
3. Sensitive to the context of the research
4. Less concern with the need to generalise

The approach of this research is mainly inductive, as the aim is providing an understanding of the way logistics is managed in construction projects. Hence, the result would be a set of hypotheses and theories that may be tested by a deductive approach in future. This is referred to as Aristotle's inductive-deductive method for the development of knowledge and is visualised by Losee (1993) in Figure 28.

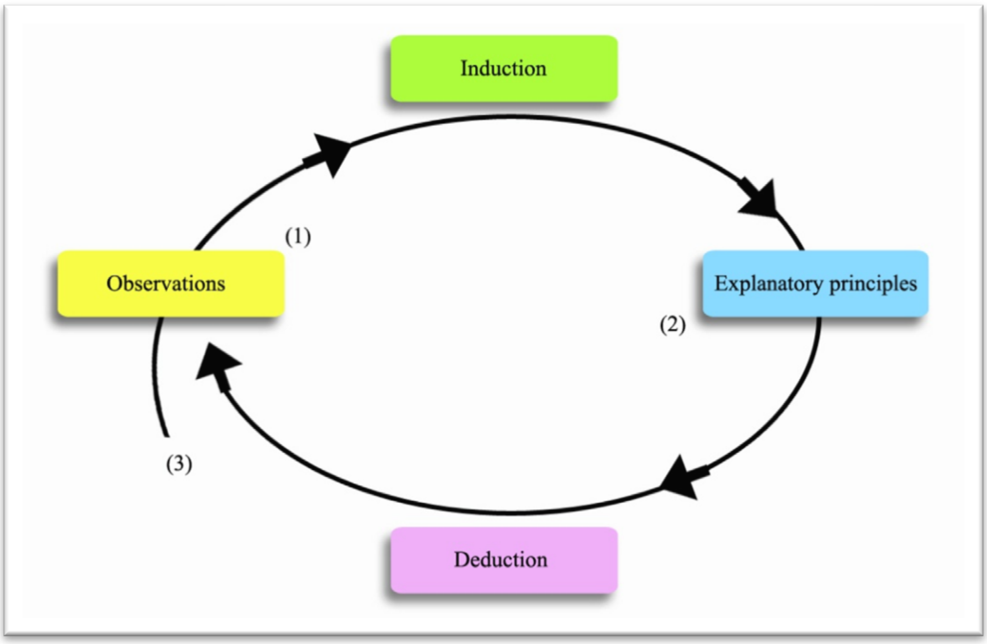


Figure 28: Aristotle's inductive-deductive method (Losee, 1993)

This research accepts that knowledge is produced through dialectical movement between the inductive and deductive approaches. The dialectic approach indicates that theories are offered based on observations (Fellows & Liu, 2003). Hegel called this explanatory theory a *thesis*. This theory (*thesis*) will be tested, criticised and its weak points will be revealed. The result will lead to the emergence of a counter-theory which is called an *antithesis*. Debate on the available thesis and antithesis will continue to produce a new theory, *synthesis*.

6.3.4. Methodology and Methods

Methodology is regarded as the theory of how research should be conducted. Generally methodology is "the study of methods and practices employed in research which involve the gathering of evidence in the process of knowledge and theory formation" (Morton & Wilkinson, 2008, p. 40). As was explained above, methodology is a research strategy based on the ontological and epistemological assumptions of the research. This strategy later will lead to the selection of suitable method(s). Methods are specific means of conducting research and regarded as procedures used to obtain and analyse data (Saunders, Lewis, & Thornhill, 2009).

As shown in Figure 24, the two methodological categories are quantitative and qualitative. In quantitative inquiry, the stress is on quantification of data collection and analysis (Bryman & Bell, 2003). Rooted in realist ontology and positivist epistemology, it includes gathering numerical data (facts) and testing theories using a deductive approach. Methods used for quantitative research include survey, statistical analysis and mathematical modelling.

In contrast, qualitative inquiry is a reformist movement of social scientists against the use of the realistic approach in social sciences (Denzin & Lincoln, 2005). It adopts a constructionist ontology and interpretivist epistemology and uses inductive reasoning to analyse data. Instead of numbers, qualitative variables and attributes are the points of concern. Pragmatism is central to qualitative research and researchers are allowed to use different methods for collecting and analysing empirical data, such as grounded theory, interviewing, case study, ethnography, and phenomenology (Denzin & Lincoln, 2005).

This research uses both qualitative and quantitative approaches. The primary focus will be on the qualitative to emphasise more describing and interpreting a construction logistics system by getting help from practitioners' experiences. A quantitative approach complements the findings of the qualitative study using descriptive statistical analysis. Mixing methodological approaches has attracted attention in recent years (Dainty A. , 2008) and will be explained under the title of methodological pluralism in the next section.

6.3.5. Methodological Pluralism

As explained above, this research uses a multi-strategy research approach. The term used in literature for this approach is methodological pluralism. It is described as the "pluralism of method that enables the researcher to use different techniques to get access to different facets of the same social phenomenon" (Olsen, 2004). The main argument of methodological pluralism is that there is no contradiction between the two research approaches and rather they can help the researcher to attain a broader understanding about the subject. The main advantage of a multi-strategy approach is that the research benefits from the strengths of both qualitative and quantitative approaches, while the weaknesses of each of them can be covered by the other.

Bryman (2003) asserts that combining methodologies tends to have a primary (leading) strategy followed by another strategy widening the research. Considering this sequence, three types of multi-strategy research were introduced by Hammersley (1996):

1. Triangulation: the quantitative approach is employed to corroborate qualitative research findings or vice versa (Bryman & Bell, 2003).
2. Facilitation: the use of one strategy in order to aid research using the other strategy (Bryman & Bell, 2003).
3. Complementarity: two strategies are employed in order that different aspects of a research can be investigated (Bryman & Bell, 2003).

The complementarity approach is selected for conducting this research because it provides two viewpoints on construction logistics management. To focus on practitioners' opinions, the qualitative inquiry is the primary strategy of this research which uses interviewing as a method. The research is also enriched by the quantitative strategy, using a questionnaire survey to achieve a broader understanding about the practice of construction logistics in Iran. Using complementarity, the research started with a literature review which provides a foundation for the research. The aim of the literature review is not to find theories, but to refine the research question (grounded theory approach). Then, a set of in-depth interviews were carried out with practitioners in Iran. After that, a questionnaire survey was utilised to enhance understanding about construction logistics in Iran using a larger sample. Although there are interactions and overlaps between the interviews and questionnaires, it should be highlighted that neither of methods was intended to test the other. In other words, in contrast to the triangulation approach, in which a quantitative inquiry usually aims to test the outcome of the qualitative study, in the complementarity approach, the outcome of each strategy should be regarded as a single entity that complements the other one. Hence, in this research, as Bryman and Bell (2003) confirmed, the qualitative strategy investigates ‘micro’ phenomena, while the quantitative strategy researches ‘macro’ ones.

Although the multi-strategy approach has brought benefits to the social research arena, it has also attracted criticism. From a philosophical point of view, research methodology should be based on clear ontological and epistemological assumptions. One may argue that positivism and interpretivism, in most cases, contradict each other and, therefore, strategies raised from them cannot be used together (Dainty A. , 2008). Although this criticism is valid in the traditional duality in philosophy of science, the particular advantages of multi-strategy research for construction management is a strong motive to use this approach in the field. Moreover, Golafshani (2003) clarifies that, while mixing methods within one paradigm may be problematic, mixing paradigms is perfectly possible.

6. 4. Qualitative Inquiry

The previous section clarified the philosophical position of the research. It was also indicated that the qualitative approach is the primary strategy of the research. This section will explain why the qualitative strategy was chosen and points out practical matters of qualitative data collection.

In general, four reasons can be given for choosing the qualitative research strategy:

1. *Lack of information.* As clarified in Chapter four, there are few studies which focus on the social side of the construction industry in Iran. Specifically on construction logistics management, no research was found that investigates this subject in Iran. Owing to the limited knowledge on construction logistics and lack of investigation of the Iranian construction industry, this research adopted an exploratory strategy. This strategy helps the research to investigate the hidden aspects of the subject which have not been covered previously. As Bryman and Bell (2003) asserted, exploratory research usually relies on qualitative data. This is the first reason that the qualitative approach is utilised in this research.
2. *Focusing on practitioners' experience.* To achieve the objectives of the study in construction management research, getting help from skilled people who have enough experience in different fields of construction industry is essential. Their experiences should be described and analysed in a proper manner to reach trusted outcomes. A qualitative strategy is chosen to emphasise the experiences of people who are involved in day-to-day logistical matters in construction projects. It helps the research to be focused on personal histories, issues, perspectives, views and opinions of construction experts.
3. *Giving priority to meaning.* The purpose of this research is to get a feel for what is going on and to understand better the nature of the construction logistics system. In other words, the aim is to describe and interpret the process of construction logistics and identify problems which are caused by the lack of enough logistics knowledge among construction practitioners. A qualitative strategy allowed the researcher to attain a deep understanding of the subject of the study by focusing on meaning and concepts.
4. *Dealing with complexity.* The process of construction logistics management is complex, not only because of the complicated process, but owing to uncertainties that arise from cultural matters, the special business environment, the economic conditions, regulations, geographical considerations and the way people organise and sort out logistical tasks. The qualitative approach allowed the researcher to deal with the complexity, context and relationships of multiple factors involved in the research. It provides information about the 'human' side of the subject, which is usually

intangible, and includes factors such as social norms, behaviours, tacit knowledge, and common sense which are not be readily apparent. The result will be rich and exploratory and describes culture, relationships and norms.

To clarify how qualitative research works, the following analogy is helpful. A Persian poet Molana (known to the English-speaking world as Rumi) has a story about a group of Indians who bring an elephant to an area for the first time. Nobody in that region had seen an elephant up to that time. The Indians put the elephant in a dark small room. Many people came over to see the strange animal. Owing to the crowd pressure, a group of people penetrated into the room. The room was dark and nobody could see the animal, but they could touch it. One person touched the trunk and said an elephant is like a tube. The second person touched the foot and said it is like a column. The third person found the ear and described the animal as a fan. Another person climbed up on the elephant, touched the back and said it is like a bed. Hence, different people had different perceptions about the elephant. Molana concluded that human senses and feelings may give us wrong directions to understand the whole, as in that story the elephant is not a tube, column, fan or bed. Yet, the point that is missed by Molana is that if we can collect different ideas about a phenomenon, attain more detailed information about each element, and identify the relationship between different elements, we may be able to provide an image which helps us to understand the whole. In the elephant example, if we put a tube, column, fan or bed in a box without any relationship among them (Figure 29, left), nothing can be understood. However, if we consider relationships, e.g. the location of each part, we may get a general view of the elephant (Figure 29, right).

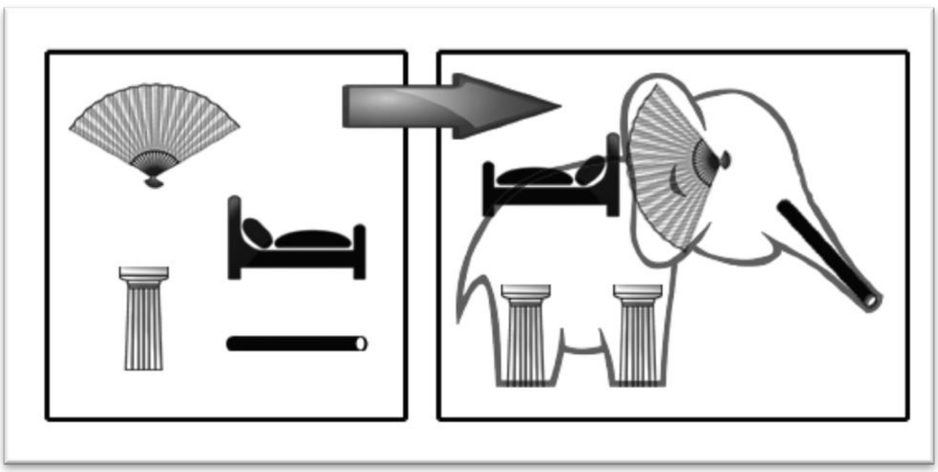


Figure 29: The analogy between qualitative research and an elephant

The more studies we conduct, the more accurate image we can get. This is the way that qualitative study works. We encounter a complex and unknown phenomenon. First, we study the elements and relationships of the phenomenon in detail and specify its boundary (context). Then, we organise data and collect them together again to have a clear image representing the phenomenon.

6.4.1. Putting Qualitative Research in Sequence

Bryman and Bell (2003) provided an outline which represents the qualitative research process (Figure 30). The main steps of qualitative research in this study, adapted from the Bryman and Bell (2003) model, are:

1. *General research questions.* This is starting point that focuses on understanding the way logistics is managed in construction projects in Iran. General research questions developed are:
    a. *To what extent are practitioners aware about logistics management in their projects?*
    b. *What is the process of construction logistics? (What activities are included?)*
    c. *What are the logistical problems and challenges that the Iranian construction experts experienced in their projects?*
2. *Selecting relevant site(s) and subjects.* In this study, practitioners with ten or more years of experience in building construction were the focal point of attention. They should have broad understanding about the building sector and be involved in logistical affairs in construction projects. More information about the characteristics of the sample will be explained later in this chapter.
3. *Collection of relevant data.* The main method for collecting data in the qualitative phase of the study was conducting in-depth interviews. On average, each interview lasted around 60 minutes. In addition to interviews, where it was possible, photos from construction sites were taken to give a visual sense to some parts of the analysis.

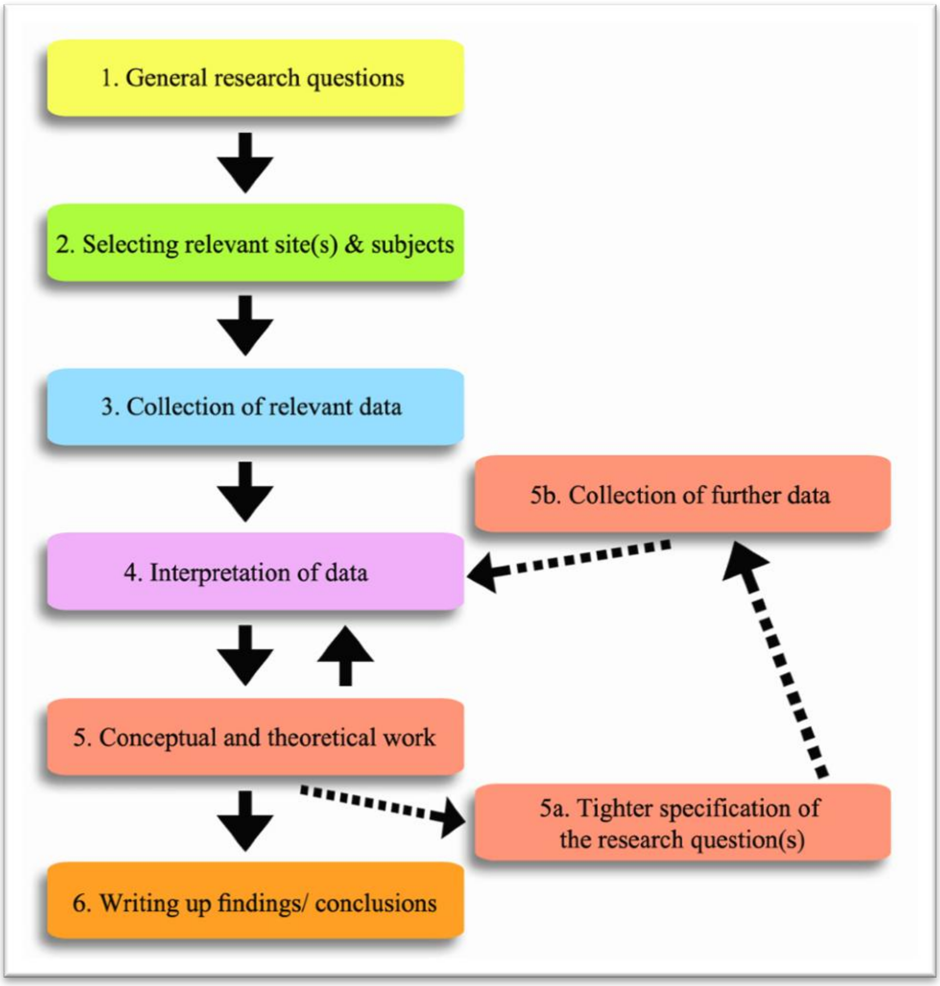


Figure 30: The process of conducting qualitative study (Bryman & Bell, 2003)

4. *Interpretation of data.* The approach to data analysis is the conventional temple analysis of interviews. This involves coding textual data, which means classifying and organising data through the creation of themes emerging from text.
5. *Conceptual and theoretical work.* This is about the contribution of the research which reveals local hidden aspects of logistics affairs in construction projects in Iran. This will be clarified in the analysis chapters (Chapters 7-10).

   (5a) Tighter specification of the research question(s) and (5b) Collection of further data. Further data was collected using the quantitative strategy and survey questionnaire to complement the qualitative study.
6. *Writing up findings/conclusions.* In the final stage, interpretation was developed to produce a conclusion about the practice of construction logistics

in Iran. Issues about the credibility and transferability of the research will be clarified at the end of the qualitative inquiry section in this chapter.

6. 5. Interviews

An interview is a contextual based collaboration between the researcher and the interviewees (Fontana & Frey, 2005). Unstructured in-depth open-ended interviewing is the major data collection method of this research. This method helps to explore in depth the subject of the research (Bryman & Bell, 2003; Saunders, Lewis, & Thornhill, 2009). In contrast to structured and semi-structured interviewing, for unstructured interviews, there is no predetermined list of questions. However, the interviewer should decide about practical matters, including how to access people, how to understand the language and culture of the interviewees, how to present him/herself, locating an informant, gaining trust, establishing rapport, and required equipment for collecting empirical material (Fontana & Frey, 2005).

In unstructured interviewing, there is no 'yes or no' question and the interviewee is expected to expand on the topic (Zami & Lee, 2009). Moreover, the researcher is not required to stick to a specific order for questions to ask different interviewees and should allow the flow of the conversation to dictate the questions (Zami & Lee, 2009). Also, considering cultural matters in Iran, the researcher should avoid sensitive questions, such as irrelevant financial matters, because this may irritate the interviewee and interrupt the interview.

In this research, twenty four open-ended interviews were conducted with the experienced Iranian building construction practitioners. The interviewer had a few general topics in mind to discuss with the interviewees. The focus was on understanding different aspects of construction logistics in building projects. The unstructured interviewing process had five steps, expressed in the following section (Figure 31).

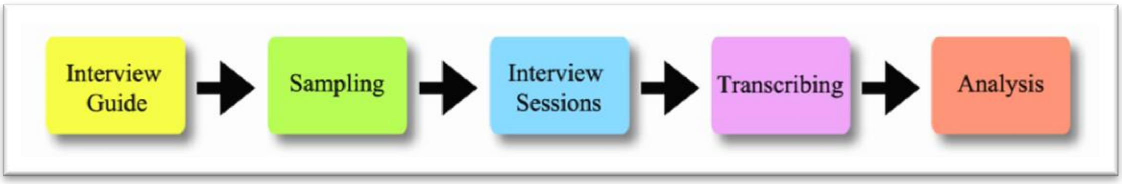


Figure 31: The interviewing process in this research

6.5.1. Interview Guide

An interview guide is a document which provides a short introduction to the research and the researcher, and includes one or two questions. It helps the researcher to be organised during the interview, ensures that important topics are covered and helps maintain some consistency across interviews with different interviewees (Zami & Lee, 2009).

An interview guide was designed for the research with five sections (Appendix one). The first part was used to record information such as date, time, name of interviewee and his affiliation. The second part introduced the researcher. The third part introduced the research, including logistics definition, aims and objectives and research methodology. This section also comprised of two general questions:

a. How do you manage logistics in your projects?
b. What logistical problems/issues have you experienced in construction projects?

In this stage, interviewees were expected to discuss logistics planning, the actual process of construction logistics, and logistical challenges. The fourth section was a blank page for taking notes by the interviewer (Figure 36). In some cases, this space was also used by interviewees, if they were willing to write a note or draw a chart or a diagram (Figure 37). The fifth section was used to remind the interviewer on how to close the interview and ask the following questions:

a. Is there any document, e.g. photos, statistical data, catalogue, etc., that you want to provide to support your statements?
b. Is it possible to take a few photos from your site?
c. Do you recommend a specific person to be interviewed about this topic?

To test and evaluate the effectiveness of the interview guide and equipment, one pilot interview was conducted with a construction management student in Iran, which led to some modifications of interview plan. The result of the pilot interview was not considered in the analysis.

In addition to the interview guide, an interview protocol was also defined. The protocol was read before each interview by the interviewer to remind himself of the purpose of the research and the way it should be carried out. The protocol asserts that:

a. The aim of the research is to understand and respect the experience of participants without imposing any priori categorisation.
b. The interviewee should be given a freedom to speak around the topic and the interviewer should avoid directing the interview as much as possible.
c. There is no need to give a detailed definition of logistics or a long explanation about the research.
d. No question should be asked about irrelevant matters including political issues and financial performance of the company.
e. No answer should be suggested and no sign of agreement or disagreement should be shown by the interviewee.
f. Before each interview, a specific interview guide should be provided and all equipments should be tested.
g. If an answer or discussion is incomplete, nothing should be presumed and the interviewee should be asked for clarification.

6.5.2. Sampling

Owing to the qualitative nature of the study, a small, but focused and carefully selected sample, was chosen to be interviewed. As the goal of the qualitative inquiry is not to generalise outcomes to all settings, a non-probability sampling strategy was utilised which means not everyone has an equal chance of being in the study. Among different non-probability sampling methods, purposive sampling and snowball sampling were used. Purposive sampling categorises participants according to preselected criteria relevant to a particular research question (Mack, Woodsong, MacQue, Guest, & Namey, 2005). Snowballing sampling is a type of purposive sampling in which a participant uses his/her social networks to refer the researcher to other people who have the potential to contribute to the study by participating in interviews (Mack, Woodsong, MacQue, Guest, & Namey, 2005). To be interviewed, participants should meet three criteria:

1. Interviewees should have ten or more years of experience in the building sector of the construction industry.

2. The interviewees' affiliated company should be involved in the building projects: residential, commercial or leisure projects.
3. Interviewees should be aware of day-to-day issues of the building industry in Iran and be familiar with logistical affairs, such as purchasing, transportation, storage and handling.

Based on these criteria, senior project managers, site supervisors and senior consultants were considered as potential participants for this study. As the researcher received his undergraduate degree in Iran, he used his network of ex-colleagues and friends to find potential participants.

In contrast to a quantitative study, in qualitative research, sample size is not fixed before the fieldwork and it is determined on the basis of theoretical saturation (Mack, Woodsong, MacQue, Guest, & Namey, 2005). This is the point in the data collection that the researcher understood responses are being repeated by new interviewees and critical and sensitive information could not be received from them anymore. In other words, new data no longer brings additional insights to the research objectives.

Overall, twenty four unstructured interviews were conducted with the experienced Iranian practitioners. Individuals were initially contacted by telephone and informed about the outline of the research and the contribution they could make to it. The majority of interviewees asked to have a list of questions before the interview session because they expected a structured interview. Although the methodology of the research was explained clearly to the interviewees, given that there was no predetermined set of questions, they preferred to have a written document in hand to know if they would be able to answer the questions. To address this expectation, a three-page letter was provided to be sent to interviewees via fax before the interview sessions. This letter had: a coversheet; a body which thanked the interviewee for participation in the study and introduced the research and the researcher; and a short introduction to construction logistics with the two general questions to be discussed.

Among the twenty four interviews, 18 interviewees categorised their companies as contractors, while six consultants were interviewed. The majority of the interviewees were civil engineers, while there were eight architects and two structural engineers in the sample (Figure 32). In terms of education, 15 participants had MSc or MA degrees, eight people had Bachelor degrees and one person had a PhD (Figure 33). In terms of job, 12 interviewees worked as senior managers, while there were five senior project managers and 7 site supervisors in the sample (Figure 34). More information about the characteristics of the interviewees is provided in Appendix two.

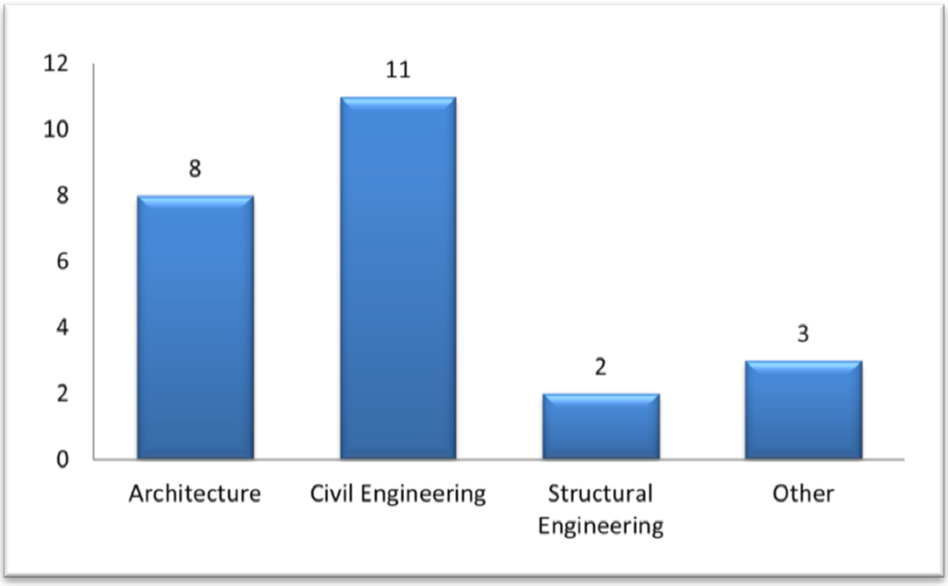


Figure 32: Division of interviewees based on their fields of study

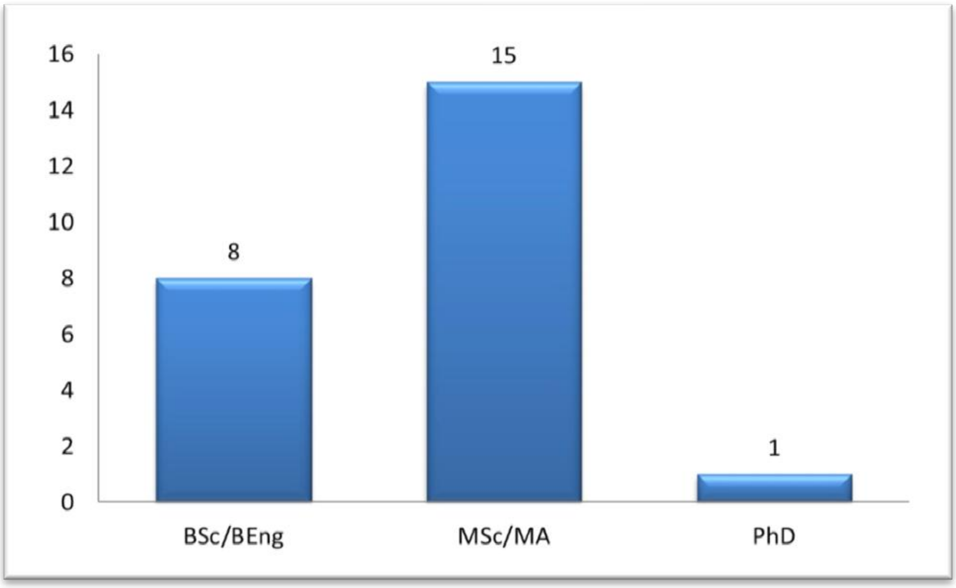


Figure 33: Division of interviewees based on their level of education

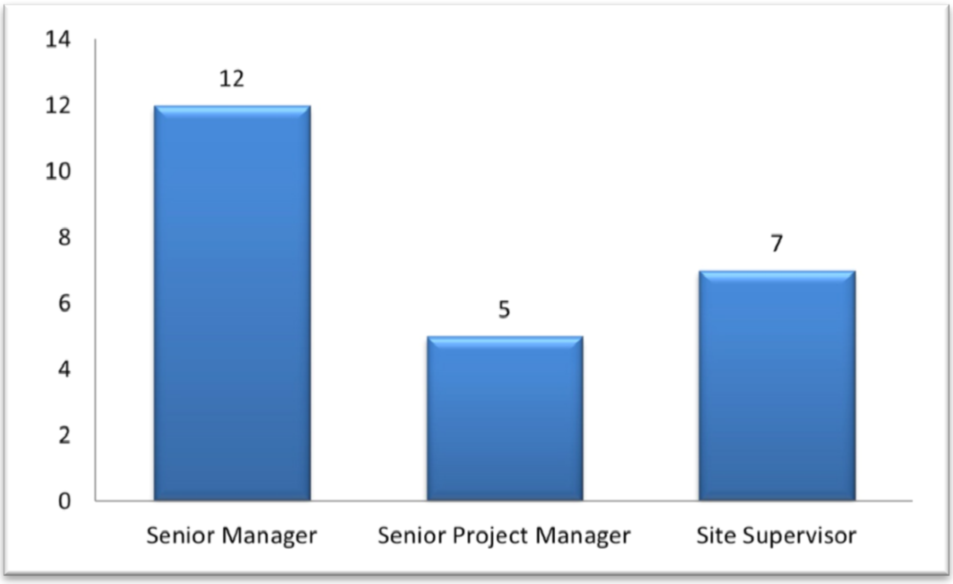


Figure 34: Division of interviewees based on their jobs

6.5.3. Interview Session

The interview session was started with an introduction of the research and the researcher based on the interview guide steps. Then, it was explained that the material gathered from the interviews would be considered confidential by the researcher. This encouraged people to speak freely about the subject.

The interviewer approached interviewees as a PhD student representing academia and as an independent researcher who has no association with the Government of Iran or the UK. It was expressed that the ultimate goal of this research is learning about construction logistics management and the researcher was not going to judge or criticise the performance of the interviewees. This was done to avoid a negative impression on the interviewees which may have led to untruthfulness. To gain more trust at the beginning of the conversation, a gift package including Nottingham Trent University marketing stationery (Figure 35), was given to interviewees to thank them for their participation.

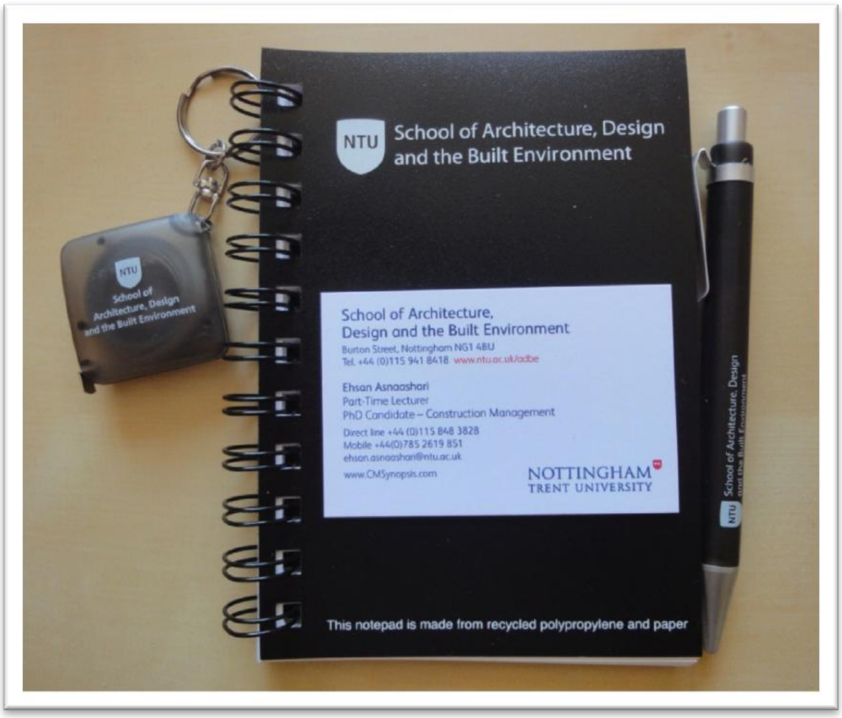


Figure 35: Nottingham Trent University marketing gift given to interviewees

The next stage was a warm-up period where the interviewee was asked to present himself and give a brief explanation about his job and achievements. The reason for having a warm-up period was to somehow start the conversation and make the interviewee comfortable to talk, as people usually like to speak about their roles and accomplishments.

After the warm-up, interviewees were asked to describe the way they manage logistics in their projects. Then, the interviewer and interviewees started a discussion about different logistical matters to explore aspects of the topic. In other words, construction logistics, as a general theme of the research, was introduced to the interviewees and they developed the discussion according to their experience, beliefs and knowledge. The researcher attempted to see the situation from the practitioners' view point during the interview and encourage them to give practical examples about different subjects. Also, the researcher tried to interpret what was heard and gain a deeper understanding from the interviewee throughout the interview. Discussions were conversational and informal and the researcher allowed questions to flow naturally based on information provided by the interviewee.

The interviews were quite wide ranging and thoroughly explored the topic of construction logistics. Interviews lasted between 45 minutes to two hours, depending on the willingness of interviewees to describe the topic. In total, around 1660 minutes of interviewing was carried out with an average of 69 minutes for each session (Appendix two). Except for five participants, the others allowed the researcher to record their voices during the interviews. All interviews were carried out in the interviewees' places of work which were usually construction sites or the company office. The author, after getting permission from the construction sites' authorities, took more than 200 photos from different projects that are used to bring clarity to the data analysis.

During the interviews, the researcher listened carefully to interviewees and took notes regularly and promptly. These notes were used in the early stage of the analysis. In fact, the keyword notes formed the primary themes of the study. For effective note taking, the researcher used a tree diagram which showed headings and subheadings using boxes and lines (Figure 36). In the tree diagrams developed in this research, a rectangle means an important topic and a circle means the topic needs clarification and is the source for more questions. In some cases, interviewees wanted to write a note or draw a shape or diagram to explain an issue (Figure 37). Moreover, a few interviewees provided some supporting documents, facts and figures to support their statements or give an example. These notes and documents were also considered in the data analysis and referred to where needed.

Interviewing had been continued up to the point that the desired level of data saturation was achieved. That was the point when the interviewer understood responses were being repeated by new interviewees and critical and sensitive information could not be received from them anymore.

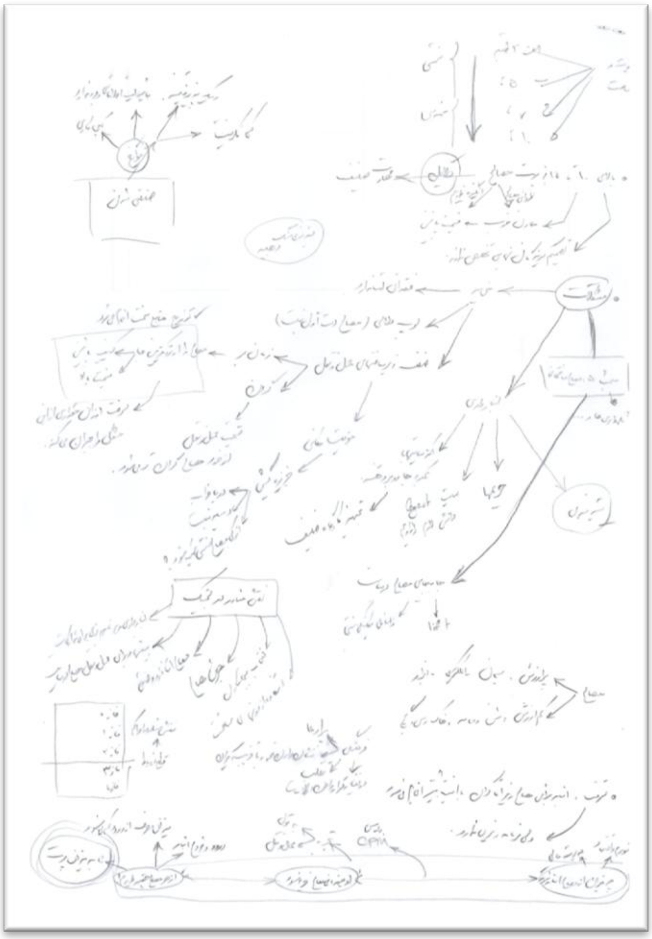


Figure 36: The interviewer's notes during an interview session (tree diagram)

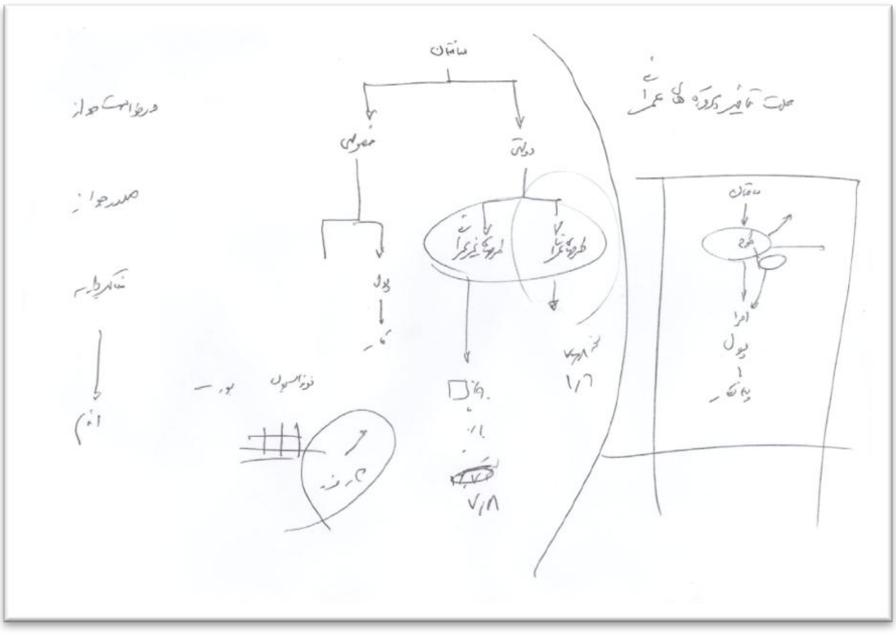


Figure 37: An interviewee's notes during an interview session

6.5.4. Transcribing

All voice recorded interviews were transcribed carefully for analysis. Transcription was an important task, as it was intended that some extracts from the transcription be used as 'quotes' in the analysis chapters. Basically, transcribing is a time-consuming task. It was attempted to transcribe the original conversation without editing. Yet, in some cases, to make a statement clear, a few words, which were separated by brackets, were added to the transcriptions. Although transcribing was a challenging task, as Haigh (2008) pointed out, it helps the researcher to re-familiarise himself with the gathered data.

6.5.5. Qualitative Data Analysis: the Grounded Theory Method

The next stage of the research is Qualitative Data Analysis (QDA). The goal is to make sense of the collected interview data. In QDA, the researcher, by reading and rereading empirical materials, tries to identify key themes and draw a picture of the meanings that constitute the reality (Perakyla, 2005). Douglas (2003, p. 53) summarised the process of analysis and expressed that "concepts has been identified, developed, discounted, and merged in order to produce the component concepts of the emergent theory". Seidel (1998) expressed that analysing qualitative data consists of three parts: Noticing, Collecting, and Thinking (Figure 38). He asserted that the process of QDA is not linear but is rather iterative (repeating the cycle), recursive (one part can call you back to a previous part) and holographic (each step contains the entire process).

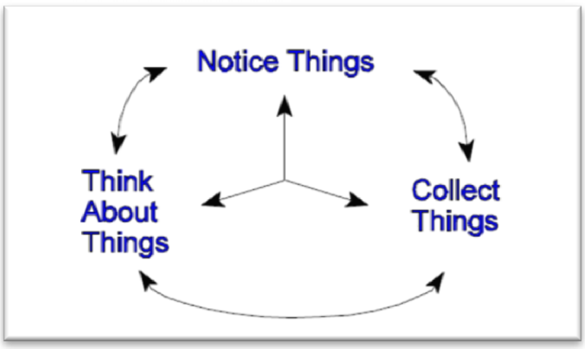


Figure 38: Qualitative data analysis (Seidel, 1998)

In the context of this research, noticing has two meanings: (a) producing records: preparing interview transcriptions, notes taken during interview sessions, photos taken from construction sites and documents provided by participants; and (b) coding: focusing on each record and finding and highlighting interesting and important themes in them. It also includes developing a descriptive naming scheme for themes. Collecting means sorting and organising data. After identifying codes, relevant data were assembled together in a meaningful way. In the thinking stage, codes were examined to figure out relationships and patterns. The aim was discovering similarities, differences and general rules by comparing and contrasting codes. In this research, first, gathered data was broken down into categories, relationships and context. Then, segments were integrated with each other to provide an answer to the research questions. Figure 39 shows the process of data analysis in this research.

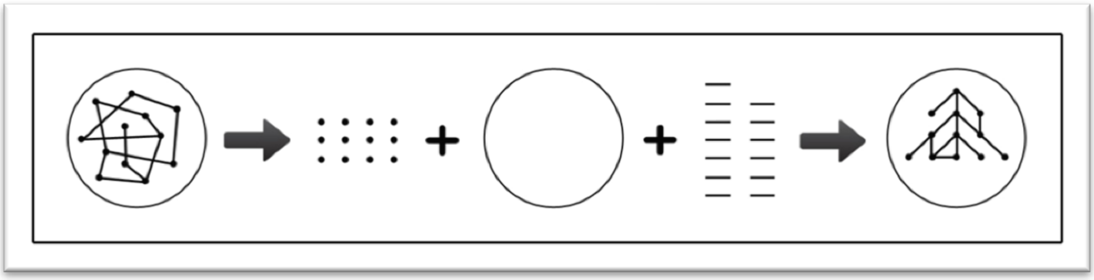


Figure 39: Qualitative data analysis steps

There are several strategies that can be utilised for analysing qualitative data. One strategy that has been widely used for QDA is grounded theory. A term developed by Glaser and Strauss (1967), the grounded theory method is "a set of flexible analytic guidelines that enable researchers to focus their data collection and to build inductive middle-range theories through successive levels of data analysis and conceptual development" (Charmaz, 2005, p. 507). In this method, theory emerges from data by making comparisons, development of categories and forming an analysis (Charmaz, 2005). In fact, there is no theory to be tested in the beginning of the research and rather the theory is the result of the research. Hence, the distinction between grounded theory and other methods is that it involves theory development. This research adopted modified grounded theory which permits reviewing literature before starting data collection. Grounded theory is flexible and allows the researcher to take a large number of issues about construction logistics into account and not focus only on one single theory. The issues range from basic logistical tasks to cultural matters and the economic situation of Iran.

There are different approaches to grounded theory which are Glaser and Strauss (1967), Strauss and Corbin (1990), Glaser (1978, 1992) and the constructivist approach (Charmaz, 2005). This research utilised the constructivist approach because it takes "a reflective stance on modes of knowing and representing studied life" (Charmaz, 2005, p. 509). Therefore, this approach is more compatible with the ontological and epistemological positions of the research. It should be explicated that the term 'Grounded Theory' has been used in two ways: (1) grounded theory as a methodology which is a set of rigorous research procedures and (2) grounded theory as a method of qualitative data analysis which leads to the creation of conceptual categories. This research has adopted the second approach and uses grounded theory as a method of data analysis. In general, grounded theory has five steps (Figure 40).

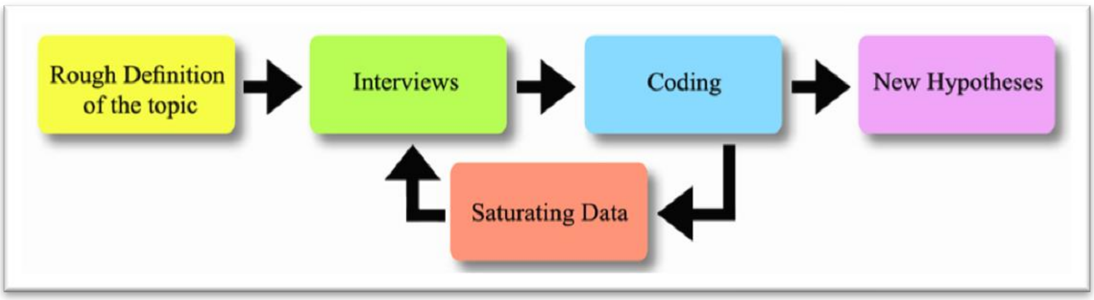


Figure 40: The process of grounded theory used in this research

The rough definition of the topic (literature review), interviews, and data saturation point were discussed above. An explanation about coding and how the hypotheses will be generated is required. The main step in grounded theory analysis is coding. Large volumes of data attained from interviews appear to be unrelated, discrete and confusing. Coding enables the researcher to organise and put the data in an order. Goulding (2007) defined coding as "the conceptualisation of data by the constant comparison of incident with incident, and incident with concept, in order to develop categories and their properties". Codes are devices to label, separate, compile, summarise and organise data (Charmaz, 2005). There are three types of coding, as explained by Strauss and Corbin (1990):

1. Open coding: “the process of breaking down, examining, comparing, conceptualising and categorising data” (Strauss & Corbin, 1990, p. 61).
2. Axial coding: “a set of procedures whereby data are put back together in new ways after open coding, by making connections between categories” (Strauss & Corbin, 1990, p. 96). This involves linking categories to their subcategories.
3. Selective coding: “the procedure of selecting the core category, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement and development” (Strauss & Corbin, 1990, p. 116).

The process of coding in this research started by detailed line-by-line reading of the interview transcripts during which every line is searched for keywords that give insight into the study (e.g. site layout). The result of this stage was generation of initial categories. In other words, in this step, responses were classified under relevant categories. The process of categorising data was tentative and, therefore, tended to be in a constant state of potential revision and fluidity. The categories emerged from the data by progressing through the transcript of interviews. Under these categories, new sub-categories were developed with the same logic and process explained before. In some cases, not all the data fitted neatly into one precise category. Thus, for interpretation, it was required to cut across different categories. The next stage is establishing relationships between categories and grouping them based on different characteristics, such as conditions, context and outcome. Also, to develop a hierarchy of codes, some categories were integrated together and constituted a new category.

The use of Computer Assisted Qualitative Data Analysis Software (CAQDAS) has increased among CM researchers owing to their ability to store, organise and manage qualitative data more efficiently (King, 2008). This research used the NVivo package for analysing interview transcriptions. The use of NVivo helped the researcher to work with large volumes of data gathered in an interactive and systematic way and also increased the speed of QDA considerably. To start the analysis, all transcriptions were transferred to NVivo to be codified. Two most useful NVivo features were digital coding (nodes) and use of memos. Digital coding means tagging a segment of text to allow for later retrieval, while memos are reflective comments on some aspect of the data to be used for future interpretation (King, 2008). In fact, coding makes important components visible and memos add the relationships which link the codes to each other. Another advantage of using NVivo is that it allows the researcher to have a better view of the whole. In traditional manual QDA, transcripts were cut up and filed according to the codes and this may diminish the whole. It should be explained that the software role is only limited to organising data and not analysing them. Getting back to the Seidel (1998) model (Figure 38), the software helped only in noticing and collecting stages, and the thinking stage was done by the researcher himself.

After analysis, data should be interpreted and integrated into a coherent report. The report structure is formed by categories, subcategories and their relationships. Wherever it was suitable in the report, the participants' direct quotes are cited anonymously to make the interpretation more meaningful. For confidential reasons, the name and organisation of the interviewees are not mentioned in the final text and instead they are named with specific labels. Labels are constituted from a letter and a following number, e.g. C08. The letter shows the role of each interviewee in the industry: contractor (C) or consultant (N). The number after each letter explains the order of interviewees in each role.

Using diagrams and models is an effective way of displaying data (Hunter & Kelly, 2008). They can clearly illustrate categories, subcategories and their relations using boxes and arrows. Using models helps to have an image of the whole process of the analysis and prevents loss of information when the researcher is dealing with large quantities of data. In this study, the results are visualised in the form of a model which will be described in Chapter eleven. To have a general view of the primary result of QDA, Figure 41 is provided. It illustrates the categories and subcategories of the construction logistics system. This diagram will be used in the quantitative inquiry to design the questionnaire.

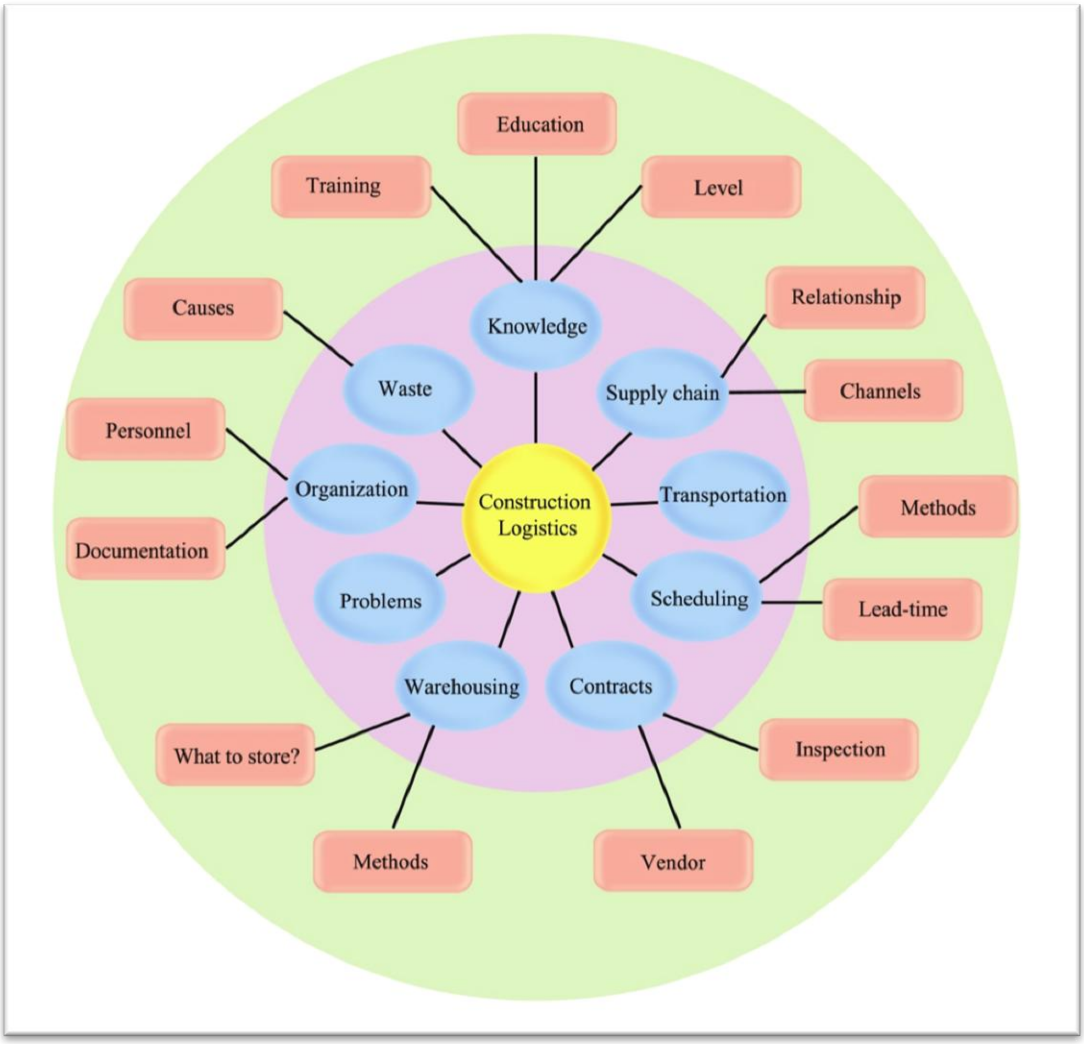


Figure 41: Primary result of QDA (Construction logistics categories & subcategories)

6.5.6. Advantages vs. Disadvantages of the Qualitative Study

It is essential for each research to explain both its strengths and limitations. This will help the readers when they want to utilise the research findings in practice or conduct another research to confirm, modify or reject the outcomes of the precedent study. This section provides a brief description of advantages and disadvantages of the qualitative strategy which was adopted for this research.

The first advantage of a qualitative strategy was that, owing to its exploratory nature, an opportunity was given to the experienced practitioners to respond in their own words, rather than to force them to choose from rigid fixed options. This was quite helpful in the context of Iran where there is limited knowledge about construction logistics. The qualitative research also bridged the gap between academia and industry, because practitioners could express their opinions, rather than focusing on theories which are the final products of academia. In fact, open-ended questions evoke meaningful, culturally significant and novel responses. Another advantage of qualitative methods is that it allows the researcher to investigate initial participant responses by asking 'why' and 'how' questions in interview sessions. This helped the researcher to attain a deeper understanding about the construction logistics process and the source of problems that practitioners may face in projects. The qualitative strategy also was useful to research and understand the complex nature of logistics management in construction projects. Identifying factors that should be considered for effective logistics management and studying relationships between these factors, that are the main source of complexity, are notable advantages of using qualitative study in this research.

Although qualitative inquiry is rich and informative, it has weaknesses owing to its nature. The first problem is that the outcomes of this research can only be extended to people with characteristics similar to those in the study population and cannot be generalised to all settings, geographical locations and populations. In this sense, qualitative research differs from scientific research. Yet, it should be explained that, in qualitative research, the aim is to generalise to theory rather than to study populations (Golafshani, 2003). Hence, the criteria of generalisability should be redefined for qualitative studies. In fact, "it is the quality of the theoretical inferences that are made out of qualitative data that is crucial to the assessment of generalisation" (Bryman & Bell, 2003, p. 300). Another problem is that it is almost impossible to replicate the results of this study. This is another point where quantitative researchers usually criticise qualitative studies. As expressed before, the biggest advantage of qualitative inquiry is its flexibility and this means that the process of data collection and analysis rely upon the researcher's background, knowledge, focus and creativity. Hence, there is no structured process to be followed to exactly replicate the outcomes. There is also another area of critique about qualitative research, which is regarded as a lack of transparency. Bryman and Bell (2003) explained that, in some cases, the process of qualitative data analysis is vague or it is not clear how people were chosen for interviews. This research addressed these two critiques by, first, providing a detailed description of QDA and clarifying how categories and subcategories were formed. Second, in terms of the way participants were selected, subjects, such as the process of sampling, sampling methods used and criteria adopted for the sample, were explained in the previous sections. To emphasise more the quality of the outcomes, the following section examines criteria that can be used to measure the validity and reliability of the qualitative inquiry.

6.5.7. Quality of the Qualitative Research

In quantitative research, validity and reliability are the main criteria for assessing the research outcomes. Validity refers to the level to which a research measured what it was intended to measure and reliability concerns the repeatability of measurement. These two terms are widely used in quantitative research. Some researchers believe that validity and reliability can be also applied in qualitative research in a similar way (Bryman & Bell, 2003). However, there are other researchers who believe validity and reliability come from the positivist paradigm. These researchers argue that the positivist paradigm considers reality as a single absolute account and this is not always true in qualitative research (Bryman & Bell, 2003; Golafshani, 2003). Hence, validity and reliability cannot be utilised as tools for measuring the quality of qualitative research. Charmaz (2005) explained that if you judge qualitative research by the criteria you have learned to use for hypothesis testing research, you will likely misjudge it. Thus, four alternative criteria f or judging the quality of qualitative research were offered (Guba & Lincoln, 1994) as: credibility, transferability, dependability, and confirmability. The associations between the alternative criteria and traditional quantitatively-oriented criteria are tabulated in Table 7 by Trochim (2006).

Table 7: Quantitative measures vs. qualitative criteria (Trochim, 2006)

Traditional Criteria for Judging Quantitative Research	Alternative Criteria for Judging Qualitative Research
internal validity	credibility
external validity	transferability
reliability	dependability
objectivity	confirmability

This research intended to use the alternative criteria to reflect on the quality of the research and, thus, they will be explained in the following section. Credibility involves establishing that the outcomes of the qualitative inquiry are acceptable from the participants' point of view (Bryman & Bell, 2003). In other words, to be credible, the results should be submitted to interviewees to confirm if the researcher has correctly understood the construction logistics system. To comply with this, the respondent validation technique was adopted, which is "a process whereby a researcher provides the people on whom he or she has conducted research with an account of his or her findings. The aim of the exercise is to seek corroboration or otherwise of the account that the researcher has arrived at" (Bryman & Bell, 2003, p. 290). To use this technique, the outcome of the research was summarised in a diagram to be presented to interviewees. As there was a two-year gap between the interviews and the model formation, ten participants were accessible, and among them, only three were willing to comment on the diagram. The general attitude of the reviewers was positive and they offered feedback and suggestions on the final model. The credibility of the model will be explained in more detail in Chapter eleven.

Transferability concernes if the results can be transferred to other settings. Since in qualitative inquiry the focus is on a small sample, the outcomes tend to be context dependent in terms of both location and time (Bryman & Bell, 2003). Hence, using the results in a wider or new context may be problematic. To solve this problem, qualitative researchers should produce a thick description of the context of the study (Bryman & Bell, 2003). The description will help the person who wants to transfer the outcome to a different context to make judgements about the level of transferability of findings. In this research, one chapter (Chapter four) is fully assigned to describing the context of the study, which is Iran. In that chapter, rich information is provided about the Iranian construction industry, building sectors, economic conditions, geographical position, regulations and cultural matters. Moreover, in Appendix two, some information about each interviewee is given that includes education, field of study, role, job, and years of experience. This will help the reader to understand from which perspective and based on what background the interviewee is developing his argument and explanation.

Dependability, which is parallel to reliability, is mainly about developing a report of the research process that allows peers to audit the work (Bryman & Bell, 2003). In order to address dependability in this research, the process of conducting the investigation was reported in detail in previous sections of the current chapter. The report clarified the research design, methods implemented, sampling criteria, data collection procedures, data preparation, and QDA. Moreover, reflective appraisal of the research was provided by explaining the advantages and disadvantages of the qualitative strategy in the research. Meanwhile, all audio files, interview transcripts, fieldwork notes, photos and documents are kept accessible as the records of the study. All of these will help peers to assess the dependability of the research.

Confirmability recognises that complete objectivity is impossible in qualitative research, but it explains that subjectivity should be minimised. In fact, the researcher should show that “he or she has not overtly allowed personal values or theoretical inclinations manifestly to sway the conduct of the research and findings deriving from it” (Bryman & Bell, 2003). To enhance the confirmability of the research, during the interviews, the researcher took a neutral stand and did not confirm or reject interviewees’ responses. Furthermore, the researcher did not transfer any knowledge about construction logistics management to respondents except a general logistics definition that was explained for all interviewees in the interview guide (Appendix one). Meanwhile, the researcher attempted to avoid directing the discussion in the interview sessions. Hence, it was tried not to interrupt respondents’ conversation as much as possible, to allow the concepts to emerge naturally. In the transcribing stage, what was heard was directly converted to text without any edits. Beside these, for the first interview transcript, the list of codes was extracted and shown to a colleague to be reviewed. A similar method was recommended by Northey (1997). The colleague was asked to rate each code by giving one if the code is weakly supported by text and five if it is strongly supported by the text. Among the 18 codes, 11 were rated at five, five at four and two at three which shows acceptable confirmability of the research. In addition to these techniques, the process of the research was explained clearly in the previous sections which can be used for confirmability auditing.

6. 6. Quantitative Inquiry

The second approach to the construction logistics investigation has a quantitative nature. Generally, the quantitative approach involves making measurements by collecting factual data. It pursues objective scientific methods and reflects the positivist epistemology. A quantitative strategy is described as "entailing the collection of numerical data and as exhibiting a view of the relationship between theory and research as deductive, a predilection for a natural science approach (and of positivism in particular), and as having an objectivist conception of social reality" (Bryman & Bell, 2003). The aim of quantitative inquiry in this study is to utilise the power of quantitative methods to complement the results of the qualitative research described in the previous sections. The advantage of using a quantitative strategy in this research can be expressed as:

- It provides a broader perspective by gathering the ideas of greater numbers of people about construction logistics management. Researching a large sample gives an indication of the experts' view on construction logistics in the Iranian building sector.
- It determines if the interviewees' opinions about a subject are supported or rejected by other practitioners involved in the industry.
- It minimises the level of subjectivity in the research. The researcher's bias is reduced by keeping a distance between the researcher and the participants.
- It has a structured and standardised process and procedures which ensures validity and reliability of the results.
- It enhances the quality of presentation of results in the thesis by using descriptive statistical methods, such as frequency distribution and bar charts. Numerical data allows the researcher to summarise and finalise data in a clear and understandable way.

The questionnaire survey was chosen as the method of the quantitative inquiry in this research. It is a standard and cost-effective way to gather data from a large number of respondents. The questionnaire is more objective than other methods, such as interviewing, and the speed of gathering data is relatively quick. In the following section, the main steps of the quantitative inquiry, including the questionnaire design and distribution, will be covered.

6.6.1. Putting Quantitative Research in Sequence

The process of quantitative inquiry has four general steps: (a) research design, (b) collect factual data, (c) process data, and (d) analyse data. Collis and Hussey (2009,

p. 188) developed a diagram for data collection for quantitative studies. Figure 42 is developed based on their diagram, with a box added for statistical analysis.

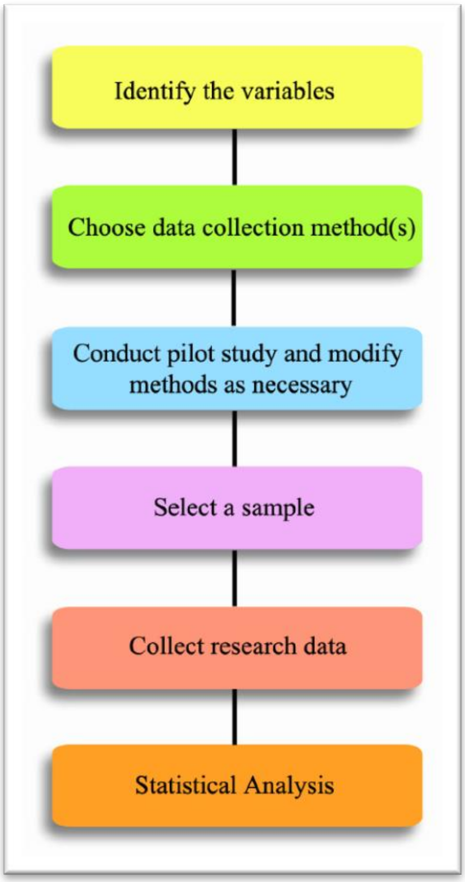


Figure 42: Quantitative data collection process, Adapted from (Collis & Hussey, 2009, p. 188)

Considering Figure 42 and the four steps of quantitative research indicated above, five stages can be defined for the quantitative approach of this research. Each stage will be expressed in detail in the following sections, but a brief description of the stages is provided below:

1. *The questionnaire design.* The qualitative information provided a ground for quantitative study. The qualitative objects are turned into variables to be measured. A questionnaire is designed based on (a) the objectives of the research and (b) identified variables from the QDA. The first draft of the questionnaire is evaluated through a pilot study.

2. *Sampling.* The Iranian contractor companies were chosen as the population of the study. A sample of 287 companies was selected randomly from the population.
3. *Administering the Questionnaire.* After confirmation of the pilot group, the questionnaires were sent to the respondents. The data gathered from the survey was entered into SPSS for conducting analysis.
4. *Quantitative Analysis.* Descriptive statistics is used to present data aligned with the QDA.
5. *Quality of the Quantitative Study.* The validity and reliability of the study are assessed at the end to ensure the quality of the results.

6. 7. The Questionnaire Design

In the Qualitative Inquiry section, three weaknesses were explained for qualitative research: (a) the outcomes could not be generalised, (b) the research is not replicable, and (c) the structure and the process of research were not transparent. None of these weak points were associated with the quality of the research and all of them are rooted in the nature of qualitative research. To improve the outcomes of the research and recover the weaknesses mentioned above, a questionnaire survey was conducted. A questionnaire "is a method for collecting primary data in which a sample of respondents are asked a list of carefully structured questions chosen after considerable testing, with a view to eliciting reliable responses" (Collis & Hussey, 2009, p. 191). The aim of the questionnaire survey is to use a relatively large sample to understand what people know about construction logistics and how they manage logistics in their projects. The type of questionnaire used in this research is self-administrated, which means the questionnaires are completed by the respondents. The survey has a descriptive form and is used to measure the present conditions of construction logistics among the Iranian contractors as the population of the research. This section is about the way the questionnaire was designed and includes three parts: (a) defining research objectives and identifying variables, (b) justifying different sections of the questionnaire, and (c) conducting pilot tests.

6.7.1. Defining Research Objectives and Identifying Variables

As explained in the Methodological Pluralism section of this chapter, in the complementarity approach, information gathered from the qualitative study provides a foundation for the quantitative inquiry. The quantitative analysis, also, complements the outcomes of the qualitative study. During the course of qualitative data analysis (QDA), many topics were identified that needed more investigation. In other words, to clarify certain situations, there was a need for numerical data to provide a broader insight in to the research.

The first step in conducting a quantitative survey is to design a questionnaire. This is an important task because it affects factors, such as response rate, validity and reliability of the collected data (Saunders, Lewis, & Thornhill, 2009). To design the questionnaire, the variables should be identified to be measured. A variable is "an attribute or characteristic of the phenomenon under study that can be observed and measured" (Collis & Hussey, 2009, p. 188). The variables should be selected in such a way that address the research questions. It is worthwhile taking a look at the three research questions again:

a. *To what extent are practitioners aware of logistics management in their projects?*
b. *What is the process of construction logistics? (What activities are included?)*
c. *What are the logistical problems and challenges that the Iranian construction experts experienced in their projects?*

Considering the research questions, it can be explained that the variables should measure three subjects: (a) the logistics awareness of respondents, (b) the process of construction logistics, and (c) the importance of logistical problems and challenges. These three subjects should be broken down to more specific topics. This is already done in the qualitative inquiry. The QDA provides the research with detailed categories and subcategories that can be used as variables for designing the questionnaire (Figure 42).

At the beginning of the questionnaire design process, 30 topics were selected from the results of the QDA to be investigated quantitatively. The selected topics should meet two criteria: (1) to have close relationship with the research questions and the three factors indicated above and (2) to add new insight to the outcomes of the QDA. The list of topics that were selected initially is provided in the following:

1. Logistics Knowledge
2. Logistics Translation in Farsi
3. Logistics Education
4. Logistics Training
5. Supply Chain Knowledge
6. Relationship with Suppliers
7. Material Delivery Channels
8. Critical Materials
9. Estimation Methods
10. Material Scheduling
11. Lead Time
12. Procurement
13. Contracts
14. Supply Sources
15. Material Inspection
16. Material Costs
17. Material Delivery
18. Warehousing
19. Consolidation Centre
20. Long-term Material Storage
21. Warehousing Duration
22. Material Re-handling
23. Logistics Organisation
24. Standardised Logistics Process
25. Logistics Failure
26. Waste Production Volume
27. Causes of Waste
28. Environmental Conservation
29. Logistics Risks
30. Poor Logistics Management Consequences

Owing to practical matters, eight topics were eliminated from the list to have a shorter questionnaire (this will be expressed more in the pilot test section). Hence, Logistics Translation in Farsi, Critical Materials, Estimation Methods, Material Costs, Warehousing Duration, Material Re-handling, Logistics Failure, and Environmental Conservation were taken out from the list. Also, Procurement and Contracts merged together to form a more generic topic. Finally, 21 topics were categorised under nine sections to be put in the questionnaire (Appendix four). One section was also dedicated to demographic questions. The categories, topics and variables are summarised in Appendix five.

The type of variable influences the wording of the questions. Generally, there are three types of variables (Saunders, Lewis, & Thornhill, 2009):

1. Opinion: to assess how respondents feel and think about a subject and whether what they believe is true or false.
2. Behaviour: to assess what people did in the past, do in the present and will do in the future.
3. Attribute: to assess characteristics of respondents, including personal and demographic information.

Most variables in the questionnaire are of the behaviour type because the research aim is to understand the current practice of construction logistics management in the Iranian projects (Appendix five). In fact, the focus is on what people do in the projects. However, there are opinion questions to find out what participants think about issues such as waste and logistical risks. A few attribute questions were also asked at the beginning of the questionnaire to make clear the characteristics of the sample. Detailed description about each question will be provided in the next section.

After determining variables, a strategy should be set to accurately measure the variables. Measurement allows the researcher to detect and explain small differences between respondents in terms of the characteristic in question (Bryman & Bell, 2003). There are four levels of measurement (Collis & Hussey, 2009):

1. Nominal: It classifies data into qualitative categories that are usually mutually exclusive. These categories cannot be ranked.
2. Ordinal: It categorises data into levels that can be ranked. Yet, there is no meaningful difference between two levels of measurement.
3. Interval: It is a quantitative measure in which data can be ranked with meaningful difference between two levels of measurement. Yet, there is no true zero.
4. Ratio: It possesses the interval measure characteristics while a true value of zero exists.

In SPSS, interval and ratio measures are grouped as scale. The questionnaire has a mix of nominal, ordinal and scale measures. These are chosen according to the purpose of each question. The variable and measure types are shown in Appendix five.

The next step is designing the questions. This includes determining the types of questions, their wording, and the order in which they are presented (Collis & Hussey, 2009). Closed questions are more appropriate for self-administered questionnaires. The questionnaire consisted of 86 closed questions that provided a number of answers for respondents to choose from. In some cases, there were dedicated spaces that could be used by the respondents to express their views about a particular subject. Saunders *et al.* (2009) highlighted six types of closed questions as: list, category, ranking, rating, quantity, and matrix. The type of each question depends on the nature and purpose of that question. The types that are used in the questionnaire are list, category, and rating, defined in the following by Saunders *et al.* (2009):

- List questions provide the respondents with a list of responses to choose from. The respondents can consider all possible responses and choose one or more options.
- Category questions are designed in a way that the respondents can choose only one response. This type is useful when behaviour or attribute variables need to be measured.
- Rating questions records responses by using a rating device. Two famous types of rating questions are Likert and scale.

The types of the questions are shown in Appendix five. As is clear, there is a balance between the numbers of category and rating questions in the questionnaire.

In terms of wording, the researcher attempted to avoid the use of jargon to minimise the ambiguity of the questions. In the whole process of question design, the target audience were considered as people who are familiar with the construction industry and have a medium level of intelligence and knowledge. However, to avoid any confusion, clear instructions were provided for some questions. Also, wherever it was appropriate, technical terms that needed clarification were defined. It should be explained that the questionnaire was originally designed in Farsi (Appendix six) to enable respondents to answer questions in their native language. The original questionnaire was translated to English later for reference only (Appendix four).

After designing questions, the questionnaire layout should be set. Considering the advice of Burns and Burns (2008), particular attention should be paid to the visual appearance of the questionnaire, because in a self administrated survey, the respondents see the actual questionnaire. It was attempted to keep the structure of the questionnaire simple and easy to complete. Normally, a questionnaire structure has four parts (Burns & Burns, 2008):

1. Introduction
2. Demographic questions
3. Body of the study
4. Expression of thanks and contact information of the researcher

This research attempted to adopt the above model but owing to cultural reasons, section one and four were merged together. Hence, the questionnaire started with an introduction and expression of thanks followed by demographic and main questions.

The questions were set in a logical order in the questionnaire moving from general to specific topics. This method is usually known as funnelling (Collis & Hussey, 2009). The questionnaire started with demographic information and this was followed by questions about logistics and supply chain knowledge. Then, based on the sequence of logistic tasks, the associated questions were put in order: scheduling, supply, transportation, and warehousing. At the end, questions were focused on more specific topics of logistics organisation, waste management and logistics risks.

Answer choices are located under the questions with plenty of white spaces between the choices and the next question (Appendix six). These spaces can be used by the respondents to add any other comment they have. In some questions, the variables were tabulated to make the answering process easier. All tables had a striped pattern to minimise the risk of confusion and mistake.

6.7.2. Pilot Testing

Pilot testing is a tool to spot potential problems in the questionnaire. “The purpose of the pilot test is to refine the questionnaire so that respondents will have no problem in answering the questions and there will be no problems in recording the data” (Saunders, Lewis, & Thornhill, 2009, p. 394).

To pre-test the questionnaire before conducting the survey, six pilot studies were carried out. The pilot group was asked to complete the questionnaire and give feedback on the clarity and suitability of questions, the structure of the questionnaire and the length of the questionnaire. They were also encouraged to comment on the questionnaire and make suggestions. The result of the pilot test was generally positive, but some alterations were recommended, summarised in the following:

- *The introduction is too long.* Too much unnecessary information was provided in the introduction section. Hence, a few lines were eliminated. Moreover, the wording of the introduction was changed to make it shorter.
- *The questionnaire is too long.* This issue was critical because it could affect the response rate. Hence, unnecessary and ambiguous questions were

discarded. For example, a question about evaluating the price of materials was removed because it was superficial and vague. Another example was a question regarding the role of the company (consultant or contractor). This question was also eliminated because it was decided that the sample should be focused on the contractors only. Furthermore, some questions with the same subjects were merged. For instance, two separate questions about the procurement methods and commonly used contract types were combined together. The pilot group believed that the question was more understandable for contractors in this way.

- *The focus on the building industry should be highlighted.* It was a useful comment to receive because some companies work in different sectors of the industry. Thus, in the introduction section, the words 'building sector' were added with bold font and underlined to stress the focus of the research.
- *Describe technical terms or English words.* To rectify this issue, the wording of some questions was changed and an appropriate translation was used. For instance, a short description about design and built procurement method was added.
- *Rescale responses.* Questions with too many options were confusing. Hence, changes were carried out on the style and numbers of responses. For example, in a question about the vendor list criteria, instead of using multiple choices, a rating scale was defined for each option.
- *Order of some questions should be changed.* In some cases, recommendations were applied to improve the sequence of the questions.
- *Use tables more.* This was a useful suggestion utilised for rating scale questions.

After shortening and revising the questions, the new amended questionnaire was sent to two more people for final checks. Following the confirmation of the second pilot test, the main survey was started. It should be explained that data gathered from the pilot study were entered into a separate SPSS file for checking the analysis process, but they are not considered in the main analysis.

6.7.3. Questionnaire Justification

To collect numerical data about construction logistics from the Iranian construction practitioners, a questionnaire was designed that included ten parts. Each part will be expressed here and information about the purpose, measure and type of each question will be explained.

The questionnaire (Appendix four) started with an explanatory introduction to the research. The introduction included information about construction logistics and its importance, the aim of the research, the importance of respondents' participation, the questionnaire structure, the research focus, expression of confidentiality, and the researcher's email.

6.7.3.1. Part 1: Demographical Information

The first section includes demographic questions which help to understand the sample better. These questions are put at the beginning so that the respondents gain confidence in answering simple questions. This section consisted of seven attribute questions about the respondents' characteristics:

1.1 *The company name*

1.2 *Job*

The two first questions were optional. This helps the participants to answer questions honestly because they are not intimidated by the feeling that they may be tracked.

1.3 *Level of education*

Among 135 respondents, 130 people answered this question. The majority (69.6%) of the respondents have a bachelor degree while 21.5% have a master degree (Table 8, Figure 43). Only two respondents do not have a university degree. Hence, the sample is characterised by individuals who participated in higher education (over 91%).

Table 8: Respondents' level of education

		Frequency	Per cent
Valid	**High School Diploma**	2	1.5
	Technician	5	3.7
	BEng & BSc	94	69.6
	MSc & MA	29	21.5
	Total	130	96.3
Missing	System	5	3.7
Total		135	100.0

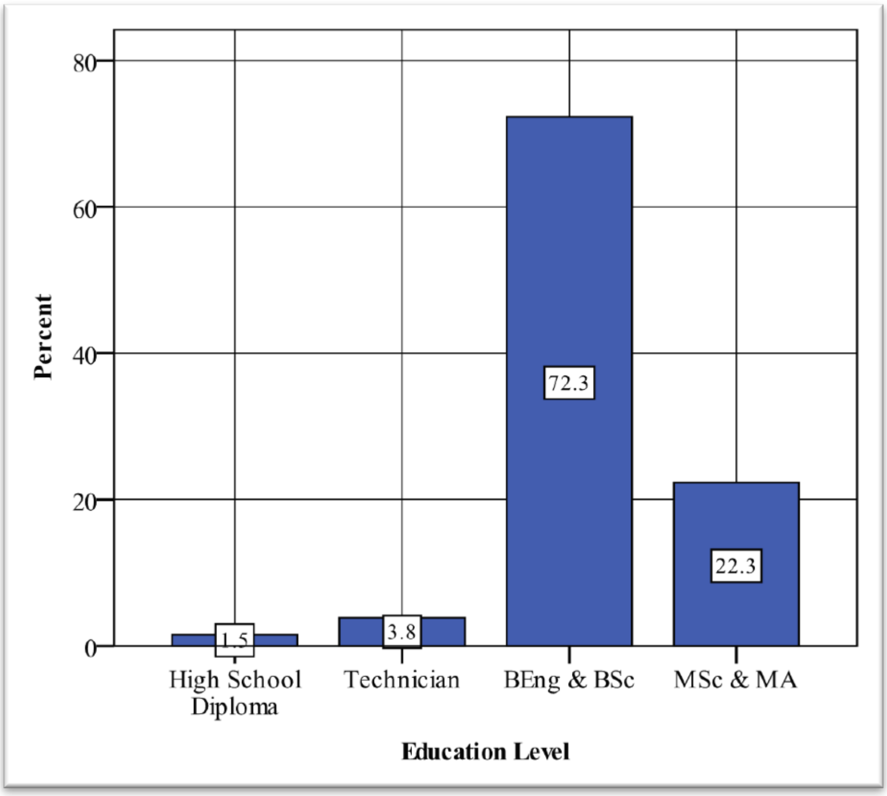


Figure 43: Respondents' level of education

1.4 Field of study

A total of 128 respondents answered this question. The civil engineers have the dominant view point in this study as 77.8% of respondents studied civil engineering (Table 9; Figure 44). Considering the fact that the survey is conducted on contractors, it is logical that most of them are civil engineers.

Table 9: Respondents' field of study

		Frequency	Per cent
Valid	**Civil Engineering**	105	77.8
	Architecture	10	7.4
	Miscellaneous	13	9.6
	Total	128	94.8
Missing	System	7	5.2
Total		135	100.0

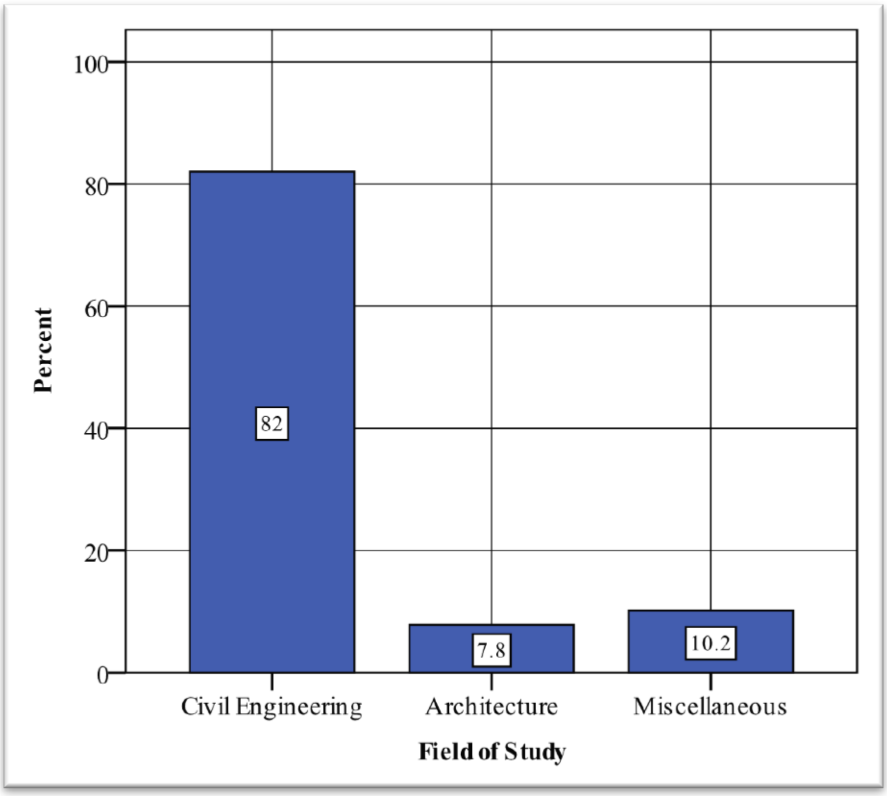


Figure 44: Respondents' field of study

1.5 Work experience

Table 10 and Figure 45 show that the majority of respondents (38) have five to ten years of working experience. There are also 66 individuals that have ten or more years of experience which constitutes 48.9% of the sample. This shows that the experience of the participants is relatively high.

Table 10: Respondents' experience (years)

		Frequency	Per cent
Valid	**1-5**	26	19.3
	5-10	38	28.1
	10-15	32	23.7
	15+	34	25.2
	Total	130	96.3
Missing	System	5	3.7
Total		135	100.0

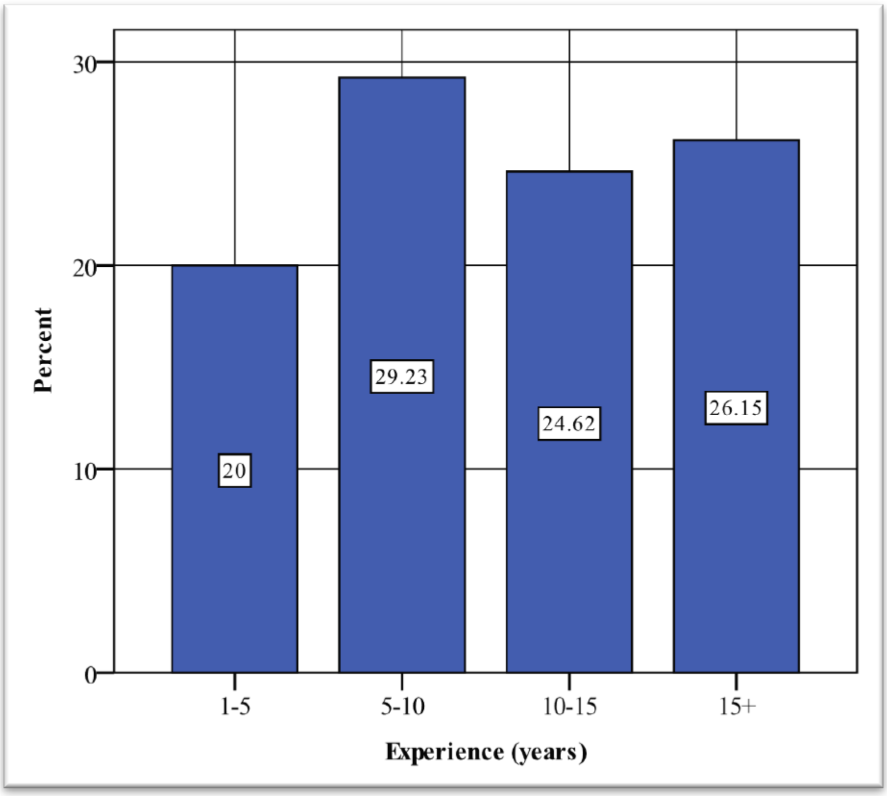


Figure 45: Respondents' experience (years)

1.6 The company grade in building construction

The contractors that have grade one, two, or three from the Office of Technical Affairs (the Iranian President Deputy) form the sampling frame of the study (this will be explained in the sampling section). Table 11 and Figure 46 illustrate the proportion of respondents based on the company grades. The majority of companies have grade two, which is logical because more questionnaires were sent to grade two companies in comparison to others.

Table 11: The company grade of the respondents

		Frequency	Per cent
Valid	**One**	39	28.9
	Two	52	38.5
	Three	44	32.6
	Total	135	100.0

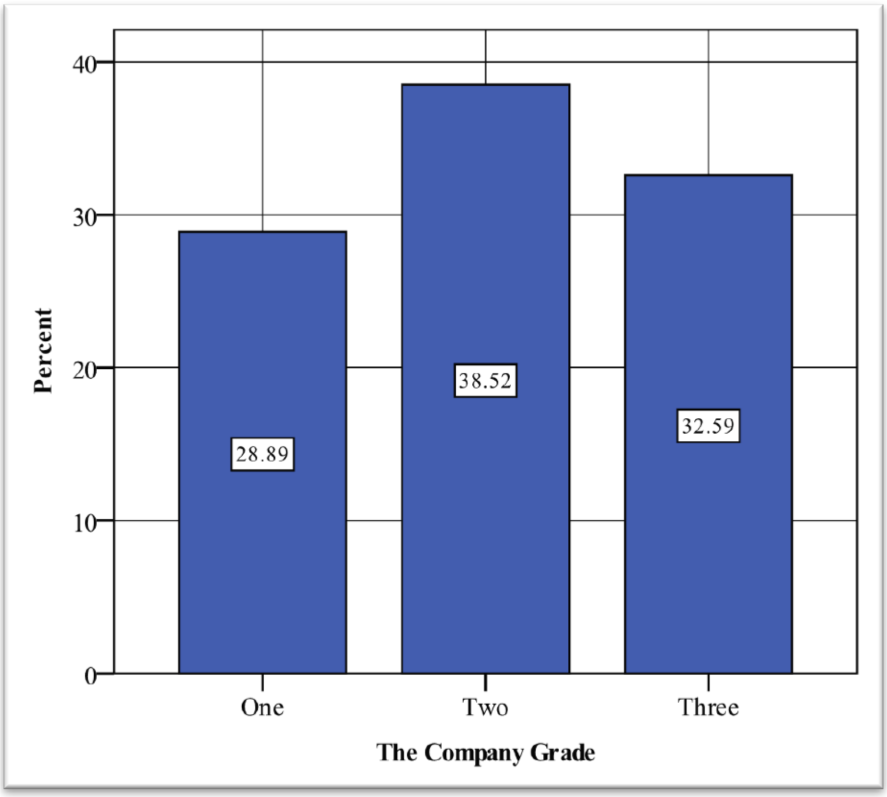


Figure 46: The company grade of the respondents

1.7 *The company possession mode*

The possession modes of the companies are shown in Table 12 and Figure 47. The private firms constitute 68.1% of the sample, while only ten public companies (managed by the Government) participated in the survey. One reason may be the fact that public companies are mostly involved in the oil and gas sector and not building construction. Over 16% of the companies were semi-private. This type of company was formerly owned and managed by the Government, but they are in a transition from public to private mode through the privatisation scheme of the Government.

Table 12: The company possession mode of the respondents

		Frequency	Per cent
Valid	**Private**	92	68.1
	Semi Private	22	16.3
	Public	10	7.4
	Total	124	91.9
Missing	System	11	8.1
Total		135	100.0

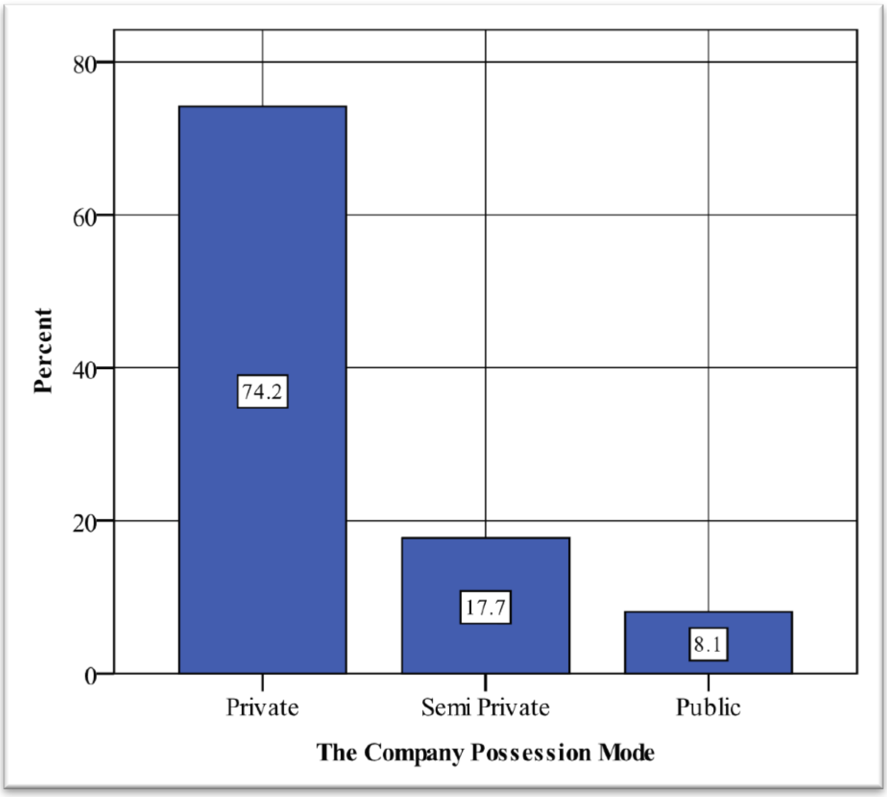


Figure 47: The company possession mode of the respondents

6.7.3.2. Part 2: Construction Logistics Knowledge

This part evaluated the respondents' knowledge about logistics. Before asking the questions, a brief definition for logistics management was provided. The reason is that, in the qualitative study, it was identified that interviewees' perception about logistics is not accurate. They missed logistics matters related to warehousing, site layout, transportation and material handling, and only focused on purchasing. Hence, a definition was expressed to give a general view of construction logistics to the respondents. The second part consisted of three questions:

2.1 *Were you familiar with the logistics concept before reading the above definition?*

This is a Likert rating question with four options which presents respondents' self evaluation about their logistics knowledge.

2.2 *Have you been educated in different logistics topics mentioned below in a university or other types of educational institutions?*

This question can give a better view of the respondents' knowledge level. The aim is to assess the level of education respondents attained in relation to logistics. The question tabulated eleven logistics topics which emerged from the qualitative study. For each topic, a four option Likert rating was allocated. A short instruction was also provided that helped the respondents on how to choose answers.

2.3 *Have employees, who carry out logistical affairs, been trained before or during taking their job?*

In the qualitative study, it was found that the role of logistics personnel is critical. This question is to understand what level of education or training the personnel receive. In the QDA, the main logistics personnel were identified as the supply and support manager, financial manager, buying coordinator, and warehouse coordinator. It is a list question with four options that are structured in a table. The choices are related to the way the personnel learn to carry out their jobs. One or more options may be selected by the respondents.

6.7.3.3. Part 3: Supply Chain

This part, in addition to assessing participants' supply chain knowledge, aimed to explore two important supply chain matters emerging from the QDA. Three questions were designed for this section. A short definition of 'supply chain' was expressed before asking questions in order to ensure an identical understanding of the term among respondents.

3.1 *Were you familiar with supply chain concept before reading the above definition?*

It was a four-option Likert rating question which reflected respondents' self assessment of their supply chain knowledge.

3.2 *In general, do you establish long term relationship with your project supply chain members or short term relationship?*

Much literature recommended establishing long term relationships between the contractors and suppliers. In the QDA, advantages and disadvantages of establishing long term relationships with suppliers were explored. This question attempts to provide quantitative data about the relationship length preference of respondents. It is a category question with four multiple options that are defined in a way that show both the current practice and the ideal mode that is desirable.

3.3 *Which purchasing channel do you usually choose to provide materials and components listed in the following table for your projects?*

Delivery channel is an important topic in logistics. This question is to find out what is the source that is commonly used by respondents to procure materials and components. It is a list question which tabulated 18 critical materials. The list of materials was developed based on the QDA. Four sources of supply which are available in Iran are considered as the measures of this question: Manufacturers, Iran Mercantile Exchange, Manufacturers' Agents, and Retailers. The respondents may choose one or more options.

6.7.3.4. Part 4: Logistics Planning and Scheduling

Logistics scheduling is one the main categories identified in the QDA (Figure 41). This section had three questions and investigated two topics: order time and lead time.

4.1 *When do you order your needed material?*

This is a list question and respondents could choose one or more options. The purpose of the question is to find out when participants order materials. The options developed according to the results of the qualitative study and include: (a) order based on the schedule, (b) order based on experience, (c) order when materials are finished, and (d) buy all materials as soon as possible.

4.2 *Do you consider lead times when you plan to purchase materials and components?*

During the interviews, it was distinguished that the long lead time of some materials causes problems for projects. This question is to find out whether contractors consider lead time in their schedule or not. Moreover, it was important to know how accurate the lead time estimation is. Four multiple options were designed in this category question in a way to address these issues.

4.3 *From what sources do you get the numerical data of the lead times?*

This is an important question because accuracy of lead time estimation affects the accuracy of the logistics scheduling. For accurate information, reliable sources should be identified. This question aims to find the common source of lead time data used by contractors. It is a list question with five choices and one or more options can be selected. Also, there is a sixth choice that is open for any other source that may be used by respondents.

6.7.3.5. Part 5: Procurement, Contracts and Supply Sources

The project delivery methods, vendor list and inspection are the main concerns of this section. Four questions were asked to the respondents:

5.1 *What type of contract and procurement method do you use in your projects?*

A mix of contracts and procurement routes that may be used by contractors is provided in a form of a list question. A discussion was conducted with three experienced contractors in Iran to develop a list of project delivery methods that are commonly used. Nine options were identified and listed in this question. Also, an open option was anticipated for any other routes that the participants may want to mention. The contract forms and procurement routes are mixed together because the experts who participated in the pilot test expressed that the question was more comprehensive and understandable in this way. Moreover, based on feedback from the first pilot test, a brief definition for each option was provided to make sure that the respondents answered the question consciously:

- *Traditional method (bills of quantities):* The client commissions the project to a consultant for design preparation and then a contractor will build the facility. The payment is based on the bills of quantities.
- *Fee based system:* It is similar to the traditional method but the client is responsible for providing materials for the project.
- *In-house:* Executing a project within an organisation instead of relying on outsourcing.
- *Fixed price system:* It is a form of the traditional method where the client commissions the project to a contractor with a fixed price.
- *Square metre priced system:* It is similar to the traditional system but the payment is based on the total area of the built facility.
- *Percentage system:* A branch of the traditional method where the payment is a percentage of the total costs of the project.
- *Management contracting:* The client employs an agent to make contracts with the consultant and the contractor.
- *Design and Built:* The contractor holds the responsibility for designing and executing the project.
- *Turnkey:* The contractor should design and build the facility according to the client's specifications and make everything ready for the client to move into the building.

5.2 *Do you have a vendor list for buying material and components?*

There was a disagreement between the interviewees about the vendor list in the QDA. Some interviewees argued that a vendor list limits their options. This question is to find out if the respondents have vendor lists for the suppliers and to what extent they choose suppliers from that list. It was a multiple choice category question with four options which addressed the above issues.

5.3 *Which criteria are of great importance when you want to add a supplier to your vendor list?*

The suppliers in a vendor list are usually selected based on several criteria. A list of criteria was developed, based on the QDA, which includes: long term relationship, quality, commitment, distance to the site, price, and payment privilege. There is also a space for another criterion that may be used by the respondents. It is a rating scale question, and for each criterion, the respondents should assign a score between 1 (least important) and 10 (most important).

5.4 *Do you inspect and control the quantity and quality of the material and components delivered to the site?*

All materials and components should be inspected before storage. The purpose of this question is to find out the level of inspection carried out on the quality and quantities of materials arriving to the site. This Likert rating question has three options: accurate inspection, general check (not accurate), no inspection.

6.7.3.6. Part 6: Transportation

6.1 *Have you experienced the following transportation issues in your projects?*

This is a short section dedicated to transportation. Delivery of materials earlier or later than what is expected is an issue which was indicated by the interviewees in the qualitative research. This question, using a Likert rating, is to measure the frequency that these issues occur in the projects. Four options were defined: very often, often, rarely, and never.

6.7.3.7. Part 7: Warehousing and Material Protection

The warehousing systems and consolidation centre are the main subjects of this section. Three questions were designed which are described in the following:

7.1 *How do you manage your warehouse?*

This list question exists to realise what system is used in construction projects in Iran to manage warehouses. The respondents may select one or more options from five choices.

7.2 *Does your company possess a consolidation centre to deliver materials and components to a portfolio of projects?*

The consolidation centre is a relatively new concept in construction management. Yet, some interviewees mentioned a temporary storage place for assembling structural parts together. Although this place cannot be considered as a classic consolidation centre, there are some similarities. Hence, the question is designed to investigate if the participants are familiar with the consolidation centre concept. A short definition of a classic consolidation centre was provided, and then four multiple choices assigned for the answers.

7.3 *Which materials and components specified below worth being stored for a long time (more than 6 months)?*

There was a debate about storing materials for long time on site. Some advantages were explained for long time storage in the qualitative study by interviewees. Yet, it was necessary to assess this topic in a larger sample. This is a list question with fourteen options: steel, cement, aggregates, gypsum powder, bricks and blocks, stone, bitumen, mechanical components, electrical components, tiles, doors, windows, gypsum and cement boards, and paint. One or more materials can be chosen. The choice “none” is also put for those people who think no material should be stored on site for more than six months.

6.7.3.8. Part 8: Logistics Organisation

8.1 *Do you have a team in your company to be responsible for managing supply and support?*

The qualitative study showed that often there is no dedicated team that undertakes all responsibility of logistical tasks in construction organisations. Yet, there are groups such as supply and support departments. This category question with three multiple choices intends to research organisational issues.

8.2 *Have you established standards for carrying out logistical task such as purchasing, warehousing, documentation, etc?*

One of the points indicated by some interviewees was standardisation of the logistics process. This category question aims to understand if the construction organisations have standardised logistics processes. The multiple choices are defined in a way to reach this aim.

6.7.3.9. Part 9: Waste Management

The volume of construction waste is large in projects in Iran, as stated by the interviewees. This section evaluates this issue quantitatively.

9.1 *How do you approximately evaluate the volume of waste production in the construction projects in Iran?*

A Likert rating question is designed to ask the respondents to reflect on the volume of waste onsite. As indicated by the interviewees, the standard volume of waste is around three to five per cent depending on the type of materials. Four options are defined as: very high, higher than standard, standard, lower than standard.

9.2 *Which factors are more important in waste production in your projects?*

Nine reasons were selected from the results of the qualitative study: poor packaging, wrong loading and unloading methods, low price of the materials, low quality of materials, traditional construction methods, project managers' unawareness, workers' unawareness, cultural matters, and material handling and re-handling. A blank space was assigned for the respondent who wanted to specify another reason. It is a scale rating question and the respondents should score each factor according to its importance in relation to waste production (1 least and 10 most).

6.7.3.10. Part 10: Logistical Problems

The final section of the questionnaire was dedicated to logistics problems and the consequences of these problems in the project.

10.1 *Ten fundamental logistics problems in the construction projects are listed in the following table. Considering the importance of each problem, choose one of the provided options.*

It is a Likert rating question with four choices. Ten logistics problems that were pointed out in the qualitative study are tabulated here. The aim is to assess how these problems affect the practice of logistics management. The problems are: low level of logistics knowledge among managers and engineers, poor logistics scheduling, estimation mistakes, financial problems, construction material shortage, inappropriate warehousing and material protection, unpunctuality of the suppliers, lack of experts in construction logistics management, early or late delivery of the materials to the site, and weakness of transportation infrastructures.

10.2 *Considering the definition given at the beginning of the questionnaire, to what extent can weak logistics management cause the following problems in construction projects?*

This Likert rating question aims to evaluate to what extent poor logistics management can lead to other problems in the construction projects. Five problems identified from the QDA were measured in this question: project costs increase, delays, low quality construction, low level of health and safety, and waste increase.

6.7.4. Sampling

After designing the questionnaire, the next stage was sampling. In quantitative analysis, the researcher often has to select a sample from a large population instead of studying the whole population because of the time and budget constraints. A sample is defined as a subset of a population (Collis & Hussey, 2009). In general, there are two sampling techniques:

1. Probability sampling: “the chance, or probability, of each case being selected from the population is known and is usually equal for all cases” (Saunders, Lewis, & Thornhill, 2009, p. 213).
2. Non-probability sampling: “the probability of each case being selected from the total population is not known” (Saunders, Lewis, & Thornhill, 2009, p. 213).

Probability sampling is used in this research. This technique is usually associated with questionnaire surveys, because it provides a sample that is representative of the population and this allows conducting statistical analysis. The process of sampling has three steps:

1. Identifying sampling frame
2. Determining sample size
3. Selecting a suitable probability sampling method

Identifying a sampling frame was a challenging stage for this research. A sampling frame “is a record of the population from which a sample can be drawn” (Collis & Hussey, 2009). It was difficult because there is a lack of enough information about the contractors’ population in Iran. Although there are associations, such as Association of Construction Companies (www.acco.ir), they cannot represent the whole industry because large numbers of contractors are not members of these associations. After discussing this matter with the Iranian academics, the most valid source identified was the Office of Technical Affairs, which works under the authority of President Deputy of Strategic Planning and Control. This office is responsible for the ranking of the construction companies based on their previous projects, financial power and staff education levels. All contractors that intend to bid for the public projects must attain a grade (a rank between one and five) from this office. After contacting this office, the researcher was provided with three lists of contractors that were grouped based on their grades. Hence, the sampling frame of the study is the contractor companies in Iran that get grades one, two and three from the Office of Technical Affairs in Iran. Companies with grade four and five were eliminated from the sample because the technical office did not provide accurate information about them. One reason is that these companies are small firms that are usually established for one or two projects and then dissolved. Table 13 summarises the sampling information of the study based on the grades of the contractor companies.

Table 13: Sampling information

The Company Grade	Number of Companies	Percentage from Total	Distributed Questionnaires	Returned Questionnaires	Response Rate
One	213	27%	78	39	50.00%
Two	303	38%	109	52	47.70%
Three	278	35%	100	44	44.00%
Total	794	100%	287	135	47.03%

The next step was determining sample size. To calculate the sample size, 'Sample Size Calculator' software was used (SurveySystem, 2010). The main menu of the software is illustrated in Photo 2.

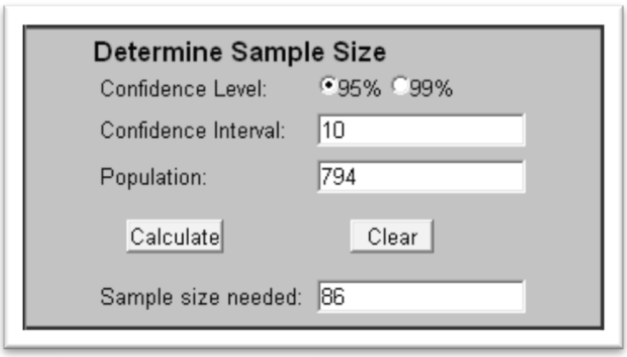


Photo 2: Sample Size Calculator software

As is clear in Photo 2, by assuming a confidence level of 95% and a confidence interval (margin of error) of ± 10, the sample size for the whole population is 86. It is assumed that a 30% response rate can be achieved. Thus, in total, 287 questionnaires were distributed. This figure is multiplied by the percentage of the company's grade to find out the number of questionnaires that should be allocated to each grade (Table 13). Thus, the number of required questionnaires for grade one, two and three was determined as 78, 109, and 100 respectively. It will be explained later that the response rate was higher than expected and 47.03% of distributed questionnaires were returned. Hence, the confidence interval can be amended as 7.69.

Simple random sampling was chosen as the sampling method, which means "selecting the sample at random from the sampling frame" (Saunders, Lewis, & Thornhill, 2009, p. 222). To choose companies from the list provided by the Office of Technical Affairs, an online random number generator was used (www.random.org). The generated number is monitored in the companies' list to find the company associated with that number. Then, the questionnaires were sent to the selected companies.

6.7.5. Administering the Questionnaire

Once the questionnaire is designed, pilot tested, and amended, it should be distributed according to the sampling strategy to collect data. At first, an internet-mediated method was chosen to distribute the questionnaire. Yet, owing to weaknesses of IT infrastructure, low speed internet, inaccessibility of email addresses, and the Government filtering in Iran, it was decided to use postal questionnaires. This is a common distribution method among quantitative researchers in which the questionnaire and covering letter are posted to the sample with a prepaid envelope for returning the completed questionnaires (Collis & Hussey, 2009). Saunders *et al.* (2009) explained that postal questionnaires with six to eight A4 size pages are likely to get a 30 per cent response rate in four to eight weeks from posting.

The questionnaire in Farsi was six and half pages long and was printed on both sides of the paper and stapled together neatly. With the questionnaire, a covering letter and a stamped returned envelope were also sent. The covering letter had a professional appearance with three sections (Appendix three):

1. The company name
2. The body, which includes: a short introduction to the research, specifying the characteristics of a person who should complete the questionnaire, posting instructions and statement of confidentiality.
3. Expression of thanks and signature

The main drawback of a postal questionnaire is that the researcher has no way to make sure that a specific person (e.g. the manager) completes the questionnaire. To solve this problem, in the covering letter, it was asked that the questionnaire be completed by a person who is familiar with the construction industry, has working experience in construction sites and preferably has knowledge about supply and support matters. The characteristics of the respondents were measured by asking demographical questions at the beginning of the questionnaire.
Two hundred and eighty seven packs were prepared and sent to the respondents. After four weeks, a total number of 78 questionnaires were returned, which indicated a response rate of 27 per cent. To increase the response rate, a random selection of 60 companies was made to be called and reminded about the questionnaire. After eight weeks from the postage of questionnaires, 135 questionnaires were received indicating a response rate of 47.03 per cent, which is acceptable for the research in construction management field (Table 13).

After finishing the survey, data were transformed into SPSS (Statistical Package for Social Sciences). The process of entering data has two stages: first, defining variables and measures and, second, inputting raw data into the software. After transferring all data into the software, the descriptive statistical analysis was started.

6.7.6. Quantitative Analysis: Descriptive Statistics

Descriptive statistics is the main method of quantitative analysis in this research, making the data intelligible and useable. Descriptive statistics, by using tables and graphs, has the potential to improve the understanding of the results of quantitative research (Black, 2005).

This method is chosen to contribute to the results of the QDA in describing the condition of construction logistics management in Iran. For each section of the analysis chapters, after explaining the qualitative information, related statistical data will be provided using frequency distribution and bar charts. For instance, where the logistics knowledge category (node) is explained, numerical data will be presented about the current level of knowledge among respondents, the amount of information they received in relation to logistical tasks in the university, and the level of training provided for staff that carry out logistical affairs.

6.7.7. Quality of the Quantitative Research

The principles of reliability and validity are widely used by positivists in their scientific methods. These illustrate the quality of a quantitative study according to the accuracy of measurements. Whenever a measuring device in any form is utilised as a part of the data collection process, the validity and reliability of the measurement is important. This section evaluates the reliability and validity of the result of the quantitative inquiry.

6.7.7.1. Reliability

Reliability refers to "the consistency of a measure of a concept" (Bryman & Bell, 2003, p. 76). The consistency of findings enables them to be replicated (Burns & Burns, 2008). A postal questionnaire is a reliable method, because it is easy to standardise questions and structure the questionnaire in a way that all respondents answer exactly the same questions (Collis & Hussey, 2009). The questionnaire used in this study consisted of closed questions which reduces the risk of misinterpreting of answers by the researcher. Furthermore, its standard structure makes it replicable and helps other researchers to repeat the study.

To test the reliability of the questionnaire, Cronbach's α (alpha) method is used. It is a test commonly utilised by the quantitative researcher to figure out internal reliability. The concern of internal reliability is "whether respondents' scores on any one indicator tend to be related to their scores on the other indicators" (Bryman & Bell, 2003, p. 76). Cronbach's α (alpha) method "calculates the average of all possible split-half reliability coefficients" (Bryman & Bell, 2003). The value of 0.80 for alpha is typically considered as an acceptable level of reliability (Bryman & Bell, 2003).

To calculate alpha, the reliability analysis feature of SPSS is used. All Likert rating and multiple choice questions are considered for the analysis. The calculated

Cronbach's α is 0.805. George and Mallery (2003, p. 231) provided the following rule of thumb for Cronbach's alpha: $\alpha > .9$: Excellent, $\alpha > .8$: Good, $\alpha > .7$: Acceptable, $\alpha > .6$: Questionable, $\alpha > .5$: Poor, and $\alpha < .5$: Unacceptable. Based on George and Mallery’s rule of thumb, the reliability of the questionnaire is good.

6.7.7.2. Validity

The validity of the results can be discussed only when the results are reliable. Validity distinguishes “whether a measure of a concept really measures that concept” (Bryman & Bell, 2003, p. 77). There are two types of validity: (a) internal and (b) external. Internal validity is “the degree to which the conditions within the experiment are controlled, so that any differences or relationships can be ascribed to the independent variable, and not other factors” (Burns & Burns, 2008, p. 427). External validity is “the extent to which the results of a sample are transferable to a population” (Burns & Burns, 2008, p. 426). In contrast to reliability, validity is not evaluated numerically and should be explained based on the way the research is carried out.

The research has internal validity because the sample size selected is large enough to study the population. Furthermore, the selection of measurement items was based on the qualitative data analysis (QDA) and this ensures a high level of congruence between concepts and measurements. Moreover, the positive feedback received from the two-steps pilot test of the questionnaire ensures that the measures can assess the concept that is focus of attention.

To make the research externally valid, the methods used were described comprehensively. Furthermore, the purpose of each question was explained and the variables associated with that question were defined (Appendix five). In terms of selected sample, the process of random sampling was expressed in detail. This sampling method ensures that the sample is a representative of the target population. Moreover, the high response rate achieved minimises the risk of bias in the sample. Also, the demographical information of the sample is provided which illustrates the characteristics of the sample and the extent to which the results can be generalised to wider contexts.

6. 8. Conclusion

This chapter described the way that the research was conducted. First, the philosophical position of the research clarified that it has a constructivist ontology and interpretivist epistemology. Then, qualitative and quantitative inquiries were expressed as two approaches to the research. It was also indicated that this research intended to mix qualitative and quantitative methods and take advantage of methodological pluralism. Hence, the complementarity approach was used, which allows the quantitative methods to complement the results of the qualitative investigation.

The next section of the chapter was assigned to qualitative inquiry. All theoretical and practical matters of the research design, data collection and analysis were elucidated. It was explained that twenty four interviews were conducted with experienced Iranian construction practitioners. The interview information was transcribed into NVivo for qualitative data analysis. The QDA included coding the interview transcriptions, identifying categories and subcategories (nodes), seeking patterns, and finding relationships among the logistics system's agents. At the end, the quality of the qualitative inquiry was evaluated and the advantages and disadvantages of qualitative methods were discussed. The results of the QDA are presented in the analysis chapter and are used to create a model for managing construction logistics in projects.

The final section of this chapter described the process of quantitative inquiry. In this section, how quantitative methods were utilised in the research was stated. The emerging variables from the QDA were introduced and the methods measuring these variables were clarified. Practical matters, including questionnaire design, questions' logic, pilot testing and sampling, were considered in detail. Then, the process of distributing the questionnaires and inputting the data into SPSS was explained. Among the population of 794 Iranian building contractors (grades one to three), 287 companies were selected randomly for completing the questionnaire. Among those, 135 questionnaires were returned, which indicates an acceptable response rate of 47.03 per cent. At the end, the reliability and validity of the quantitative inquiry was discussed. The result of the quantitative study is presented in the analysis chapters, wherever appropriate to complement the results of the QDA.

Chapter 7

ANALYSIS: ENVIRONMENTAL FACTORS

CHAPTER 7: ANALYSIS-ENVIRONMENTAL FACTORS

7. 1. Overview

This chapter is the first analysis chapter. Before describing the Environmental Factors as a subsystem of the construction logistics system, a brief introduction to the analysis process will be given. In the introduction section, nodes which are the result of the QDA will be presented. Also, how relationships between agents are formed will be described. Furthermore, the ordinary construction logistics model will be introduced.

In the next sections, the first subsystem which emerged from the QDA will be discussed. Interviewees' quotes are cited wherever required to make the analysis more mature. Further information about the interviewees, such as level of education, field of study, years of experience, nature of job and their company role, is provided in Appendix two. The Environmental Factors subsystem has four agents: (1) Resource Conservation, (2) Project Size and Location, (3) Weather Conditions and Geographical Position, and (4) Construction Peak Working Seasons. These agents will be explored thoroughly and the relationships between them will be established. At the end, the Environmental Factors subsystem will be illustrated visually as the first part of construction logistics model. The model will be completed step-by-step by going through the analysis chapters and incorporating other subsystems to the main body of the model.

7. 2. Introduction to Analysis

In the Methodology Chapter, it was explained that the grounded theory approach is utilised to analyse qualitative data. This includes identifying, developing, discounting and merging concepts to produce a theory. The first step of the qualitative data analysis (QDA) was to import interview transcriptions into the NVivo. The second step was open coding of textual data. By reading the interviews, the researcher broke down the text into categories and then coded each category by a descriptive label. In NVivo, these codes are called 'Nodes'. For each node, a 'memo link' was defined. In NVivo, a memo link is a place to record the researcher's thoughts and observations which is related to a particular node. In total 41, nodes were identified in the open coding stage. The list of codes (nodes) is provided in the following:

1. Three Parties Relationships
2. Client's Role
3. Construction Method
4. Continuous Improvement
5. Cultural Issues
6. Delay
7. Demolition and Excavation
8. Design
9. Economic Issues
10. Resource Conservation
11. Estimation
12. Finance
13. Health and Safety
14. Information and IT
15. Lead-time
16. Logistical Problems
17. Logistics Knowledge and Personnel
18. Logistics Organisation
19. Material Cost
20. Material Delivery
21. Material Handling
22. Material Inspection
23. Material Inventory
24. Material Packaging
25. Material Purchasing
26. Material Quality
27. Material Scheduling
28. Material Selection
29. Material Shortage
30. Material Storage
31. Material Suppliers
32. On or Off Site Production
33. Parties
34. Project Size
35. Reverse Logistics
36. Security
37. Site Layout
38. Site Location, Weather, Season and Geographical Issues
39. Technology
40. Transportation
41. Waste

In the third step, each node and its memo link were read carefully to put data together in a new way (axial coding). This involved identifying subcategories (more nodes) and connections (relationships) between nodes. Furthermore, in this stage, smaller nodes were merged into the other nodes and larger nodes divided into smaller nodes. In the fourth step, the selective coding, a core category was formed as 'construction logistics'. The aim of this step was to build a hierarchical structure for nodes moving from a general category at the top (the parent node) to more specific categories (child nodes). The boundary between the third and fourth steps was not apparent and, in some cases, they were conducted at the same time. In other words, axial coding and selective coding may be carried out interchangeably. The four parent nodes which are under the core category (construction logistics) are: (1) Environmental Factors; (2) Operational Factors; (3) Commercial Factors; and (4) Managerial Factors (Figure 48). These are subsystems of the logistics system and analysis chapters are named after these parent nodes.

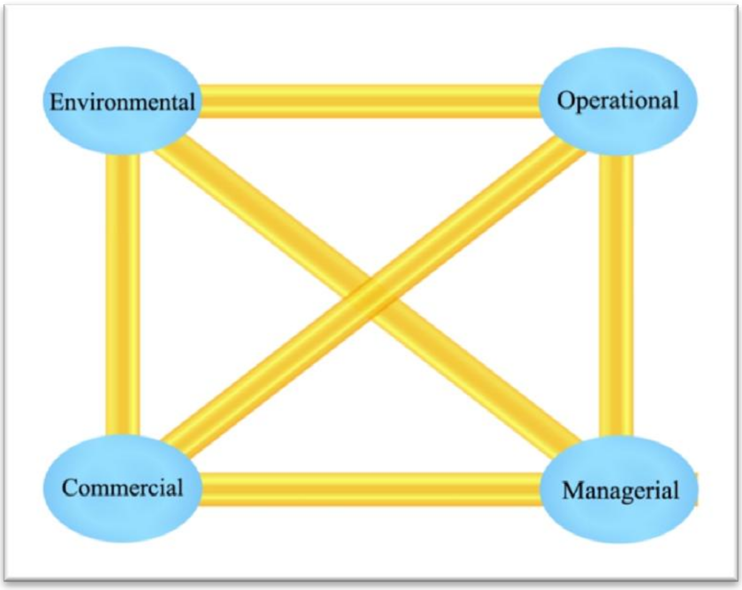


Figure 48: Logistics Tetragon, four subsystems of construction logistics system

Figure 49 shows the number of interviewees who spoke about the different nodes in interview sessions. In NVivo, interview transcriptions are referred as sources. As clear in Figure 49, the majority of interviewees explained their ideas about material purchasing, warehousing and transportation, while a few people mentioned resource conservation, lead-time and parties involved. Each node is like a container for references. In NVivo, references are the contents that are related to the nodes. In each source (interview transcription), there may be several references that are related to a specific topic (node). Figure 50 illustrates the number of references in each node. Material purchasing, warehousing and material packaging attracted much attention from the interviewees, while they were less worried about resource conservation, lead-time and parties involved. Figures 49 and 50 are indications that show the focus of construction logistics. It can be concluded that purchasing, warehousing, transportation, packaging and finance are the focal points of concern in construction logistics management from the practitioners who participated in the interviews.

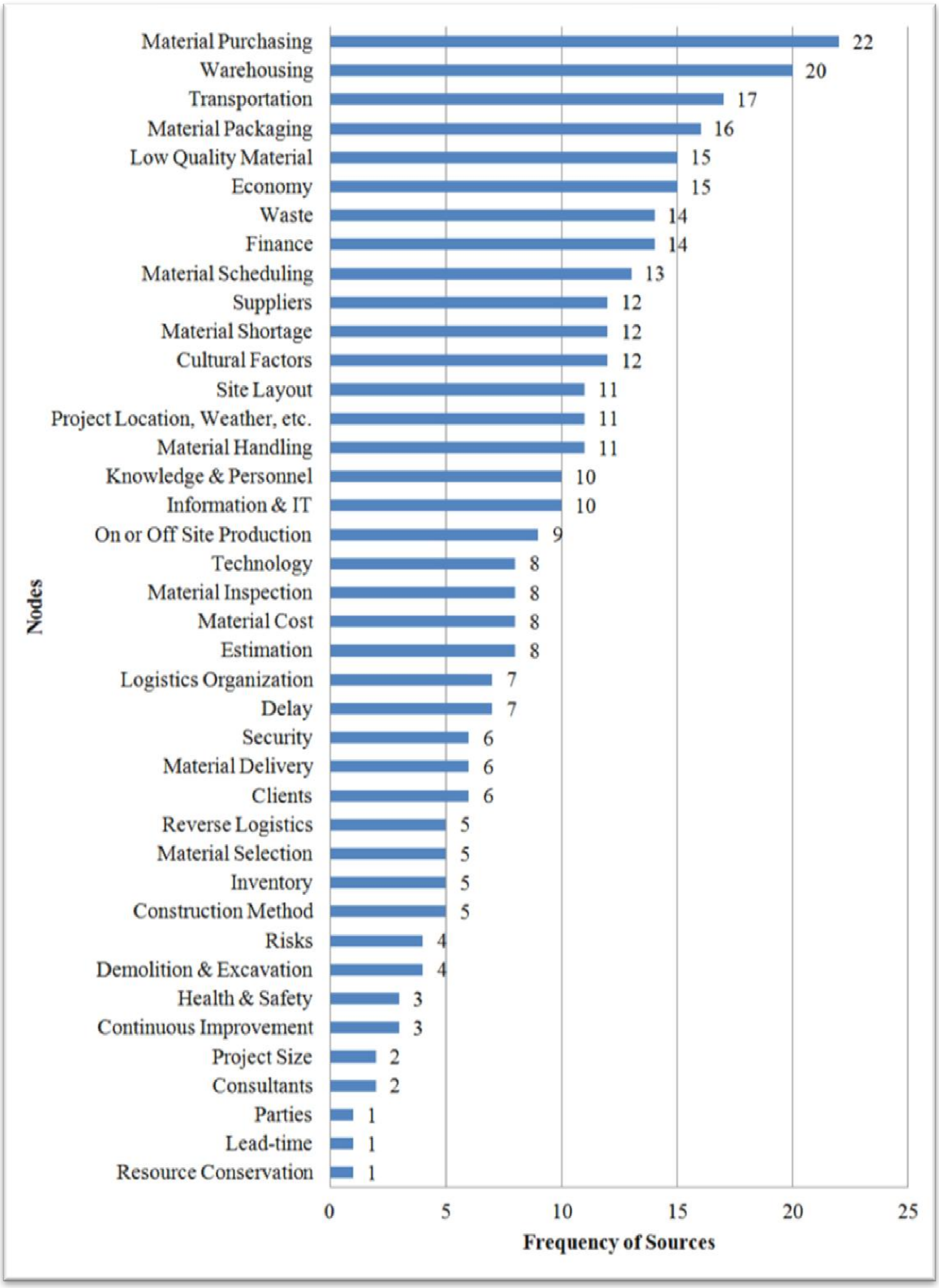


Figure 49: Frequency of sources for nodes

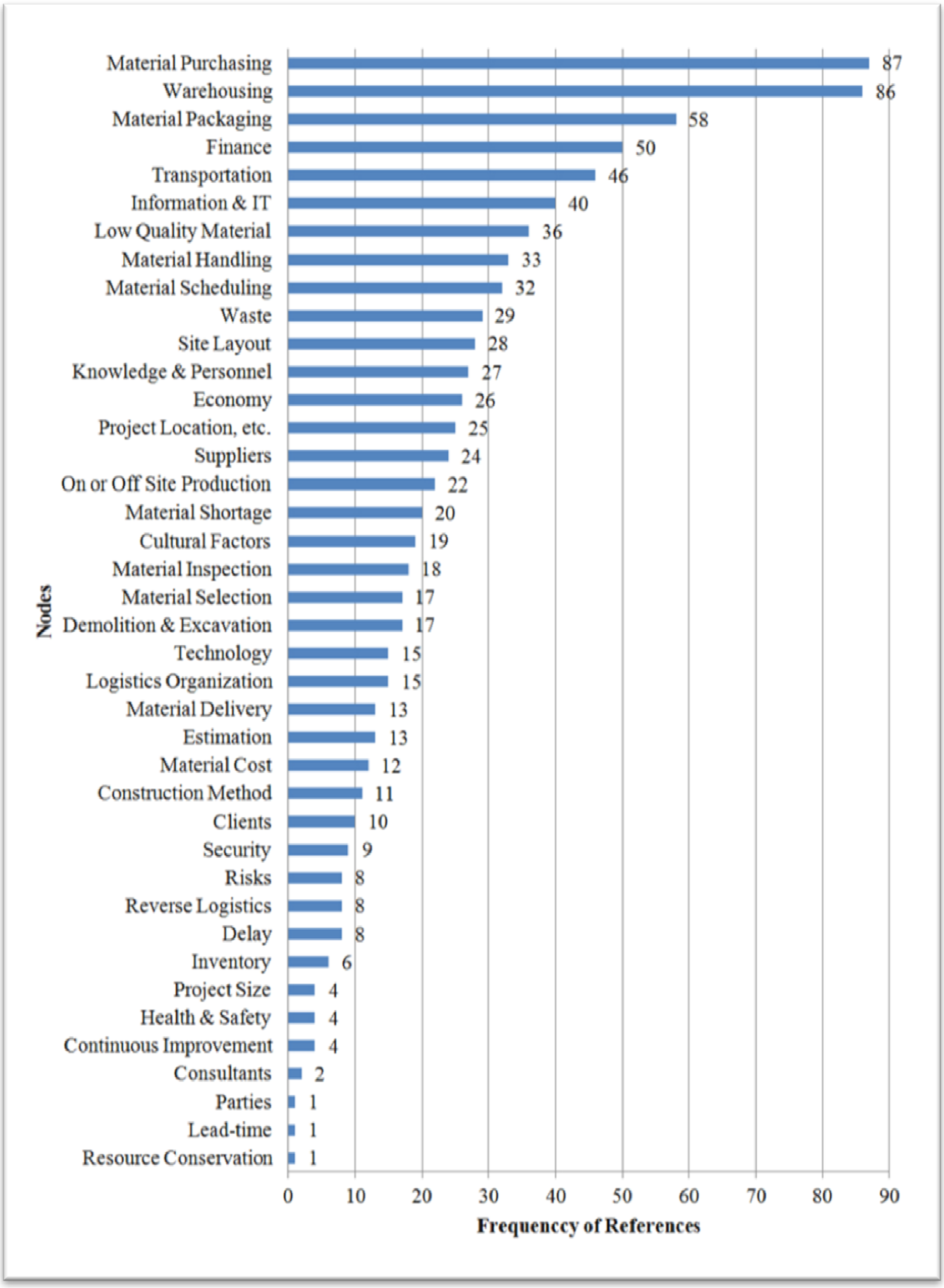


Figure 50: Frequency of references for nodes

7.2.1. The Construction Logistics Model

The construction logistics model started emerging from the early steps of the qualitative data analysis. The nodes identified in the text formed subsystems and agents of the construction logistics system. Coding data and hierarchy of nodes provided a basis for building the model. The parent nodes formed a tetragon which is the core of the system (Figure 48). Around the tetragon, there are branches that lead to child nodes. Figure 51 illustrates the ordinary model of construction logistics (the final model is available in Appendix seven and will be described in Chapter eleven).

In the ordinary model, agents are shown in rectangles that are positioned in three layers shown in different colours (purple, green and orange). Agents that belong to a subsystem are linked with dotted lines. This model is not complete and relationships between nodes are not shown. By going through the analysis chapters, the model will grow and relationships between agents (child nodes) be revealed. In the analysis chapters, wherever a relationship identified, it is labelled with a specific code. The code is placed in brackets and consists of two letters and one number. For instance, Relationship CW1 links ‘Culture’ and ‘Waste’ in the model. The description of relationships is summarised in a table and is presented in Appendix eight. The construction logistics model will be explained in more detail in Chapter eleven.

7. 3. Logistics and Environmental Factors

Iran is located in a special geographical location with diverse weather conditions. Poor weather conditions, very high or very low temperatures, working in mountains, deserts or islands and dealing with natural disasters, such as storms or earthquakes are issues that should be considered in the construction logistics model. All of these factors plus environmental protection and natural resource conservation are covered under the category of Environmental Factors. This includes (1) Resource Conservation, (2) Project Size and Location, (3) Weather Conditions and Geographical Position, and (4) Construction Peak Working Seasons, which will be described in the following sections.

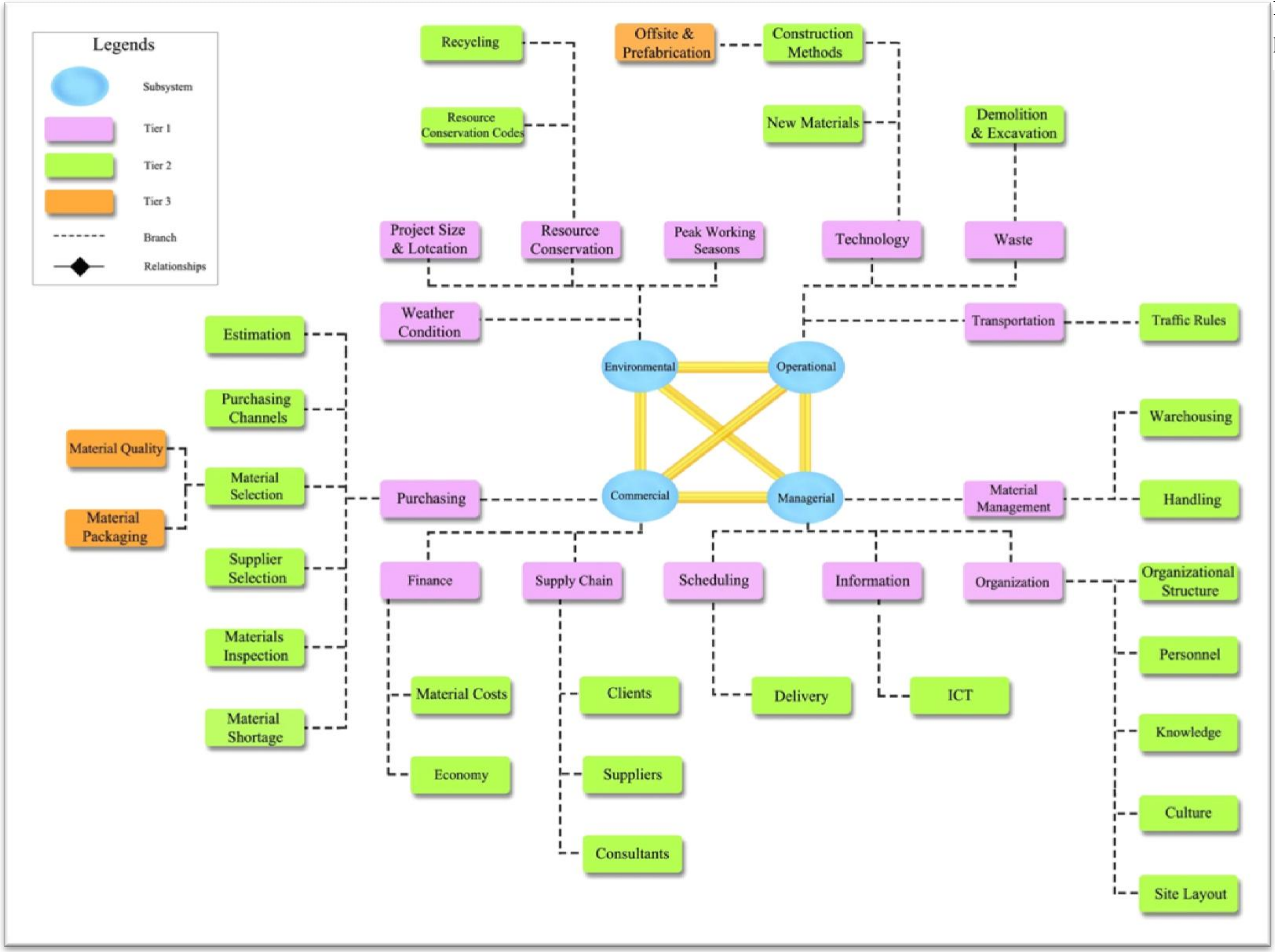


Figure 51: Construction logistics ordinary model

7. 4. Resource Conservation

Most construction materials, such as steel, stone, cement, aggregates, gypsum and brick, are produced from transforming natural resources. Since these resources are not renewable in a short period of time, efficient use of them is critical. Saving and recycling natural resources are two main strategies that should be deployed to deal with dwindling resources. However, construction natural resource conservation has not attracted the attention of the Iranian construction industry so far. This may owe to lack of standards and codes about environmental issues or low price of resources.

From twenty four interviewees, only one directly mentioned resource conservation. C14 explained:

> *"Yes, we are rich in terms of resources and have so many mines. But these are our national wealth and we should protect them. For example our aggregates mostly come from the river beds. We should protect them and pack them properly and bring them to the site with care and acceptable standards to minimise the waste and prevent environmental pollution. If an earthquake occurs in Tehran, there will be piles of construction materials that are not recyclable and this will cause a dramatic environmental pollution".*

Hence, from C14's point of view, resource conservation management has three dimensions: (1) establishing standards for materials and resource conservation practice, (2) using proper packaging, and (3) using recyclable materials.

The first strategy for resource conservation is to establish a code of practice on how to deal with natural resources. This code should include both producers and users. In other words, how materials are produced and how they are used should be considered in the code. The next strategy is to change the way that resources are delivered to the sites. In many cases, material, such as aggregates, bricks, and even cement, are transported to the projects without any packaging (in a loose form). Regardless of the resources' price, because natural resources have a high value from an environmental point of view, proper packaging should be provided for materials produced from natural resources. Proper packaging protects the resources and reduces the risk of damage or wastage (Relationship RP1). One may argue that packaging may increase the amount of debris onsite. To solve this problem, attention should be paid to materials that are used to make bags and boxes to make them reusable or recycle able. For instance, in terms of reuse, Photo 3 shows that, in a construction site in Tehran, bags are reused to deliver debris from floors to the base level.

Photo 3: Reusing material bags for delivering debris outside

The third strategy for resource conservation is to promote recycling. Recycling materials and waste has rarely been done in the Iranian construction sites. Photo 4 shows a poor practice of waste management. Recycling in this condition is not possible because all the materials and debris, such as tiers, cardboards, plastic containers, polystyrene boards, and bags, are mixed together. Using separate containers, such as skips, for different types of waste is a basic solution for this problem. Yet, before using skips, a cultural basis should be built regarding recycling (Relationship RC1) and training should be provided for staff and labourers to recycle materials. Utilising these strategies will decrease the amount of waste produced in a construction project (Relationship RW1).

Photo 4: Unrecyclable materials

7. 5. Project Size and Location

In logistics management, the size and location of the project is important. Working in urban areas, outside cities, and undeveloped regions requires taking a different approach towards logistics management. Large size projects can be differentiated from two perspectives: 1) area to be built and 2) capital required. Figure 52 illustrates the relationships of area, capital and location of construction projects in Iran. Projects with 500 or more units to be built are usually referred to as large projects. These types of projects are large both in terms of the area and the capital. There are also projects that have fewer units, but require large capital. For example, C04 said:

> *"In Fereshte Street [a luxury area in north Tehran] we have a development with 160 units. Each unit costs around £500,000. We also have a project with 1000 units outside of the city. Each unit costs £20,000 to £25,000".*

Logistics planning for each type can be different. In large projects, when several apartment blocks are to be built, a high volume and large numbers of different materials are required. This increases contractors' bargaining ability on price and quality when a particular material is to be ordered. Yet, for large capital projects, this cannot be done, because, in these projects, fewer items are required but the value of them is high. Hence, finance (Relationship PF1), warehousing, and cash flow for each project type will be different.

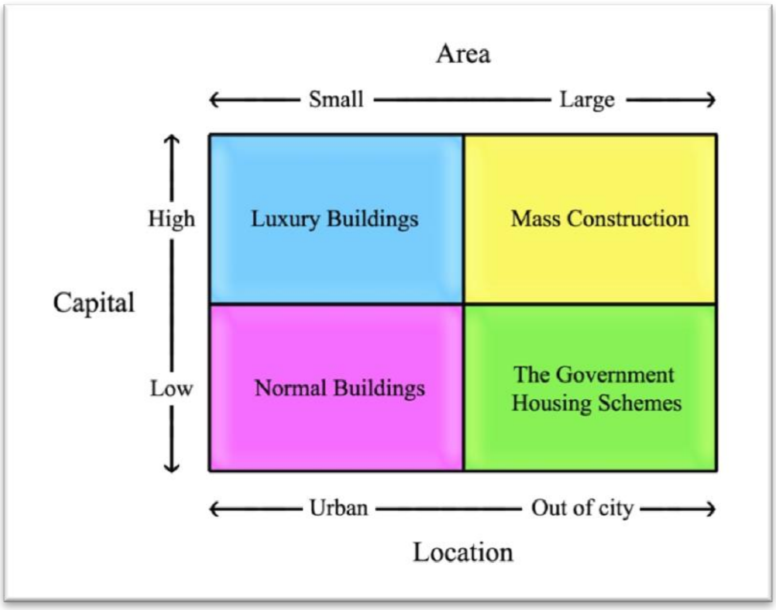


Figure 52: Area, capital and location relationships

In urban projects, and specifically in small sites, storing material onsite is a big issue (Relationship PW1). C07, who worked in an urban project, explained that *"there is not enough space to store material on site. So, we cannot buy materials sooner than one month before usage"*. Beside this, the proportion of land that will be constructed on affects storage space. Usually between 60 to 100 per cent of the land is constructed on and, until finishing the foundation and the first floor, storing materials onsite is problematic. The direction of the land is also important in logistics management for urban projects. Based on urban planning regulations, if the land is located on the north side of the street, the yard will be in front and if the land is on the south, the yard will be at the back (Figure 53). In north-face buildings, materials can be unloaded directly in the yard and stored there to be handled to the points that are needed. Hence, the process of unloading, handling and warehousing is easier. However, in south-face projects, the load should be put in the street for a while and then handled into the building or to the yard for storage. In this situation, loads may block the road and cause heavy traffic. Moreover, extra labour is required to handle the materials from the street into the site for storage and then re-handle them to consumption points. Photo 5 showed the entrance of a south-face construction site in Tehran in which aggregates were stored in the street and blocked the pavement.

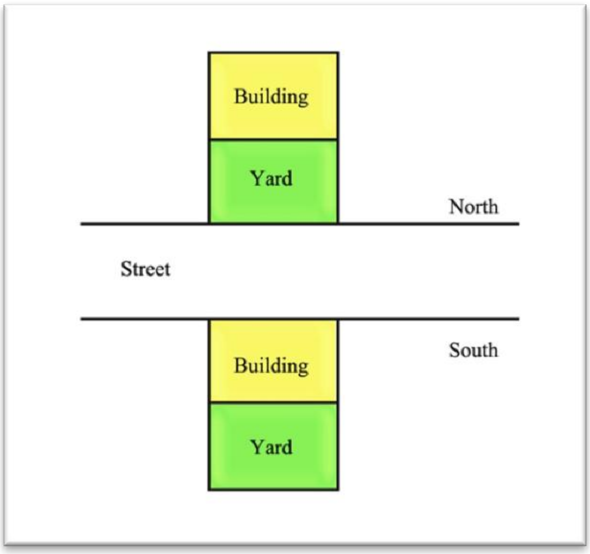


Figure 53: North-faced and south-faced lands in a street

In urban projects, the importance of packaging is higher because there is a limited space available onsite. Proper packaging helps to keep the site tidy and use the space efficiently (Relationship PP1). C01 said:

> *"People who work in urban projects love good packaging because it reduces the cost of labour for unloading materials. Furthermore, in urban projects we should be sensitive towards space and use it logically. But for projects outside of the large cities usually there are lots of spaces to store materials".*

Photo 5: Storing materials in the street in an urban project in Tehran

Another issue in urban projects is transportation of resources to the site (Relationship PT2). In some regions, streets are narrow and steep and this makes movement of construction machines and equipment difficult. C02 mentioned this issue and expressed that *"in urban projects you cannot bring a large lorry into a small street"*. C03 confirmed this and said:

> *"When you work in an urban project which is located in a street with six metres of width, building construction will be hard. For example, excavation will be problematic or you cannot use cranes. But new urban areas have better planning with wide streets and we do not have such problems there".*

Hence, attention should be paid to delivery modes when the project is located in a busy urban area with narrow streets.

In urban projects, extra structural works may be required. Also, the method of excavation, required machines and delivery mode of removed soil may be different (Relationship PE1). C02 said:

> *"Our project is out of the city so we do not have a retaining wall because there is no structure around us. Moreover, we can carry out excavation at*

> *once. But if you work in a city you may have to excavate the soil in two or three stages".*

Availability of resources and services is an important issue that is affected by the location of the projects. C02 explained that *"If I want to construct a facility somewhere, first I will investigate the availability of materials locally"*. Having several suppliers in a region provides a competitive market that eventually leads to a better purchase. Furthermore, using local resources reduces the transportation cost. C01 said:

> *"Transportation costs of materials that are not available locally is so important. For example we have limited numbers of bitumen and asphalt in the country. We have to pay a high price to have bitumen in our sites".*

Shortage of material, such as cement, concrete, steel and bitumen, is a critical problem in some regions (Relationship PL1). C01, who had a similar problem, expressed:

> *"In the east and north-west of the country, cement is available. But in the south there is a shortage of cement and we have to pay a high cost for transportation. Aggregates and gypsum powder are like cement too. Our steel sections should be transported from manufacturers in Isfahan or Ahvaz which are far from our site and this incurs a high cost too".*

In some undeveloped regions of the country and outside of cities there is a shortage of construction facilities and machines (Relationship PL1). C01 expressed:

> *"Availability of construction machines is different from one place to another. In some small cities we do not have concrete factories. We do not have enough numbers of concrete mixers and batching plants. I remember before the earthquake [the city of Bam earthquake on December 26, 2003 in Kerman province-central Iran] we had a project in Bam and we could not find batching plant. So, we had to get concrete from Kerman [200 km distance]. And because that plant was so busy we had to work at night. In addition to high cost of transportation, the quality of the concrete was low because of the long trip. But in medium or large cities we never have these issues".*

In addition to the facility shortage, skill shortage is also an issue in undeveloped regions. N05 said *"in some regions there is a shortage of skilled workers. I mean working skills depends on the geographical position of the project"*.

7. 6. Weather Conditions and Geographical Position

In the time of logistics planning, adverse weather conditions should be considered. In the southern part of the country, specifically in summer, when the temperature rises to 50 degrees centigrade, the site is practically closed because labourers are not able to work effectively and some materials start to melt. In mountains and in cold seasons, the temperature goes below -10 degrees. In this condition, many construction materials, such as concrete, will be frozen and this disrupts the construction process. Thus, variable weather condition and the geographical location of the project affect the logistic schedule and may change materials ordering time and delivery sequence (Relationship WS1).

C01 gave an example about the effect of the weather on construction sites:

> *"We have a project in Khuzestan [which is a hot and humid region in South West of Iran). Working hours in the summer is 2-3 hours per day mostly in the afternoon. But in winter the workload increases sharply. We also have a project in Ardabil [which is a cold city in North West of Iran] and from October to March we should work inside of the building or do not work at all. So, we should balance our resources for different regions in different places".*

N05 also confirmed structural works are not possible in winter in most regions because according to Iran's National Code of Concrete Structures, pouring concrete in temperatures below 5 degrees centigrade is not allowed. Even in the central north of the country, which has a moderate climate, the weather may cause problems. C18 said:

> *"Two years ago we had a very cold winter in Tehran and because the site was located in a mountain area we had to close the site for three months. In -20 degrees no construction work can be done. Of course it was quite exceptional."*

To avoid the negative effects of the adverse weather, firms attempt to achieve weather-tightness as soon as possible. N04 expressed his experience:

> *"We usually complete our projects to a certain level in the summer. So, in winter we do not have concrete jobs or structural works. In winter we cover windows with plastic shields and provide heavy-duty heater to be able to work inside the building".*

7. 7. Construction Peak Working Seasons

It is important for logistics scheduling to know when the construction peak time is in the particular region where the project is located. The peak period may lead to labour and material shortages (Relationship PO1), price increase (Relationship PC1) and low commitment among the supply chain.

C05 expressed that *"the material consumption peak is often in summer. The reason is that the projects usually start in April and in September structural works are finished"*. N04 confirmed this and said *"for example you can buy as much cement as you want in cold seasons even with cheaper price"*. N05 had a different view and said:

> *"There are some problems in relation to the purchasing of main materials [such as cement and steel] in September, October and November. But in June and July there is no serious problem because projects are usually defined in May and site preparation works lasts up to August when the physical work is started".*

Regarding peak times, C09 explained:

"Most people who want to build a steel structure attempt to do the structural works in winter. So, in April they can start building external and internal walls, installing M&Es and isolation. Then, in October, they can do plastering, tiling and carpeting". Figure 54 shows the peak periods that are explained by C05, N05 and C09. It seems that the peak time for building construction is the period between April to November. C13 also confirmed this and said *"demand increases from April and May"*. However, the effect of the weather and geographical position of the projects should be considered, as explained in the previous section. In fact, peak times may be

variable in different regions (Relationship PW2). For instance, in hot areas, the peak time may be in winter. Thus, there is no rule that can be generalised to the whole country.

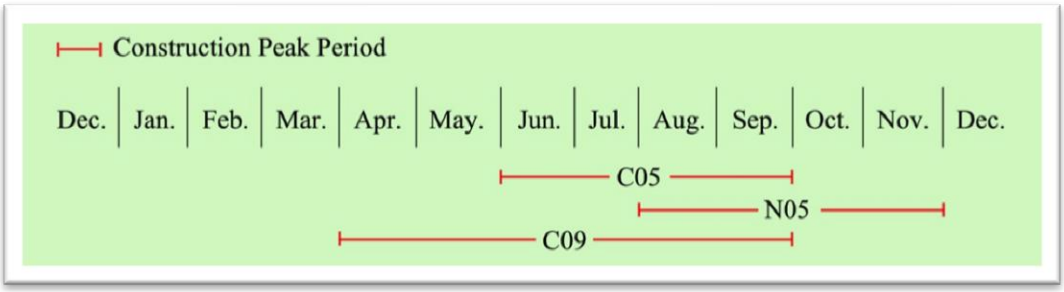


Figure 54: Construction peak period explained by three respondents

In terms of transportation, peak times are more sensitive. For instance, in the time of harvesting agricultural products, finding trucks may be problematic. C05 said:

> *"Sometimes transportation firms substitute construction materials with another product. In spring, specifically in the time of wheat harvesting, we experience transportation problems."*

The peak period should be estimated before starting the project and attention should be paid to it in the schedule (Relationship PS2). Peak periods should be considered in the schedule. It may affect the time of order, transportation or change the sequence of deliveries.

7. 8. Conclusion

This chapter covered the environmental factors that may affect the logistics system. The results attained from the QDA had three steps of open, axial and selective coding. By analysing the qualitative data, the agents associated with Environmental Factors (the first part of the construction logistics model) were identified and relationships were set among agents. The Environmental Factors branch of the model is almost complete. This branch is illustrated in Figure 55. In this model, the relationships between agents are labelled with specific codes which are written in small diamonds. A list of established relationships is provided in Appendix eight which describes the nature of relationships between different agents. In later chapters, more agents and relationships may be added to this branch to make it more mature. Branches will be incorporated into the tetragon part at the end of the analysis which forms the holistic model.

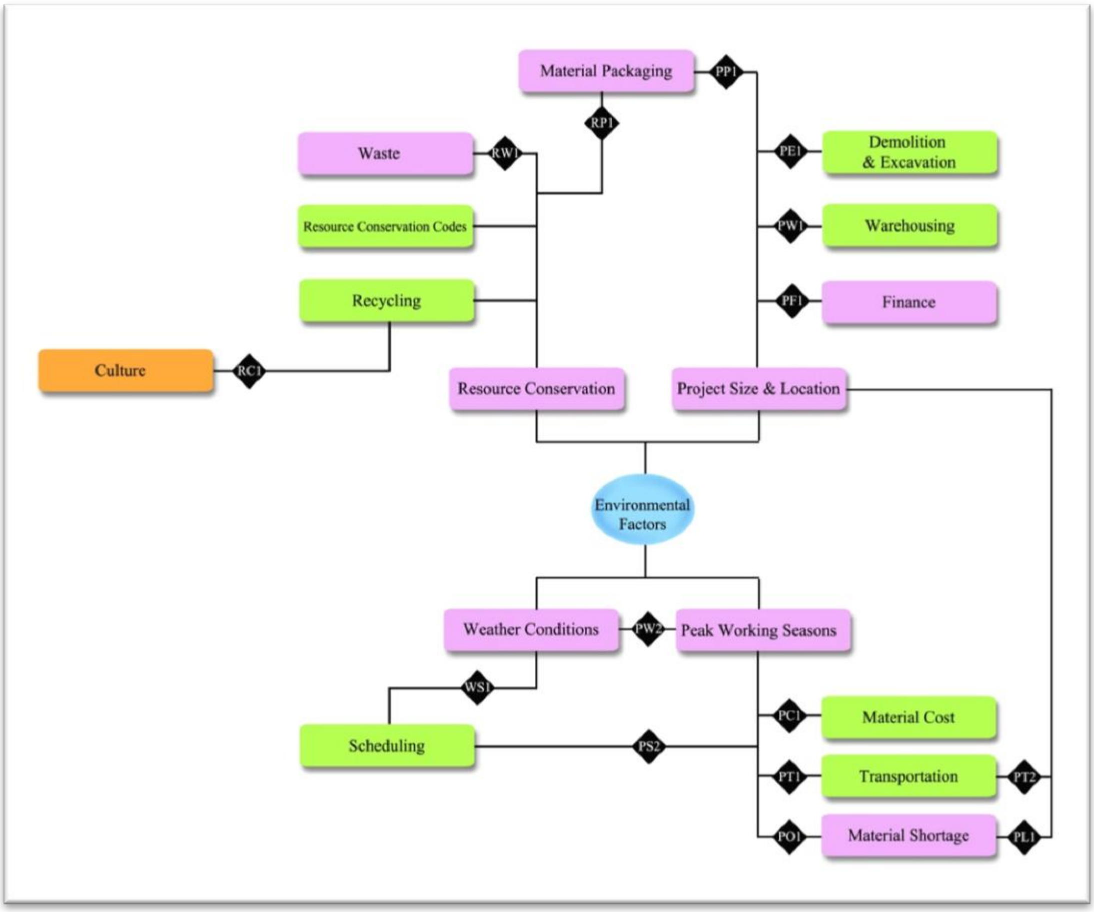


Figure 55: Environmental factors subsystem

Chapter 8

ANALYSIS: OPERATIONAL FACTORS

CHAPTER 8: ANALYSIS-OPERATIONAL FACTORS

8. 1. Overview

This chapter reflects interviewees' comments and opinions about the association of construction logistics and projects' operational factors. The chapter is divided into three sections: technology, transportation and wastage. The technology section focuses on using new construction methods and materials in building projects in Iran. Transportation covers transportation price, transportation mode and traffic matters. In the wastage section, the causes of waste production are explained and several photos are presented to illustrate the real situation.

8. 2. Technology

The technology which is used in construction projects may affect logistics in different ways. C08 summarised the advantage of using new technologies as *"reducing time, reducing the weight, and high durability"* and disadvantages as *"high cost and unfamiliarity of labour with new technology" (Relationship TF1).* In this section, technology is approached from two angles: materials and construction methods. It should be explained that this section only covers the benefits that the new technology can provide from a logistics point of view and other topics such as energy saving and better quality are not considered.

8.2.1. New Materials

Although traditional materials are widely used in building projects in Iran, there is a positive attitude to the new materials. C12 stated:

> *"Currently we use new materials for building walls instead of traditional bricks. [working with bricks was problematic for example] in the unloading time bricks may be broken and wasted ... when they are handled to the storage area they may be broken ... again when we want to lift them to higher floors they may fall and be broken. Working with traditional material increases the amount of waste".*

According to the interviewees' comments (N05, N06, C08, C12, and C16), the advantages of using new materials from the logistics point of view can be summarised as:

- *Light weight:* makes materials easier to be loaded, unloaded and handled without any special equipment (Relationship NH1). Light weight also makes the transportation easier and means large number of materials can be loaded in a vehicle which means fewer deliveries to the site (Relationship NT1).

- *Flexibility:* materials are not broken during transportation, unloading and handling and this reduces the volume of waste generation onsite (Relationship NW1).

- *Packaging:* new materials are often expensive and come in proper packages (Relationship NP1). This leads to having an organised onsite warehouse with materials that can be labelled and identified easily (Relationship NW3).

Some popular new materials that have been used during the recent years are foam (polystyrene) sections, plasterboards, light blocks (Lika) and steel joists. Foam sections are used for building walls and flat roofs (Photos 6 and 7). Their light weight, flexibility and flat shape provide logistical advantages, but they are sensitive to damp, heat and pressure. Hence, special care is required when they are stored (Relationship NW3). Photo 6 shows a roof foam section which was damaged by heat.

Photo 6: Foam roof sections damaged by heat

Photo 7: Foam sections for building walls

Some of new material can have several functions. For example, 'Lika' blocks (Photo 8) while forming the exterior walls of the building, can provide a cavity and insulation as well. C16 clarified *"if we want to use traditional methods, we should put a block, fix the insulation and then put another block. Yet, Lika can do it all at once"*.

Photo 8: A Lika block

Steel joists also provide advantages over traditional joists made from clay or cement. C16 said *"we used to use traditional joists. Yet we recently changed it to steel joists. They are easier to handle and do not get broken in the time of transportation and unloading"* (Relationship NW1).

The main disadvantage of new materials, as C16 mentioned, is the high price (Relationship NM1). Basically, new materials are more expensive than the traditional alternatives. N06 also explained that some clients do not trust the new materials and it takes time to convince them to use new technology. Another issue is the low quality of some new materials. N05 described this in the following:

> *"We use foam sections that are lighter and increase the speed of work. But it does not answer our need because we should fix insulation on it and then plaster it ... another problem is the shortage of skilled workers who are familiar with the new materials"*.

8.2.2. Construction Methods

The choice of construction methods affects logistics in projects. Using a steel structure may require a different logistics strategy in comparison to a concrete structure. For example, the design of site layout may be different in the early stages of construction (Relationship MS1). The logistics strategy also changes according to the construction phase. Each construction phase (excavation, substructure, superstructure and finishing) needs different resources and a different approach to logistics. Another point is the choice between onsite and offsite construction. Much literature recommends offsite construction owing to its speed, low wastage of materials, on time delivery, budget certainty, cleaner site, few labourers onsite and fewer vehicle movements to the site. Most interviewees were aware of benefits of offsite construction. For example, C03 said *"One solution for reducing the amount of waste is to use prefabricated materials and offsite construction"* (Relationship OW1). However, using prefabricated materials and offsite construction is not so popular in the Iranian building industry. C03 explained *"the investors are not keen to use offsite construction. They do not take the risk of something that has not been done before".* C03 believed that: *"offsite construction needs effective transportation that we do not have. Moreover, transportation is so costly".* In addition to special vehicles, prefabricated materials may need special handling equipment (Relationship OW1 and OT1). Yet, C16 commented *"the transportation cost is high but the fast speed of construction can recover it".* As clear, there is an ongoing debate among practitioners about offsite and onsite construction.

For concrete structures, the most important elements are foundation, concrete beams and columns. There are two options for pouring concrete: ready mix and mixing onsite. Ready mix concrete should be delivered to the site on a JIT basis (Relationship OW1). Hence, enough labour should be available to pour concrete and install pumps and pipes. Yet, it is not possible to use ready mix concrete for all structural elements, specifically in small projects. C01 pointed out:

> *"Ready mix concrete cannot be used for building columns because the volume of concrete delivered to the site by the truck mixer is so much larger than what is required and this causes waste (Relationship MW1). So, we have to mix the concrete onsite and this reduces the quality. Yet, for the foundation and roof ready mix concrete is a good option".*

C02 and C14 also mentioned the importance of formwork in concrete structure. Formwork should be delivered to the site ahead and stored in a suitable place with much care (Relationship MW2). Steel rods are another component of concrete structures. They are usually delivered to the site in full size (11-12 metre) and should be cut into the size required. Hence, some parts of the rods are usually wasted. Their long length makes them hard to store. In urban projects, steel rods are stored outside of the land and in the street which may be dangerous for street users (Relationship MW2).

Some interviewees believed that concrete structures are the only option for sites with access difficulties in urban areas (e.g. narrow streets). The reason is that steel structures need a crane to be built up. In small sites, installing a tower crane or a mobile crane is not always possible (Relationship MP1). An important point is that concrete structures take a longer time to be completed. This means that it takes longer to prepare a suitable storage place (Relationship MW2).

Using prefabricated concrete sections is rare and only C12 commented on this method:

> *"We fabricate concrete beams and columns in a factory and deliver them to the site. Only the connections between elements should be done onsite. This method reduces the waste dramatically. For example, when we want to pour concrete for a column with dimension of 40x40 cm using traditional methods because of the movement of the pump, a large volume of concrete is wasted. But with new methods we do not have this problem".*

In steel structures, steel sections are used for building columns and beams. They may be delivered to the site in standard sizes and cut to the required size onsite or fabricated offsite, and erected based on JIT onsite. C01 said *"The choice of offsite and onsite fabrication of steel sections depends on the available space onsite which allows having a small steel workshop or not"*. N03 explained how to choose between offsite and onsite fabrication as:

> *"It depends on the location and type of the building. If the building is located in a good area [high land price] and we want to build a luxury facility we will use fabricated steel sections. If we want to build affordable*

> *houses we will build the sections onsite. The reason is that fabricated sections have the higher price" (Relationship MP1).*

Building steel sections onsite increases the number of deliveries to the site (Relationship MD1) and requires more staff to work at the same time. Furthermore, as N06 mentioned, the quality of construction decreases as welding in the site conditions and high up is difficult and, thus, in many cases, proper connections between two sections cannot be done. C01 pointed out the welding issue:

> *"Many site supervisors do not allow fabrication and welding onsite. They may say the welding does not have standard specifications and should be tested. In steel workshops they have tools to ensure a good quality welding is done".*

He also added *"in onsite fabrication you should deliver the sections, cut them to the size, erect them, weld connections and then cover them with stainless coat. The process is time consuming and hard to do"*.

The benefits of fabricating steel sections offsite is highlighted by N03 and C16. N03 explained that delivery of steel sections is based on JIT (Relationship MD1). He said *"the sections come to the site stage by stage and when they are needed. Thus, space management is easier in the site"*. C16 pointed out:

> *"Unloading loose steel sections is noisy and because it should be done at midnight [owing to traffic regulation] it is very annoying for neighbours ... So, I build the sections offsite [then deliver them to the site] ... and unload them using a crane. The ready column is lifted and unloaded without any disturbing noise".*

In large projects, some other structural elements may be made onsite. N01 and C01 explained it is better to make joists onsite (Photo 9). C01 said *"joists are broken during transportation and in large projects we prefer to build them onsite"*. N01 similarly stated:

"Sometimes if we have enough space we have a workshop for making components. For example, we made joists onsite because we needed large numbers of them and making them onsite is cheaper" (Relationship MP1).

C12 also outlined:

> *"We may have a workshop onsite for making concrete sections ... the formworks are available and we have a batching plant. So, we mix the concrete and pour it in the formwork and then we will send it to a curing room. Then cranes will handle sections to corporate into the building" (Relationship MP1).*

Photo 9: A joist making workshop onsite

It can be concluded that offsite construction is not always the choice of practitioners in Iran because of the high price. They usually carry out trade-offs between transportation cost and price of a ready product on one hand, and labour cost and raw material price, on the other hand. All of this is subject to availability of enough space onsite and the specific deadline for finishing the project. For urban areas, or for projects with tight deadlines, using prefabricated materials is the best choice.

8. 3. Transportation

Transportation is an important part of the construction logistics system and means movement of resources between the source of supply and the construction site. One of the factors that should be considered at the time of material selection is transportation (Relationship TS1). C04 stated *"for different materials I gather information about the price and quality. Then I will search for local suppliers ... transportation is key for us because it incurs so much cost".* C02 also insisted that buying from local suppliers is a priority. He said *"although the transportation facilities are enough, buying from long distance suppliers should be minimised".* The importance of transportation increases when the site is in an undeveloped area (Relationship PT2) or when an item is not found locally. C01 gave an example:

> *"We do not have bitumen factories in all provinces. Transportation of such materials costs us a lot. We have the same problem for cement and gypsum which cannot be locally sourced specifically in the south of the country".*

C03 also elucidated his experience about long distance transportation:

> *"If you have a project in Kish [an island in south of Iran] you should bring the aggregate from Damavand [a city in the north of Iran]. The transportation cost exceeds the price of the product. If you add the value of time to it the price will be very high" (Relationship PT2).*

C01 also expressed the same situation if high quality materials are required:

> *"High quality stone or brick for facade work should be purchased from specific manufacturers. You cannot buy them from the local sources. So, you should expect high transportation costs".*

C10 continued in the similar way: *"transportation limitations force me to use a specific type of material and not the one that has the best quality or cheaper price"* (Relationship TQ1). Another problem of long distances was expressed by C05: *"drivers prefer to carry loads to short distances with maximum earnings and do not go long distances"*.

Road freight is the dominant form of transportation of construction materials. N01 said that, in terms of road infrastructure, the service is acceptable, specifically in developed urban areas. However, C03 believed:

> *"Transportation is time consuming and relatively costly [in Iran] if you consider the value of time. In many cases we have to ignore quality products because of high transportation costs (Relationship TQ1). So, our*

transportation is weak but because the fuel price is cheap it somehow recovers the weaknesses".

The fuel price increase in recent years is a factor that may affect transportation in Iran. Yet, C07 believed the fuel price is still cheap and does not cause serious problems. In addition to the fuel price and distance, factors such as type, height, volume, size, and weight of the load affect the transportation cost (Relationship TF2). C01 and C02 expressed that the transportation cost may be calculated based on the price index, weight/distance or a general quote given by the driver. C15 stated *"the price that transportation companies offer is different in some cases but not by much"*. Usually a cost trade-off is conducted between the material price and the cost of transportation to procure the material with the best value. C05 pointed out an interesting point about the transportation cost:

"The further the distance the more capacity of the vehicle should be increased. The reason is that the cost of both small and large vehicles will be almost equal ... Transportation costs consisted of two parts: the driver's cost and capital ... Each vehicle whether small or large needs a driver and the driver cost is almost the same for both options. The capital has three parts: the fuel cost, depreciation and the vehicle price. Small vehicles burn petrol that is more expensive than diesel burnt by large vehicles. At the end, a vehicle with a capacity of 5 Tonnes compared with a vehicle with a capacity of 10 Tonnes is only 20% cheaper. But the large vehicle capacity is two times more than the small vehicle".

Transportation can be conducted by manufacturer, suppliers or, as C03 and C15 expressed, by a specialised contractor. Some manufacturers have offices in cities to provide a direct service to the customers. C05 confirmed this and said *"when the customer buys from the manufacturer directly he can get a discount [no commission for the distributer] and he saves money in handling and transportation"*. This works if the load is delivered to the site directly and the contractor can save money by avoiding double handling and double transportation. Yet, sometimes the manufacturer stores products in a warehouse close to the city centre and then delivers the products to the site from that warehouse. This may change the situation, as C04 pointed out:

> *"The manufacturers that store materials outside the cities charge us for the warehouse, handling and transportation costs. In fact we have to pay extra for double transportation and storage".*

C02, although mentioning the extra cost, explained *"[buying directly from the manufacturer] has benefits too. In this way you do not have to deal with poor weather conditions, road blockages, and shortages of vehicle".*

The loads can be transported by specialised contractors. C14 stated:

> *"The relationship with these contractors should be managed properly. There should be clear terms and conditions in the contract. In the case of any issue, a strong contract enables us to prosecute any contract violation".*

C12 described the difficulties of dealing with transportation contractors:

> *"The main problem is that the transportation contractors do not have any responsibility towards delivery time. For example, a driver should carry a load from Tehran to Mahshahr [1000 km]. Sometimes it takes one week or ten days ... the driver does not even answer his mobile phone ... another problem is that the drivers are not competent enough and accidents happen".*

The commonly used modes of transportation are vans, trucks and trailers. C16 explained *"[the mode of transport] depends to the site location and traffic conditions".* C05 commented: *"the transportation mode depends on the volume of materials that should be transported. Trucks have the capacity of 6 to 10 Tonnes and trailers can carry up to 24 Tonnes".*

N03, C02 and C18 mentioned the transportation mode in narrow streets and busy urban areas (Relationship PT2). C02 stated:

"A large truck cannot go through a narrow street ... you have to use vans. Thus, the cost increases. For example, it is not possible to deliver a full length steel section to the site and you have to cut it into three metres pieces and deliver it to the site".

8.3.1. Traffic Regulations

Traffic regulations in urban areas are critical in transportation of construction materials (Relationship TD1). The travel time for heavy vehicles is the first limit enforced by the police and highlighted by N04 and C02. C02 said: *"movement of heavy vehicle is prohibited between 6am to 10pm. Often unloading time is around 12pm to 1am".* He continued:

"Time management is so critical ... If we could not finish the job before 5am we have to pay the vehicle fee for one more day because after 6am it cannot move in the city ... So, we should provide enough workers to unload the materials timely. We should also consider the weather condition that may disrupt our work".

C15 and N04 mentioned other traffic regulations, such as road limitation and size consideration. C15 stated:

> *"Loads that are so tall, so wide or so heavy need special consideration. These types of loads must be transported at night and should go through the specific roads that are determined by the police. So, the police should be informed about the load and the time it should be transported. Sometimes the heavy vehicle should be escorted".*

N03 and N04 explained that there is also regulation for mobile cranes. N04 said *"crane regulations depend on the site location"*. N03 added:

> *"The crane operator should get a licence from the police to work in a specific day, time and area. If the site is located in a busy street the licence is usually issued for Thursdays and Fridays [weekends]. For quite areas if we control traffic we can work during the week."*

Violating the traffic regulation may cause serious problems for the project. N04 explicated his experience: *"It happens several times that the load is seized because the driver breached the law".*

In Chapter three, the project location, capacity, allowed delivery hours, and delivery slots were covered as factors affecting transportation and delivery. All of these were factors identified in this section and a new factor introduced as traffic regulation. Hence, the findings of this section support available literature.

8. 4. Wastage

In general, construction waste includes unwanted, damaged, and leftover materials or components. The amount of material wastage in the Iranian building projects is very large. Most interviewees, such as C01, C02, C04, C03, and C15, confirmed this. Photos 10 to 15 illustrate materials, such as insulation, foam, wiring, pipes, wood, gypsum, tiles, stone, bricks, blocks, steel sections, steel rods, aggregates, cement, and concrete, that are wasted in different projects.

Some interviewees provided an estimated figure for the amount of material waste. C02 explained *"normally we have 5 to 10% material waste"*, and C03 said *"there is about 10 to 15% of material waste onsite"*. However, as seen in Photos 10 to 15, the waste proportion should be more than the figures C02 and C03 mentioned. N06 confirmed that *"about one fourth of construction materials will be wasted"*. C02, C04, and C15 gave more detailed numbers for material waste. C04 stated *"there is a standard figure for each material that shows its allowed wastage percentage. For example, 2% of wastage is standard"*. C15 pointed out the standard percentage of waste for some materials: *"for cement 5%, steel rods 3%, steel sections 4-5%, gravel 10%, sand 15%, and gypsum 5-10%"*.

Question 9.1 in the questionnaire asked respondents about the amount of waste in building projects. Figure 56 shows that more than 26% of respondents believe the amount of waste produced is standard, while less than 4% mentioned that the waste production volume is less than standard. Yet, around 60% of respondents explained that the amount of waste generation is high or very high in building project. Hence, the figure provided by N06 (25%) is closer to reality.

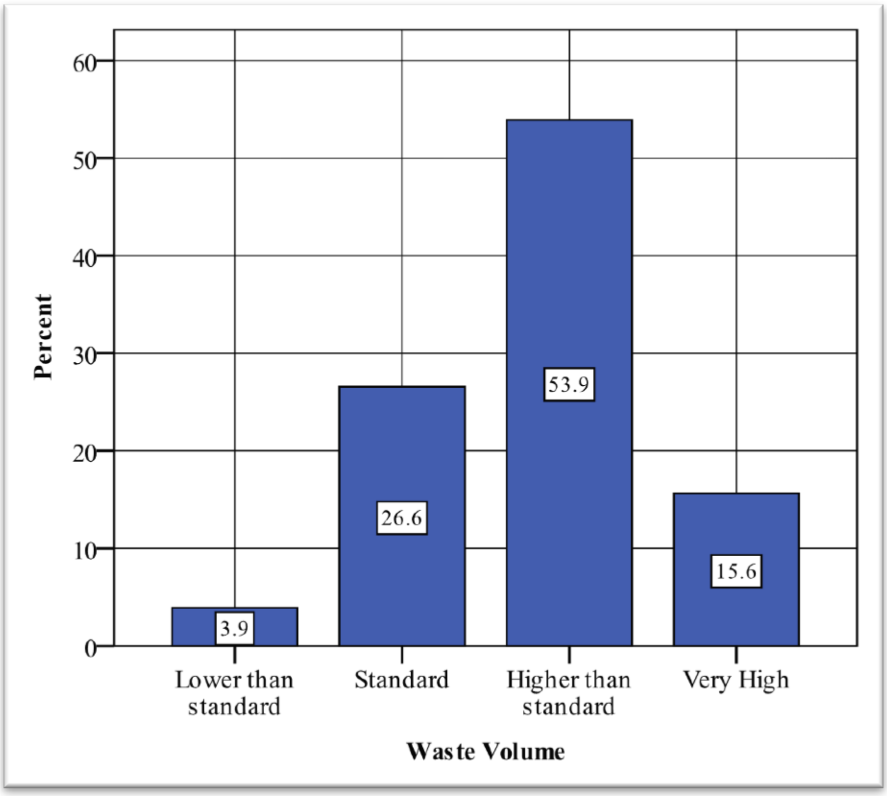


Figure 56: Approximate evaluation of waste production in building projects

There are several issues onsite that lead to waste production. C02, C07 and C18 said a large amount of waste is due to the poor loading and transportation. C04 and C12, also, emphasised the role of poor handling in generating waste (Relationship WH1). C12 stated *"[for example] some bricks are broken because of poor unloading. Some others are broken during horizontal or vertical handling"*. Poor storage is also a cause of waste (Photo 10). N01 said *"in many construction projects you can see that materials that are sensitive to damp are left without protection. Or concrete is poured on the ground (Photo 11) ... similarly steel sections (Photo 12) and glass"* (Relationship WW1). C07 confirmed that poor storage leads to material wastage and expressed *"we have to buy materials six months ahead of when they are needed to minimise inflation impact. This affects the quality of materials. For example, steel rods become damaged by corrosion"*.

Photo 10: Poor storage of stone

Photo 11: Mixing concrete on floor

Photo 12: Steel sections waste

Poor packaging is a factor mentioned by C02 and C04. C02 said *"a large proportion of loose materials [without packaging] is wasted"* (Relationship WP1). C04 pointed out poor packaging and gave an example *"tiles and ceramics come to the site in packages. However, the quality of packaging is poor. The packages will be damaged after two or three times of handling"*.

Some interviewees believed one reason for a large wastage amount is that construction materials are relatively cheap in Iran (Relationship WM1). C03 said:

> *"There is no motivation for reducing wastage because materials are cheap. If materials were expensive, we would be motivated to use them in the best way ... For example, one pack of gypsum powder or sand is cheap [and waste volume is large for these materials] but tiles are expensive and we have to use them efficiently. The more expensive the product, the more attention will be paid to it".*

C08 commented on the low price of materials and its association to waste production: *"in some cases contractors order more materials than what they require because the price is low. This increases wastage".* C09 expressed the role of poor quality material in waste production: *"[for example] when the quality is poor, in the time of unloading, some bricks become powder and cannot be used any more"* (Relationship WQ1).

Cultural matters can also affect waste production (Relationship CW1). C03 confirmed this and added *"maybe we waste our materials because we have rich natural resources. So, we do not think about how to use them properly"*. C18, also, stated:

> *"Subcontractors and workers produce so much waste. They do not have a sense of responsibility [because they do not pay for materials]. For example, a subcontractor opens a gypsum powder bag. If you do not supervise them they will leave leftover gypsum on the ground and waste it ... We should put so much effort onsite to avoid the mixing of different materials with each other"* (Photo 13, 14 and 15).

Lack of training about managing and minimising waste is an important point explained by N01: *"contractors have no training about site tidiness and you can see disorder and mess onsite".* In addition, C12 and C18 believed traditional methods of construction produce much waste.

Photo 13: Wasted gypsum powder

Photo 14: Leftover cement that is mixed with sand

Photo 15: Debris onsite

In comparison to the causes of waste explained by Dainty and Brooke (2004) (cited in Chapter three), only one factor is common which is poor storage and handling of materials. The reason is that construction logistics, as explained above, is a context dependent subject that varies from one country to another.

To rank the causes of waste based on their importance, the survey respondents were asked to score causes from one to ten. Table 14 shows the average score for each cause. Cultural matters and workers' unawareness have the highest scores. This is interestingly aligned with one of the weaknesses of the Iranian culture pointed out in Chapter four. As elucidated in that chapter, Iranians do not accept responsibility, because they do not want to be accountable. Project managers' unawareness and the low price of the materials have the lowest scores. Wrong loading and unloading methods, low quality of the materials, and materials storage and re-handling have similar scores and their importance is high. Attention should be paid to causes ranked one to five to reduce the amount of wastage onsite.

Table 14: Ranking of waste production causes based on their importance

Rank	Causes of Waste Production	Average Score
1	Cultural Matters	7.41
2	Workers' Unawareness	7.38
3	Wrong Loading & Unloading Methods	6.88
4	Low Quality of the Materials	6.86
5	Materials Storage & Re-handling	6.86
6	Poor Packaging	6.59
7	Traditional Construction Methods	6.48
8	Project Managers' Unawareness	5.87
9	Low Price of the Materials	4.60

8.4.1. Demolition and Excavation

Demolition and excavation generate much waste which is sent to a landfill (Relationship ET1). Some materials, such as bricks and steel sections, can be reused after demolition (Relationship ER1). N03 said:

> *"I demolished an old building with very thick walls ... around 55 to 60 centimetres thickness. At the end of project, I only bought 200 blocks and the old bricks were nearly enough for the new building".*

Some other materials, such as door and window frames, can be sold. The demolition subcontractors usually take materials, such as steel sections, aluminium sections, and door and window frames, and demolish the old building for free. N03 described this in the following:

> *"The subcontractor evaluates the existing building ... for example the old building has 20 Tonnes of steel and 20 Tonnes of door and window frames. The subcontractor evaluates the value of these and also gives a price for the demolition works. Usually these two figures are equal but sometimes the contractor should pay extra to the subcontractor".*

After demolition, the soil should be removed for laying the foundation (Photo 16). The earth excavation and site grading involves movement of heavy machines that should be planned properly. N05 explained an important point about excavation *"there should be coordination between the number of lorries and the excavator's capacity"*. N03 described the way excavation cost is calculated:

"The calculation is based on cubic metres of soil that should be excavated. The provision of the machines is done by the excavation subcontractor. The subcontractor is also responsible for carrying the removed soil to the landfill ... If during the excavation the subcontractor reaches a rock or an old foundation an extra cost should be paid based on an agreement between the contractor and the subcontractor ... If the dimensions of the old foundation is more than 70x70 centimetres much attention is required in the time of loading the lorries, because the foundation is heavy and may damage the vehicle".

Photo 16: Excavation

C07 expressed an issue about the excavation: *"one of the problems is that excavators cannot work in day time because the municipality does not give permission to them. So, the excavator should work at night and that is disturbing for the neighbours".*

8. 5. Conclusion

In this chapter, first, the positive effects of using new materials and methods on construction logistics were discussed. It was stated that the choice of construction method affects different aspects of construction logistics, such as site layout, storage spaces, and delivery options. New construction materials make the process of handling, transportation and storage easier. Yet, they may need more care and attention when they are handled and stored. Second, transportation, as an important agent of the construction logistics system, was described. Factors affecting transportation costs, such as fuel price, distance, type, height, volume, size, and weight of the load, were introduced. Moreover, traffic regulations that affect the movement of heavy vehicles in urban areas were highlighted. Third, it was shown that the amount of waste production in building projects in Iran is very high. Moreover, causes of waste generation were identified and ranked in the order of cultural matters, workers' unawareness, wrong loading and unloading methods, low quality of materials, and poor material storage. Finally, a brief description of demolition and excavation was explained. Based on the relationships identified in this chapter, the operational subsystem of the construction logistics system is visualised in Figure 57. The final model will be described in Chapter eleven.

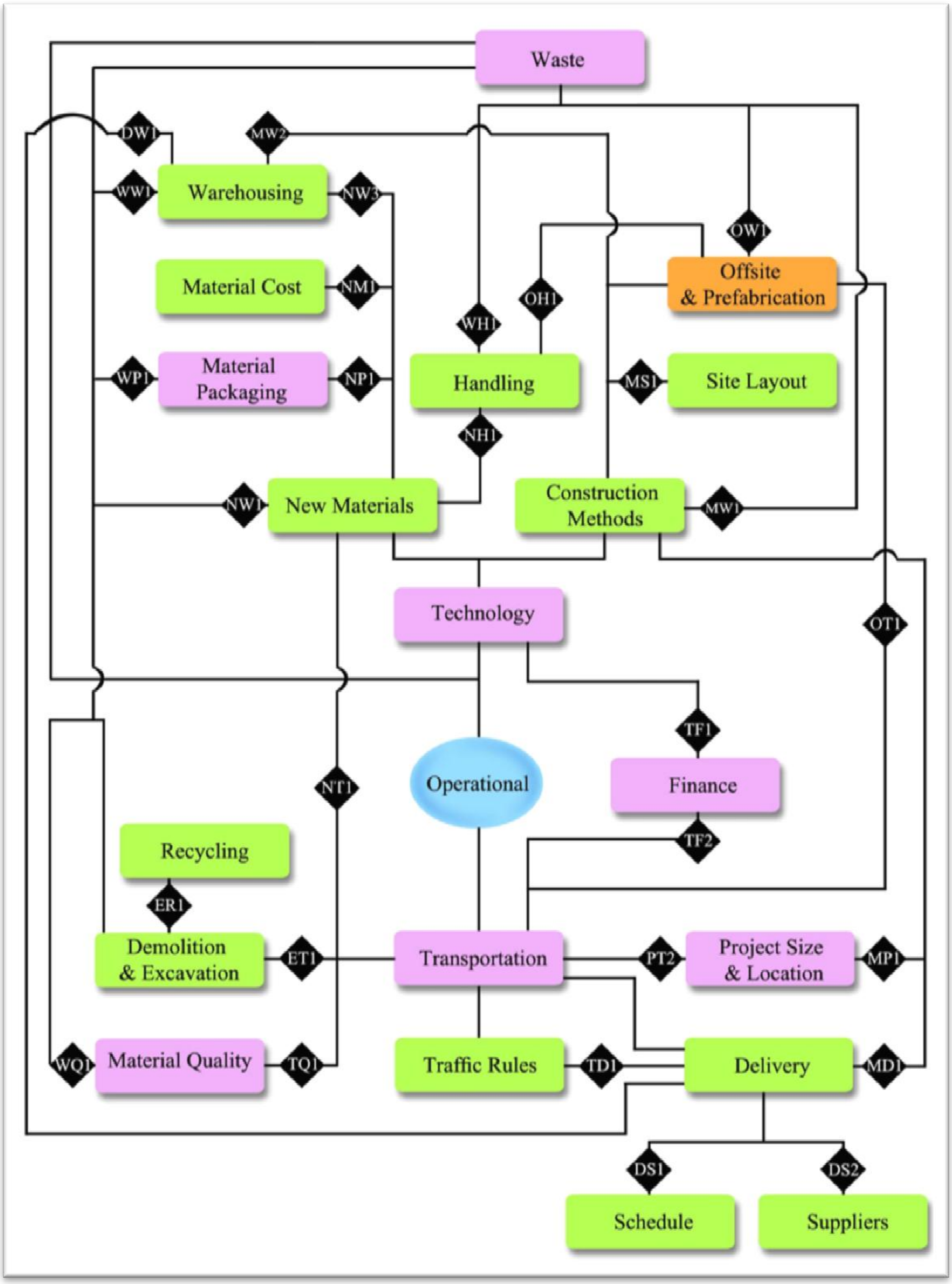


Figure 57: Operational factors subsystem

Chapter 9

ANALYSIS: COMMERCIAL FACTORS

CHAPTER 9: ANALYSIS-COMMERCIAL FACTORS

9. 1. Overview

Trading and acquiring resources for construction projects is a part of the construction logistics system. This chapter investigates commercial factors affecting construction logistics. The chapter is divided into three parts (Figure 58). In the first part, the role of the three main supply chain members in construction logistics will be explained. This part looks at the ways clients, consultants and suppliers affect the construction logistics system. The second part focuses on purchasing matters. It describes the purchasing process and covers subjects, such as material selection, supplier selection and material shortage. The third part explores financial matters from the construction logistics view point. The role of financial sources will be described and the effects of recession and inflation on construction logistics will be discussed. At the end of each section, a diagram will be presented that reflects the complex network of relationships between different agents of the subsystems.

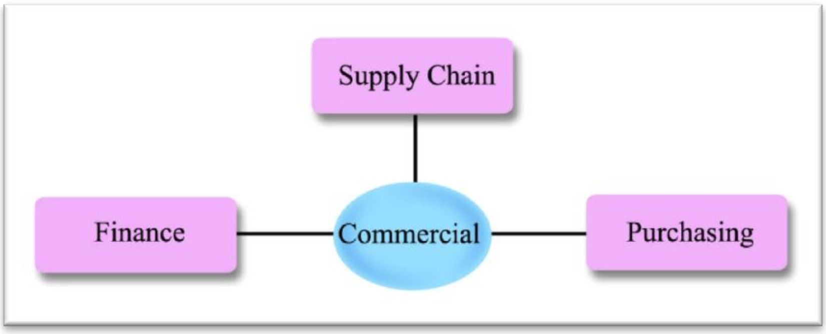


Figure 58: General view of commercial subsystem of the construction logistics system

9. 2. Supply Chain

The construction site is the meeting point of different parties involved in the project. This section aims to explain the role of the three main parties, which are clients, consultants and suppliers, in construction logistics and study their relationships with contractors from the logistics point of view. The formal relationship between the contractors and other parties is through a contract. The contract affects directly different construction logistics aspects, such as purchasing, material selection, site mobilisation, material delivery, material scheduling, finance, logistics organisation, and construction methods. C07 stated:

> *"[To choose a logistics strategy] our relationship as a contractor with other parties should be defined. ... The dominant form of contract has three agents: client, consultant and contractor. Yet, we are moving away from a three agents system towards two agents (client and contractor) and four agents (client, consultant, contractor, and project management)".*

The importance of the contract was also pointed out by N02: *"In our company it takes so long to sign a contract with a firm. We do this to avoid any conflicts in the future"*. To find out the dominant form of contract, question 5.1 was allocated to this topic in the questionnaire. Figure 59 shows the popularity of contract forms. As C07 mentioned, the most popular form is the traditional method (three agents). A square metre priced system, design and built, and a fee based system are frequently used, while management contracting and in-house contracts are less popular.

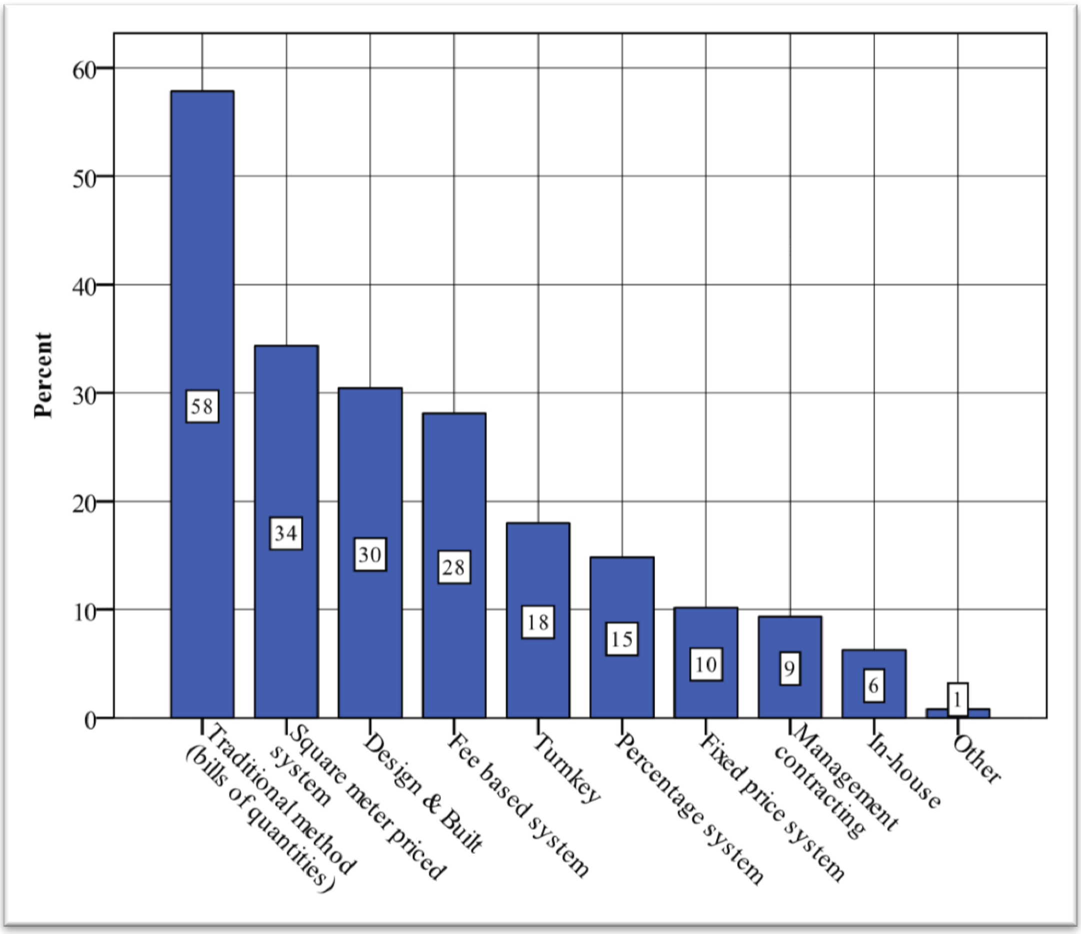


Figure 59: Popularity of contract forms in the Iranian building industry

9.2.1. Clients

Clients have an important role in construction logistics because they define a project and pay its costs (Relationship LF1). C07 said *“the client should confirm all bills of quantities. After that he will pay the fees”*. Clients are, also, the main source of decision making. C18 said *“we have a group of clients that only pay the cost and only supervise the work generally. Yet, some clients get involved in the project directly”*. Both groups can influence the projects and the decisions they make affect the logistical affairs. C03 stated *“for some clients quality is very important and they prefer to use prefabricated steel sections instead of cutting and welding onsite”* (Relationship LM1 and LQ1). C18 confirmed this and said *“clients may also change the sequence of construction tasks”*. Also, in some cases, clients may ask for a specific type of material (Relationship LS2). C12 explained *“sometimes the client give us a list of materials and ask us to purchase from that list. He may provide us with a specific code for purchasing tiles”*.

Changing decisions by clients during the course of the projects is an issue raised by several interviewees, such as C06, C09, and C18. C18 said *“changes after completion of the work damage the building’s cosmetics. It happens that we have to change or fix a section several times”*. C06 also expressed:

> *“Changing project objectives by clients affects the work process because you sign a contract with a subcontractor. When changes happen you should terminate the previous contract and find a new subcontractor and supplier to do the job”*.

9.2.2. Consultants

Some interviewees, such as N02, N04, and C16, explained that consultants are influential in construction logistics because they often decide about material choices and construction methods (Relationship NS1 and NM2). C16 confirmed the role of consultants in construction logistics and said *“there should be coordination between contractors and consultants on choosing suitable materials”*. An area that consultants can contribute to in managing construction logistics is to use standard sized components when they are designing the project. N02 made this point clear *“[when your project needs 1000 doors] you should standardise their dimensions in the design stage. All doors should have equal dimensions. Otherwise I cannot order* *all of doors from one single manufacturer".* Standardised materials can be ordered in bulk to get discounts (Relationship NF1). Moreover, it reduces the variety of materials delivered to the site, which leads to improvement in storage practice onsite (Relationship NW2). The SFfC (2005) report also pointed out the role of the consultants in construction logistics and recommended their early involvement in preparing the logistics plan.

9.2.3. Suppliers

Suppliers, as materials providers, have an important role in construction logistics. The way contractors establish relationships with the suppliers is critical. C06 expressed *"we try to have meetings with suppliers ... and establish a friendly and continuous relationship with them"*. He continued:

> *"[The way we establish relationships] depends on the professional and social level of supplier, the person that we are in contact with, the initial location where we first met, recommendations of colleagues, and our previous working experience with them".*

Cultural matters should be considered when a contractor is trying to establish a relationship with suppliers (Relationship CS1). The positive points in the Iranian culture that can help to have an effective relationship with suppliers are collectivism and the ability to produce joy and excitement. The negative points that may prevent parties establishing close relationships are team-working inability and jealousy (these factors are explained in Chapter four).

Much of the literature, such as Virhoef and Koskela (2000), Cox *et al.* (2006), and Benton and McHenry (2010), recommends having long-term relationships with suppliers. The benefits of establishing long-term relationships were also pointed out by several interviewees. The benefits include payment instalment, purchasing using credit, purchasing via phone, receiving special discount, service priority and getting help to deal with unanticipated issues (e.g. material shortage). N03 said:

> *"When you have a good relationship with suppliers they will support you if any unexpected issue happens. For example, when you are in instant need of a material the supplier sends it to you immediately".*

C02 and C07 pointed out the financial benefits of establishing effective relationships with suppliers (Relationship SF1). C02 gave an example:

> *"If the cement price is £2 per bag and suddenly the price goes up to £3 [in a long-term relationship] you can still buy cement at £2. But if the price goes down to £1 again you should pay £2. So, it is a mutual relationship".*

C06 also stated: *"we keep a good relationship with suppliers. So, when they get our requisition they will give it priority and review it rapidly"*.

Some interviewees believed that a long-term relationship is not so critical. C04 said:

> *"In today's economic conditions [recession] a long-term relationship is not important. For example, our company entered into a partnership with a heating radiator manufacturer. They gave us a 12% discount. But another manufacturer comes to us and offers a 15% discount. So, this partnership is not profitable for us".*

To distinguish respondents' approaches towards relationship length with suppliers, question 3.2 in the questionnaire was allocated to this topic. The result is presented in Figure 60.

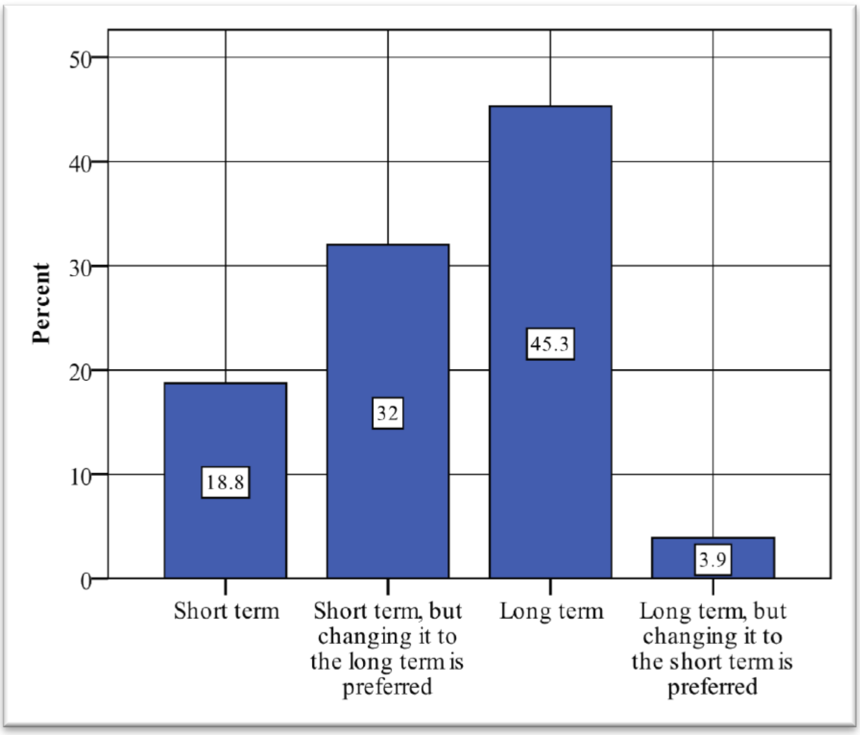


Figure 60: Respondents' preferences towards the length of relationship with suppliers

More than 45% of respondents expressed that they are keen to have long-term relationships with suppliers, while 32% said they wanted to change the mode of their relationships to long-term. Only 18.8% stated that they usually have short-term relationships with suppliers.

There are two problems that endanger the relationship of contractors and suppliers: low commitment of suppliers and turbulent economic conditions. Several interviewees explained that, in some cases, suppliers are not committed to providing materials on time or at the quality expected. N03 made the point clear by an example:

> *"Yesterday I asked a supplier to send two lorries of sand to my project and emphasised that I am in urgent need. This morning at seven I was here and he did not send them. I called him and he said his cousin had been involved in an accident and he was busy with him. What should I do? If I order now from another supplier I will get sand at 4pm at the soonest because the lorries are not allowed to enter the urban area until 4pm".*

C04 provided a solution to minimise the effect of suppliers' low commitment:

> *"Fortunately there is a variety of suppliers and manufacturers ... so, why should you buy from one supplier? In a competitive market like this, you can buy materials from three different suppliers. In the case of having problems with any of them you still have two suppliers that meet your needs".*

C01 and C06 believed the economic conditions affect the behaviour of the suppliers (Relationship SE1). C06 stated: *"[when the economy is down] suppliers do everything to sell their products because they have downstream relationships. They should keep those relationships. So, they reduce their profit to sell their products".*

N05 described the condition if the economy is booming:

> *"We bought cement at a certain price. After that [because of high demand] the price of cement increased. The supplier asked us to pay the fee rise and was not committed to the contract. Owing to the fact that we were in immediate need and the difficult prosecution process we could not make a complaint about this situation".*

Based on the analysis and relationship identified in this section, Figure 61 has been produced. It shows the relationships of supply chain agents with other agents of the construction logistics system.

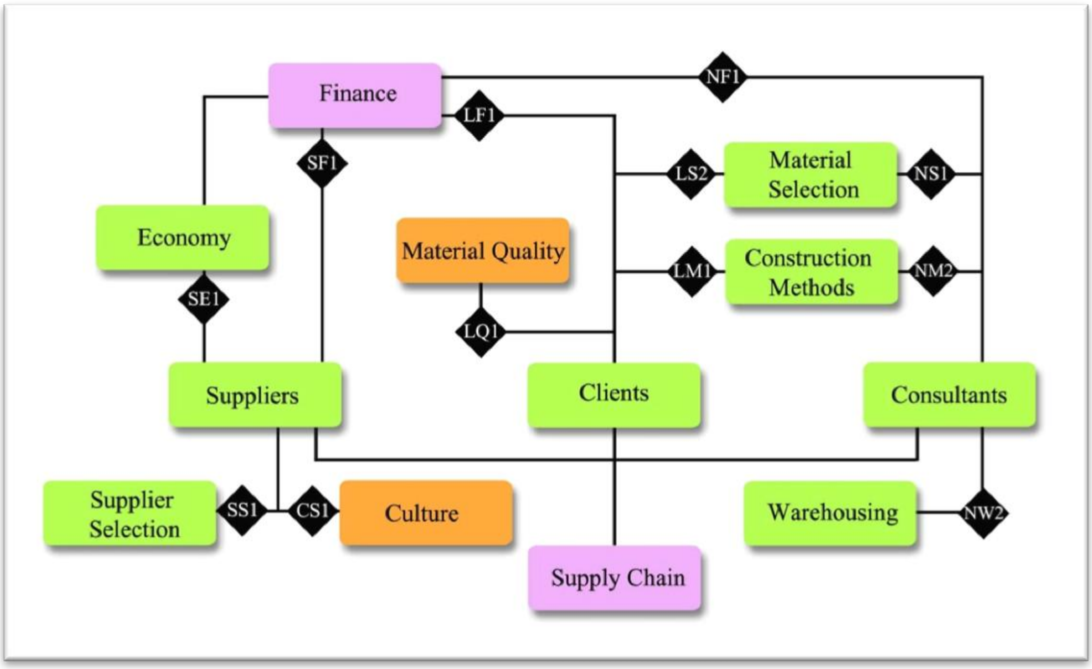


Figure 61: Supply Chain agents of the construction logistics system

9. 3. Material Purchasing

Acquiring materials for the projects is a challenging task in the Iranian building sector. This section explores purchasing as an agent of the logistics system. First, the general purchasing process is discussed, and then more detailed information is provided about the different stages of purchasing.

9.3.1. Purchasing Process

As clear in Figure 62, the process of purchasing usually starts with a need for a specific material in the project. C11 said *"as construction is a project based business, the starting point of the purchasing process is the project"*. The construction materials can be purchased from suppliers, agents or directly from manufacturers. The volume of the material that will be bought depends on the construction stage, availability of cash and availability of space for onsite storage (Relationship PF3 and PW5).

The purchasing process also depends on the size of the project (Relationship PP3). In small projects, usually the site supervisor, based on his previous experience, estimates the volume of required materials and buys them. Orders can be made by phone and the bill will be sent via fax when the quantity of the material is low. For large quantities, a formal contract may be signed. When the onsite stored materials go below a certain level, the construction manager will be informed by the foreman to buy more (Relationship PW5). Although this method is not accurate and sometimes causes problems, owing to indifferences and late deliveries, it has been widely used in small projects. Firms involved in small projects are often small and medium enterprises (SMEs) and usually buy materials from local suppliers, because, in this way, they can save transportation costs.

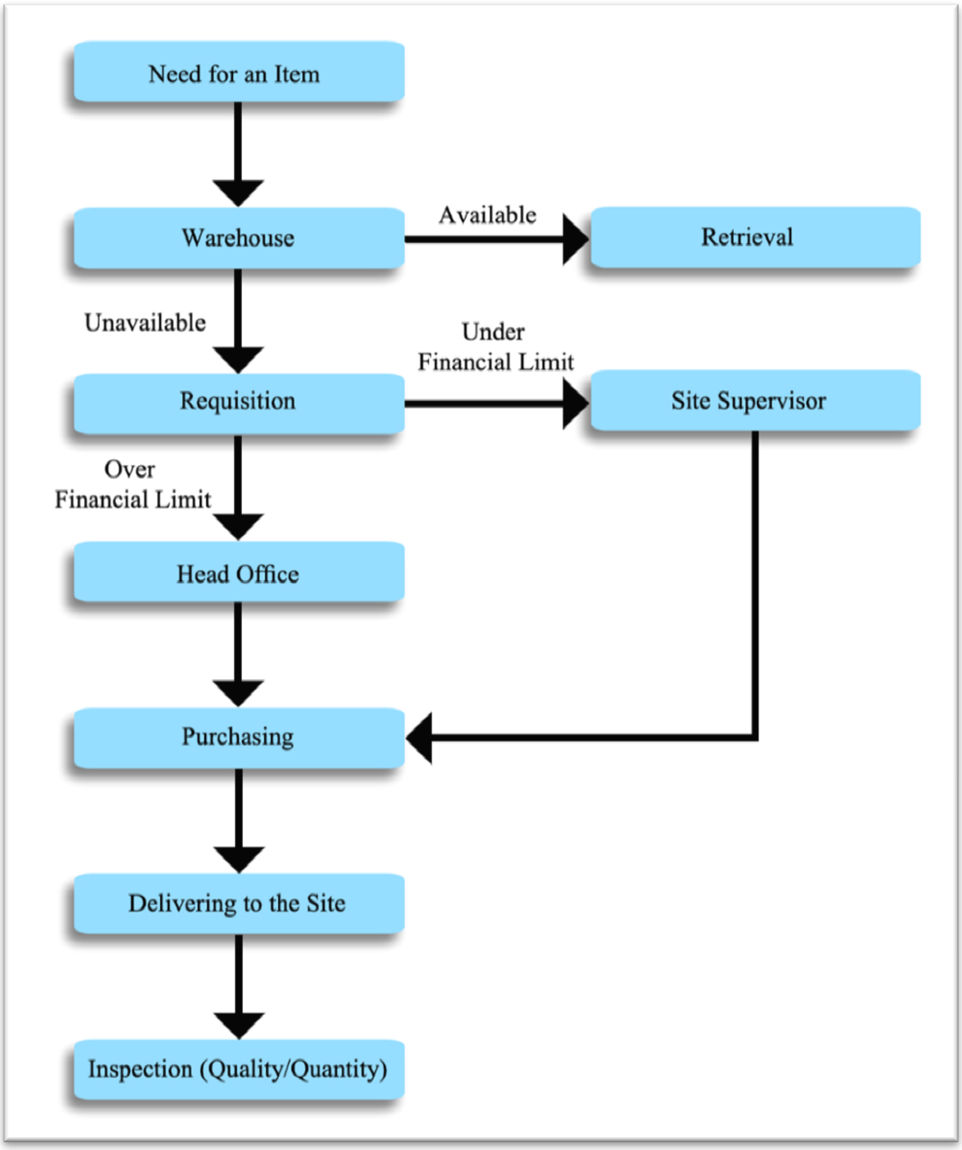


Figure 62: The purchasing process

In medium and large projects the process is more complicated. In these projects, purchasing is carried out based on the schedule that is mostly developed by the Critical Path Method (CPM) (Relationship PS7). When the architectural drawings and structural design are completed, the volume of required material in each phase will be estimated. The site supervisor, considering the drawings and the schedule, will ask for purchasing materials by filling in the relevant forms.

Purchasing can be conducted directly by the site staff (site supervisor) or by the head office. C11 illuminated *"we have a code for purchasing. The site supervisor should make material requisitions. Then decisions should be made on whether to buy material directly or send requisitions to the head office"*. C12 explained *"ordering expensive materials or ordering in bulk is often done by the head office"*. N06 also said *"materials with a heavy financial load should be bought by the head office but materials with lower financial loads can be purchased by the site staff"*. C07 expressed:

> *"If the onsite staff have the knowledge about the required material they can purchase it directly. Yet, if a special component, such as an air conditioning, should be bought, professional staff in the head office should undertake purchasing"*.

If the materials are to be bought by the head office, the site supervisor should fill in the material requisition forms (Figure 62). C18 elucidated:

> *"The subcontractors should tell us what they require ahead of time. We check the warehouse and if the material is available, it will be given to the subcontractor. Otherwise, we calculate the amount of required material and prepare a material requisition"*.

The requisitions should be sent to the head office to be confirmed by the Project Control Unit (PCU). This unit is responsible for verifying and matching the volume of required material against the schedule and the work progress. C11 described the next step:

> *"If the head office is to procure materials, there will be two possibilities. If the required material is available in the central warehouse or in other*

> *projects, we will deliver it from one site to the other. If the material is not available, it should be purchased from the market".*

After PCU confirmation, the buyer coordinator should gather quotes from different suppliers. Based on the price, delivery time, transportation cost, technical specifications, quality and payment instalments, a supplier will be chosen to provide the project with the required material. C04, C06, C08, C12, C15 and C18 explained that, for purchasing materials, price quotations should be attained. C06 said *"when we receive the materials requisition, we start gathering quotes from suppliers based on market condition, the volume of required materials and their financial load"*. C18 also stated *"we usually gather quotes from three or four suppliers and choose the best offer"*. C08 added *"the technical office gives us quantities and specifications of needed items. Then based on that information we start getting quotes"*. N05 pointed out *"for the State projects a tender should be carried out to gather quotes"*. C15 described the process of getting quotes:

> *"The buyer coordinator contacts suppliers in our vendor list. He asks about the availability, price, and the time that the supplier can deliver the item to the site. Based on the quotations gathered, the buyer coordinator should prepare a report that should include prices, quality, payment instalment, delivery time, and payment privilege. According to this report the head office will select the best supplier who can meet our needs".*

Getting quotes is often done via phone or written application. However, ICT makes the process easier and faster (Relationship PT4). C04 made this clear in the following:

> *"We send an email to the suppliers and asked for the price and other considerations. They will reply with pre-contract documents. When we confirm and sign the document, the payment will be made. Finally, they will send us the materials. We do not even go out of our office".*

The site supervisor will be informed when the purchase is conducted. C15 said *"the site supervisor should be informed about the purchase and delivery time to prepare suitable storage space for the coming materials"* (Relationship PW5).

9.3.2. Estimation

Estimation is an important issue that affects purchasing. In fact, purchasing is carried out based on information provided through estimation. When the architectural and structural drawings are ready, the amount of materials required should be estimated. C04 said *"the estimation gives us information about type, quantities, and price of different materials"*. C09 explained *"the first thing I do is to determine the technical specification, type, and quantity of the materials required. Then attention should be paid to quality"*.

Estimation involves taking out measurements and dimensions from the plans, calculating volumes and areas, and pricing different items. The results are usually presented in several tables. ICT is helpful in estimating and increases the speed of preparation and the accuracy of estimation (Relationship TE1). N01 explained *"software accurately calculates even the numbers of bolts and nuts"*. Different software is available in the market for estimating, such as MS Excel. C11 and C16 expressed that they use more developed software for estimating. C11 described the way estimation software works:

> *"Detailed information about type, quantity and price unit of materials should be inputted into the software manually. Then the software produces different estimation reports such as an estimation brief which includes the total cost of the project".*

Some interviewees explained that there is another method of estimation that gives a rough approximation of the materials required. This method is developed based on the experience of practitioners and is not accurate. However, it can provide a general idea about the total amount of materials required. C13 made this clear:

> *"For example, 40 kilograms of steel rods are required per square metre. So, for a 2000 square metre building around 80 Tonnes of steel rods is needed. If you presume that ten per cent will be wasted (Relationship EW1) the final figure for steel rods will be approximately 90 Tonnes. [Another example] each square metre needs 100 kilograms of cement and 80 kilograms of gypsum powder. Or for each five square metres, one cubic metre of concrete is needed. After finishing two or three projects you can estimate these figures ... [the accuracy range is around £25 per square metre] so, if you estimate*

> *the cost of a building is £250 per square metre, the tolerance will be £225 to £275".*

The main problem that endangers estimated figures is inflation (Relationship EC1). If the inflation rate is high, the required materials cannot be purchased at the estimated prices. This may put the project in financial difficulties. C04 gives an example *"last year [2008] the price of steel rose from £0.20 [per kilogram] to £0.65 [per kilogram]. So, we had to pay three times more than the estimation for purchasing steel".*

9.3.3. Material Selection

To construct a building, thousands of different types of materials and components should be purchased. For each material, there are a variety of choices with different specifications and properties. Hence, choosing the right materials is challenging in all projects. What matters most is that the selected materials should meet the client's expectations and ensure the functionality of the facility in its working period. To select the most suitable materials, attention should be paid to the quality and packaging of materials, while considering the overall budget assigned for buying each material.

In terms of selecting and purchasing, N05 believed there are two types of materials:

> *"One type is items that are listed in the Price Indexes such as concrete and steel sections [usually determined by the technical office] and another type is selected based on matter of taste such as tiles and taps [may be determined by the client]".*

C01 highlighted the role of clients in material selection (Relationship LS2):

> *"In one of our projects in Bam [a city in Kerman province-Southern Iran], although bricks are produced in Bam, the client asked us to buy bricks from Esfahan [a city in Central Iran 900km away from Bam]. It was just matter of taste".*

For structural, mechanical and electrical components, as C06 explained, the project's technical office is responsible for preparing a report about the specification of the materials required (Relationship MM1). C04 gave an example *"when we want to buy* *stone, we determine the type, name, specification and even the place that the stone is mined"*.

Information about the specification and properties of materials can be found in books, manuals or manufacturers' catalogues (Relationship MI1). Information may be accessible in published or electronic forms. C14 stated *"we use databases and websites to gather information about products"* (Relationship MI2). Some interviewees explained that material selection should not only rely on information provided by the manufacturers and suppliers and that more investigation may be required. C11 made this clear:

> *"When we have a huge project we should evaluate materials. Although our information resources are not enough and we do not have robust standards to rely on, we are able to investigate materials and select materials at a price and quality that are desirable".*

Factors affecting material selection decisions were described by several interviewees. For example, C01 elucidated:

> *"The recession we have experienced [since 2008] changes the views towards material selection (Relationship ME1). In the current situation, the clients are looking for cheaper materials while keep the functionality and quality. Since, they cannot sell houses at previous prices [prices drop]. [Another factor] was the establishment of 2800 Code-version three about earthquakes that was very sensitive to the buildings' weight. So, contractors started to use light materials such as foam sections to reduce the total weight of the building and comply with the 2800 Code (Relationship MN1). Using new technologies is important (Relationship MT1). For example, instead of using cast iron pipes, other types of piping have been used in recent years because they are more convenient to work with. Or new heating and cooling system are used that eliminate the need for ducts and canals".*

In summary, factors affecting material selection decisions are price, quality, technical regulations, new technology, new materials and packaging. In the next section, material quality and material packaging, which are cited more than other factors by interviewees, will be covered.

9.3.3.1. Material Quality

In the material selection stage, enough attention should be paid to quality. The word 'quality' does not mean the best product available, but an attribute that meets the expectations of the client and the project objectives. The importance of choosing quality material was mentioned by many interviewees, such as N02, C03, C06, C08, C10, and C15. C10 said *"in my project I consider quality and price equally"*. C09 also explained:

> *"Basically an engineer [contractor] should be sensitive to economic issues and budget in projects but he must not sacrifice quality, since quality is an actor that affects the whole life cycle of the building".*

If the quality of the materials does not meet the expected level of standard, many problems may happen during the course of the project or later in the usage period. Demolishing, material reordering and redoing the job are a few consequences of using low quality materials in projects that waste time and incur extra cost.

To ensure that quality materials will be ordered, enough information about specifications, properties, expected quality and brands of materials should be provided (Relationship MI3). C06 made this point clear:

> *"[when we want to purchase materials], we determine the brand as well as the technical specification. For example, we do not just say that we need size-14 steel section. We say this section from that company"*

Some interviewees expressed that, in addition to determining the exact specification of materials, samples should also be collected. C04 said:

> *"For example, we want to buy stone. The stone we want has first, second and third class. We asked the supplier to provide us with samples from each class. So, we can check the quality and also we can compare the main load with the samples and if any differences are noticed we can reject the load".*

C10 also explained that *"I take samples and evaluate them. For example, I take window profile samples from different manufacturers and compare them to find the best quality"*.

One tool to ensure the quality of materials is standards that are provided by manufacturers or the Institute of Standards and Industrial Research of Iran (ISIRI). C01 stated *"for steel sections we usually accept the manufacturers' standard. Except in sensitive cases, we do not test them again"*. ISIRI is an organisation that develops and designates official standards for products and also endorses compulsory standards. However, this institute has not developed standards for all construction materials. C02 said *"a serious problem in Iran is the lack of standards for some construction materials"*. C11 added *"for some materials we do not have standards at all. Even those materials that are standard do not meet our expectation in many cases"*. C10 commented:

> *"Although all materials should get a standard certificate from ISIRI, practically it does not happen. So, different manufacturers produce a variety of materials that in many cases do not meet international standards. This is mainly owing to corruption".*

The situation is worse for imported construction materials as there is no robust mechanism for checking the quality of these products. C06 expressed:

> *"We try to avoid buying Chinese products. Yet, low quality Chinese electrical and mechanical components saturate the market. Even for professionals it is so hard to distinguish between a Chinese product and a high quality German product".*

N01 and C10 explained that even sensitive structural elements that are imported have low quality. N10 said *"the steel sections imported from Russia and Kazakhstan do not have high quality and do not comply with international standards"*. It is a serious issue because it endangers the safety of the building users. N05 added:

> *"When you put a Chinese steel section and an Iranian steel section beside each other [similar size] you can notice that the Chinese one is thinner. When you weigh them, the Iranian steel section is around 570kg but the Chinese one is 280 to 290kg".*

9.3.3.2. Material Packaging

Packaging has different roles, such as providing information for the customer and establishing brand image. However, its main role is to protect a product. Packaging provides a container for items, groups small items together, and makes transportation, warehousing and handling easier. Despite the high importance of packaging, enough attention has not paid to it in the Iranian construction industry. N06 and C03 expressed that the majority of materials are delivered to sites loosely. N06 said *"90 to 95 per cent of masonry materials do not have any packaging"*. However, C14 believed *"in recent years we have seen advancements in materials packaging. Yet, more effort should be made. For example, cement comes in packs but aggregates do not"*.

Many interviewees pointed out the benefits of packaging. C14 said *"packaging is vital for construction materials. Without packaging, waste increases, quality decreases and standards fall"* (Relationship WP1). N03, C04, C03, and C13 mentioned the role of packaging in reducing waste and providing easier transportation (Relationship WP1 and PT5). C03 said *"packaging reduces waste and increases transportation and handling speed"* (Relationship MH1). N05 also commented on the benefits of packaging: *"it makes transportation easier, provides a more organised working space (Relationship PS8 and PW6), reduces the amount of dust and pollution onsite, and minimises the volume of waste"*.

C01, C02, and C14 emphasised that delivering materials in loose form increases the rate of waste generation, because a large proportion of materials gets damaged during transportation, unloading, handling and the warehousing process (Relationship WP1). C02 explained his experience about joists:

> *"Many loose joists became broken during transportation and handling. Also, the joists should be handled one-by-one and that takes a long time. So, we decided to buy packed joists. Each set of 25 joists are fastened together properly and come to the site on pallets. We unload them easily and handle 25 of them with a wheelbarrow".*

In urban projects, owing to space limitations, selecting materials with standard packaging is more critical (Relationship PP1). C16 gave an example about cement:

> *"For a small project I choose packed cement because we do not have space for a silo (Relationship PW6). Wastage is high in loose cement and it also*

> *makes the site dirty. Moreover, unloading and handling of packed cement is easier. We can also order the exact amount we need".*

N03 expressed *"loose cement is cheaper but enough space should be available to install a silo and allow the movement of trucks"*. C01 also said:

> *"In large cities packaging is more popular. The reason is that there is not enough space onsite to store materials loosely (Relationship PW6). Yet, when you get further from the cities, you have a large space to store loose materials".*

C15 made clear why in large projects loose cement is preferred:

> *"In large projects loose cement is used, while for small projects packed cement is used. For a batching plant it is better to buy loose cement because it is easier to store loose cement in silos".*

C01 explained another reason for buying loose cement:

"In 90 per cent of our projects cement is delivered loosely and stored in silos. [The reason is that] cement with proper packaging is expensive and costs around 20 per cent more than the loose form (Relationship PC2)".

However, C01 appreciated the benefits of packaging and added: *"it should be considered that around 20 per cent of loose cement is usually wasted. So, the price of packed cement is not too high"*. Some interviewees believed that packaging is not required for all types of materials. C01 gave an example:

> *"For traditional bricks packaging is not important because we can use even broken bricks. But for blocks that may be broken during transportation and handling, packaging is important because the broken blocks cannot be used".*

Interviewees, such as N01, pointed out that packaging also depends on the material price (Relationship PC2). C01 stated *"high value materials should necessarily come in proper packaging"*. C03 added "*luxury items such as stone, taps and tiles have standard packages"*. C01 confirmed the relationship between material cost and packaging and said:

> *"It is not worth it to pack all materials. For example, tiles can be delivered to the site with or without packaging. We consider the value of tiles. For cementious tiles [which are cheap] it does not matter if 5 per cent become wasted. So, it does not require packaging because packaging may increase the cost by 10 to 15 per cent. Yet, if you want to buy first class tiles they should be delivered in standard packs (Photo 17). Another example is joists' bases. They do not have high value and it is not worth it to pack them"* (Photo 18).

Use of pallets (Photo 19) is also criticised by C05 and C16. C16 explained *"we reject the idea of pallets because it needs special equipment such as a lift truck or crane to unload pallets. Having this equipment incurs extra cost"* (Relationship PH1 and PF4). C05 added:

> *"Pallets are useful only when unloading equipment such as a lift truck is available onsite. Furthermore, there is no mechanism for collecting pallets from the sites and returning them to the suppliers".*

Another problem in terms of packaging is that the quality of the packaging is low. C09 stated *"owing to poor quality packaging, a large proportion of tiles coming to the site are damaged"*. Photo 20 illustrates the poor packaging of pavement tiles. C04 also commented on the quality of packaging in the following:

> *"The quality of packaging is not high ... For example, tiles come to the site in packs. Yet, the quality of packaging is poor and after two or three times of handling the package will be damaged".*

Photo 17: Tiles in standard packaging

Photo 18: Poor quality packaging of joists' bases

Photo 19: Use of pallets for packing materials

Photo 20: Poor quality packaging of pavement tiles

In some cases, poor packaging can damage the materials. For example, in Photo 21 foam roof sections are damaged by the straps used to fasten them together.

Photo 21: Straps damage the foam floor sections

Packaging may also have negative sides. One problem is that it increases the amount of debris onsite (Relationship WP1). Hence, extra time and labour is required to collect and dispose of packaging waste. The environmental impact of materials used for making packages is also critical (Relationship RP1). C05 expressed:

> *"Some packaging materials are dangerous for the environment. For example, propylene bags that are used for gypsum powder packaging cannot be recycled in the environment. The best option is paper bags that are very expensive".*

To solve the two above issues, and also to reduce packaging cost, a few manufacturers collect undamaged packs from sites for reuse. C15 highlighted this in the following:

> *"Some materials such as concrete admixtures have quality packaging. So, in some cases, if they are not damaged, we can sell them to the manufacturer to use them again".*

9.3.4. Supplier Selection

Selecting a competent supplier to procure materials is key in construction logistics. Supplier selection may be based on the previous experience of working together (Relationship SS1), recommendations by colleagues or by arranging a tender. C02 described the process:

> *"We look for suppliers to procure the different materials we need. Some of them come to the site and give us marketing stuff. In some cases we are familiar with the suppliers and have worked with each other before. In your first project it is too difficult to know all the suppliers and manufacturers that sell you materials. But, you will become experienced after three or four projects".*

C04 gave an example about how to select material manufacturers:

> *"We identify ten manufacturers for a specific material. We evaluate their documents, their products, their record, their advantages, their disadvantages, and their distance to the site. From those ten, we select three to get quotes".*

One useful technique for selecting suppliers efficiently and keeping a long-term relationship with them is to develop a vendor list. In this list, suppliers are ranked based on the service provided previously. Selecting a supplier from the vendor list can minimise the risk of indifference, having low quality material, and delivering wrong quantities to the site. The procurement officers usually select the first three to five suppliers from the list to get quotations. C17 stated *"for both material suppliers and service providers you should have a list and evaluate their performance"*. C06 added *"we have a vendor list that is being updated continuously during the year. We may add or delete suppliers from the list"*.

Question 5.2 in the questionnaire aims to understand to what extent the Iranian building practitioners use a vendor list to purchase their needed materials. The result (Figure 63) shows that around 73% of respondents have a vendor list and use it frequently to purchase materials. Yet, they also consider alternatives and, as C06 mentioned, update the list continuously. Figure 63 also shows that more than 10% of respondents do not have a vendor list, while more than 12% strictly select suppliers from the vendor list.

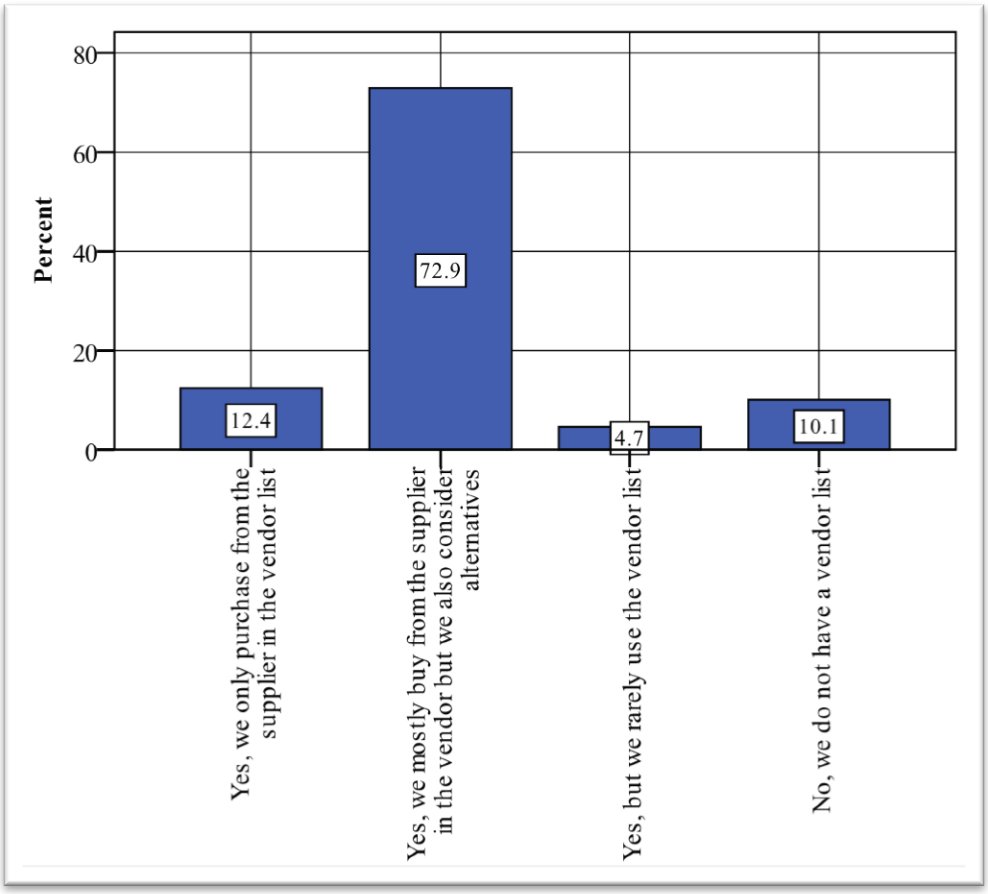


Figure 63: Extent to which the practitioners develop and use vendor list for selecting suppliers

An important subject in developing a vendor list is to set some criteria to add or delete suppliers from the list. C15 expressed his view in the following:

> *"We select suppliers according to different criteria. We assign a score for each criterion. For example, quality is 20, price is 20, delivery time is 20, and honesty is 10. Then we add up the score of each supplier and if they get more than 70 we will work with them [add them to the list]".*

C18 pointed out criteria, such as quality (Relationship SQ1), price (Relationship SC1), payment privilege, and long term relationship (Relationship SS1). C06 also highlighted commitment (Relationship SS1), quality, delivery speed, distance to the site (Relationship SL1), and long-term relationship as criteria for developing a vendor list. The criteria identified in this chapter are almost the same as those expressed by Benton and McHenry (2010) (Chapter three). Yet, two new criteria are introduced which are the supplier's distance to the site and the continuing long-term relationship. To rank criteria according to their importance, question 5.2 was dedicated to this topic in the questionnaire. The result is depicted in Figure 64.

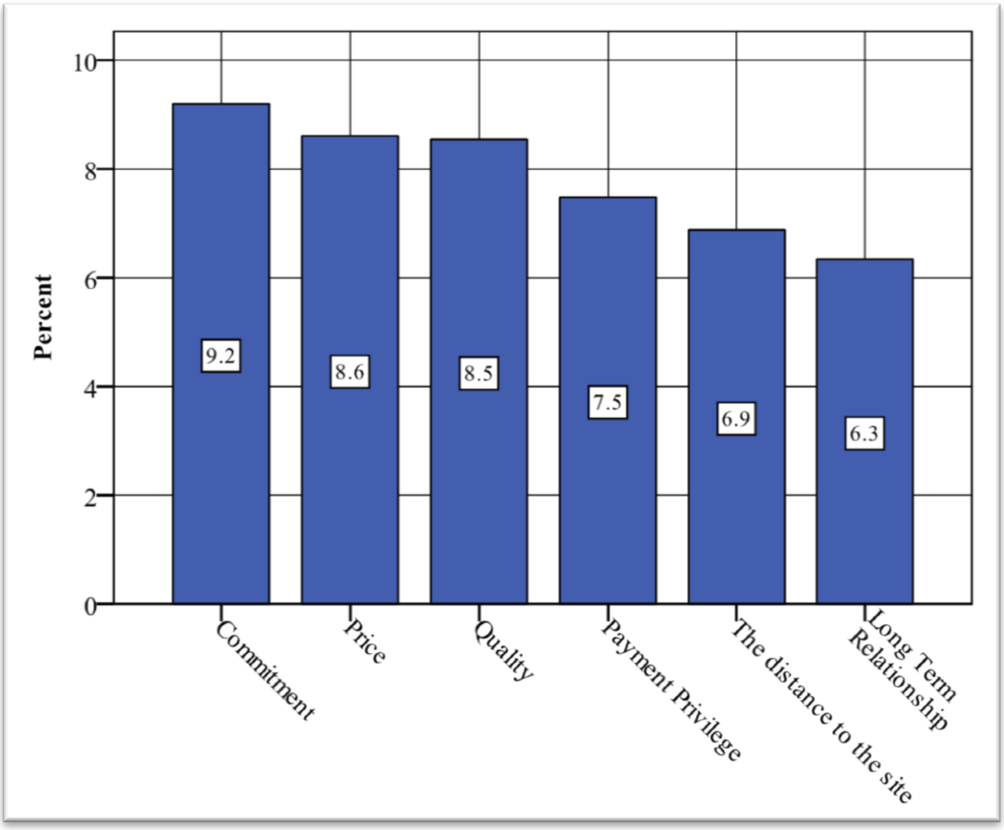


Figure 64: The rank of criteria used to develop a vendor list

As illustrated in Figure 64, commitment has the highest score among all the criteria. This is aligned with the analysis provided in section 9.2.3 of this chapter which discussed the contractors' concern about suppliers' commitment. Other important criteria, as was expected, are price and quality which have almost the same score of 8.5 (Figure 64). The distance of suppliers to the site and long-term relationship are criteria that have lower scores in comparison with the others. Payment privilege, with a score of 7.5, is also a factor that may affect the vendor list for purchasing a material.

9.3.5. Purchasing Channels

Popular purchasing channels, as mentioned by the interviewees, are: retailers, agents, manufacturers, and mercantile exchange. N03, C02, C05, C06, C08, and C12 elucidated that selecting channels highly depends on the amount and volume of materials required. For small volumes, usually retailers and suppliers are selected, while for large volumes and bulk ordering, manufacturers are the better choice (Relationship CS2). C06 gave an example: *"if we need one truck of sand, we will buy it from a local retailer. But if we need 50000 cubic metres of sand we will buy from a manufacturer"*.

C02 and C03 explained that buying from manufacturers is often beneficial because they usually offer a lower price in comparison to the retailers and agents (Relationship CC). C02 clarified this in the following:

> *"The closer to the source of supply, the lower price can be got. For example, the manufacturer sells tiles to an agent with three per cent interest. The agent sells the tiles to a retailer with five per cent interest. Finally, in some cases the real customer should buy the product at 25% more than the manufacturer price".*

Purchasing from the manufacturers is not always possible. C02 expressed *"if the amount of the order is less than a certain value, the manufacturers do not sell their product to you and direct you to their agents"*. Another problem is that the manufacturers do not offer payment privilege (Relationship CF). C18 made this point clear:

> *"The manufacturers only accept cash. Payment instalment and purchasing by credit is not possible when you deal with manufacturers. But the retailers usually offer payment privilege because we have a long-term relationship with them".*

Another purchasing channel which was explained by C16 is the Iran Mercantile Exchange (IME). C16 said *“some [contractors] purchase materials such as steel from the mercantile exchange. For large volumes, it is beneficial”*. This channel was not covered by other interviewees. One reason is that the first commodity exchange was established in 2007 (IME, 2009) and is still unknown for many experts. The main benefit of the mercantile exchange, as expressed by IME (2009), is having an organised, superviseable, transparent, fair, and competitive market.

To find out the frequently used purchasing channels, question 3.3 was dedicated to this subject in the questionnaire. Table 15 and Figure 65 illustrate the popularity of four purchasing channels for 18 different materials. Figure 65 shows that, for most materials except concrete, bricks and blocks, aggregates, prefabricated joists, doors and windows, manufacturers’ agents are the main source of procuring materials. For these six items, the most popular channel is the manufacturers. The materials that are purchased from the retailers are paint, bitumen, stone, aggregates, gypsum powder, bricks and blocks. As expected, the mercantile exchange is not considered as a main source for any item. However, between 10 to 20 per cent of respondents expressed that commodity exchange is a source for procuring steel, bitumen and cement.

Table 15: Purchasing channels classification for each material

Materials/Components	Retailers		Manufacturer's Agents		Iran Mercantile Exchange		Manufacturer	
Steel	28	21%	79	59%	20	15%	38	28%
Concrete	15	11%	42	31%	0	0%	80	59%
Cement	22	16%	72	53%	10	7%	68	50%
Gypsum Powder	45	33%	67	50%	3	2%	42	31%
Bricks & Blocks	40	30%	47	35%	5	4%	66	49%
Aggregates	42	31%	27	20%	3	2%	77	57%
Prefabricated Joists	26	19%	23	17%	3	2%	79	59%
Stone	42	31%	57	42%	5	4%	48	36%
Tiles	28	21%	90	67%	4	3%	27	20%
Plaster & Cement Board	25	19%	77	57%	2	1%	36	27%
Pipes	28	21%	86	64%	5	4%	35	26%
Mechanical Components	18	13%	97	72%	5	4%	40	30%
Electrical Components	32	24%	91	67%	5	4%	30	22%
Taps & Sanitary Services	37	27%	93	69%	4	3%	20	15%
Bitumen	43	32%	63	47%	12	9%	32	24%
Doors	28	21%	58	43%	4	3%	68	50%
Windows	22	16%	52	39%	2	1%	72	53%
Paint	53	39%	73	54%	3	2%	32	24%

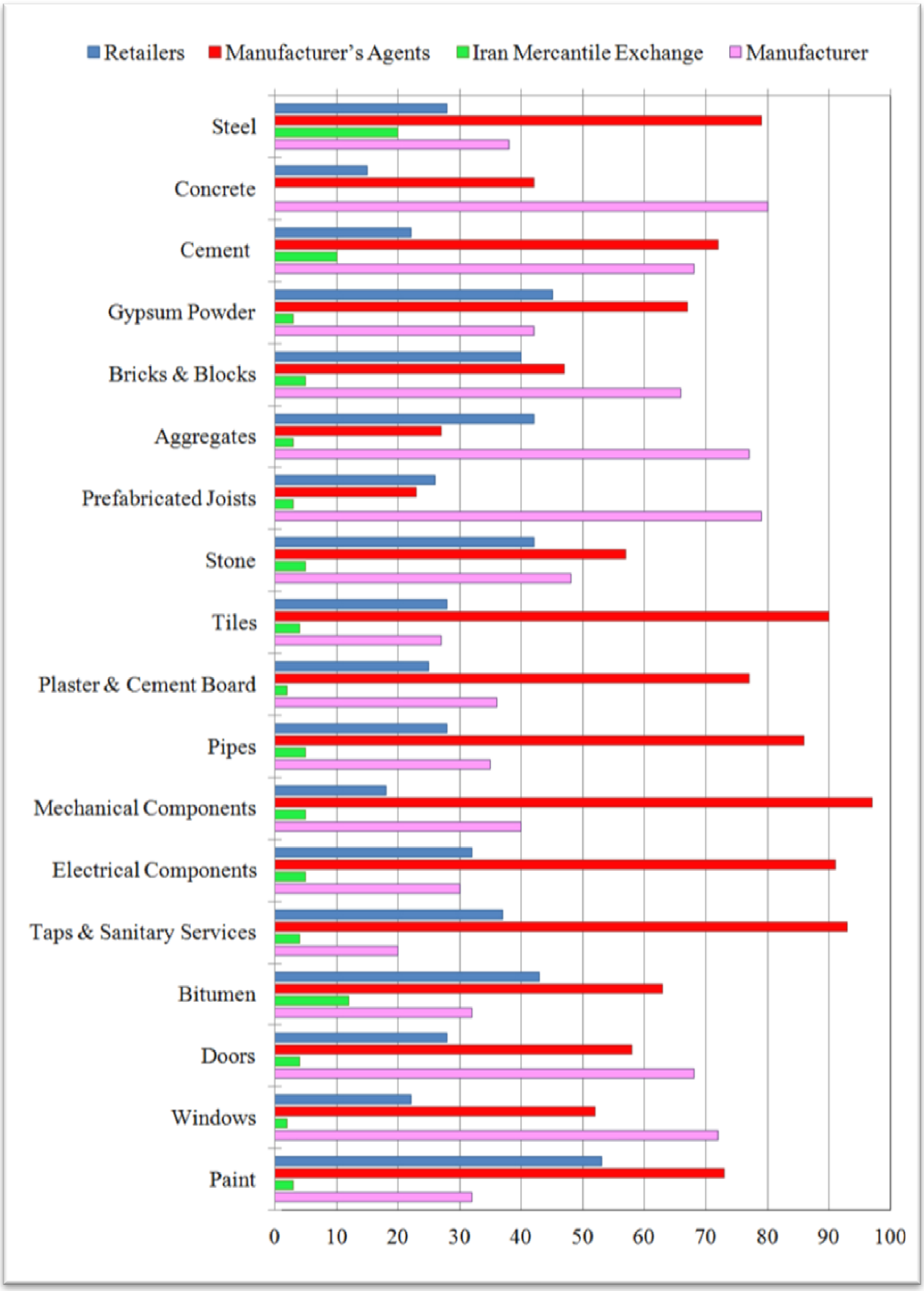


Figure 65: Purchasing channels classification according to number of respondents

9.3.6. Material Inspection

N05 and C06 explained that all materials and components arriving to the site should be inspected before storage (Relationship IW2). N05 said *"the contractor should* *inspect all materials and confirm that a certain amount of materials have arrived to the site at a specific date"*.

Lack of inspection or inaccurate control can cause problems such as delay, low quality work and capital waste. C10 explained that inaccurate inspection may happen at night owing to lack of visibility. After inspection, as C18 mentioned, if there is any difference between the order and the load, materials should be returned to the suppliers and new materials should be reordered. Inspection should be carried out on two attributes: (a) quantity and (b) quality.

Counting and weighing are methods of quantity inspection. C12 said *"if the load comes in packages we count them and if it is loose it should be weighed"* (Relationship IP1). C02 stated *"for counting packages in a truck, columns and rows should be counted and multiplied by the height"*. C12 and C15 confirmed that loose loads, and specifically steel and cement, should be weighed. C15 said:

> *"For weighing we may send the vehicle to the closest scale. But in some cases we may buy a scale and install it onsite. For example, in one of our projects we had a scale onsite because we purchased 10,000 Tonnes of steel rods and accurate weighing was required".*

The respondents were asked if they conduct material quantity inspection onsite (Question 5.4). The result is shown in Figure 66. Around 78% of respondents have accurate inspections, while 19% of them only carry out general checks.

In addition to quantity, the quality of delivered materials should also be checked too (Relationship IQ1). C12 expressed:

> *"There are two types of materials. Mineral materials, such as aggregates, should be tested in a lab. If the lab does not confirm its quality we do not use it. For manufactured materials such as concrete admixtures, we usually accept the factory quality assurance certificate. But some clients asked us to test at least one sample of those materials as well".*

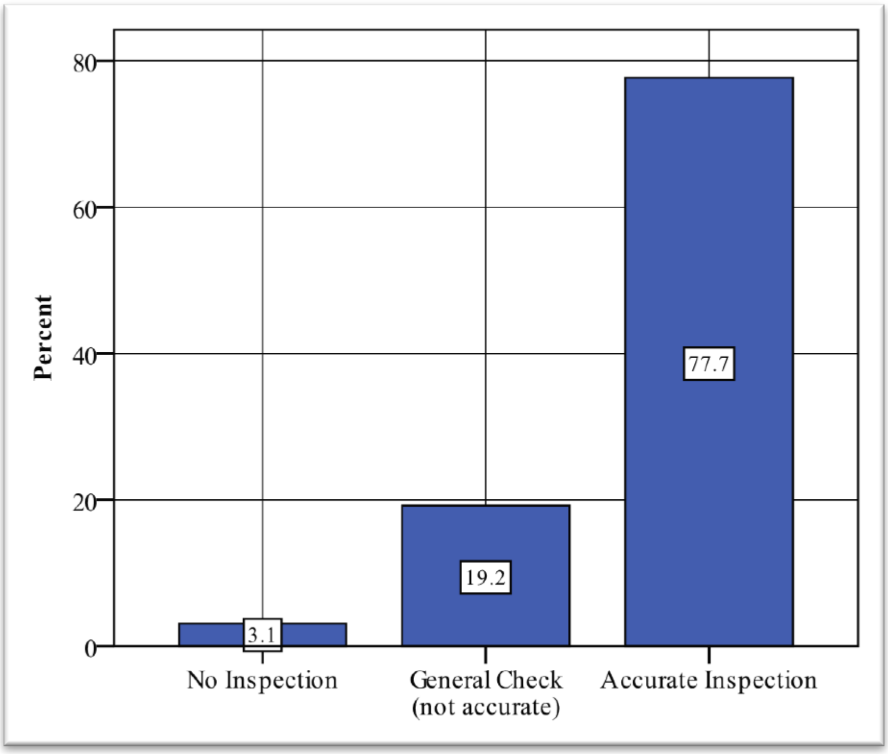


Figure 66: Inspecting quantity of materials

C10 also said *"we usually work with some specialised labs that take samples from materials such as concrete and carry out different tests on them"*. C18 and C12 explained that professional people, and even subcontractors, can inspect the load and confirm the quality of the materials. C12 stated:

> *"When the load arrives to the site, staff in the technical office will be informed to come and check the quality of materials. For example, they check steel sections for corrosion. If they do not confirm the quality of the load, it will be returned [to the supplier]".*

In question 5.4 (of the questionnaire) respondents were asked about the level of quality checks they conduct onsite. The result is shown in Figure 67. More than 53% expressed that accurate inspection is done, while around 45% of respondents carry out only general quality checks.

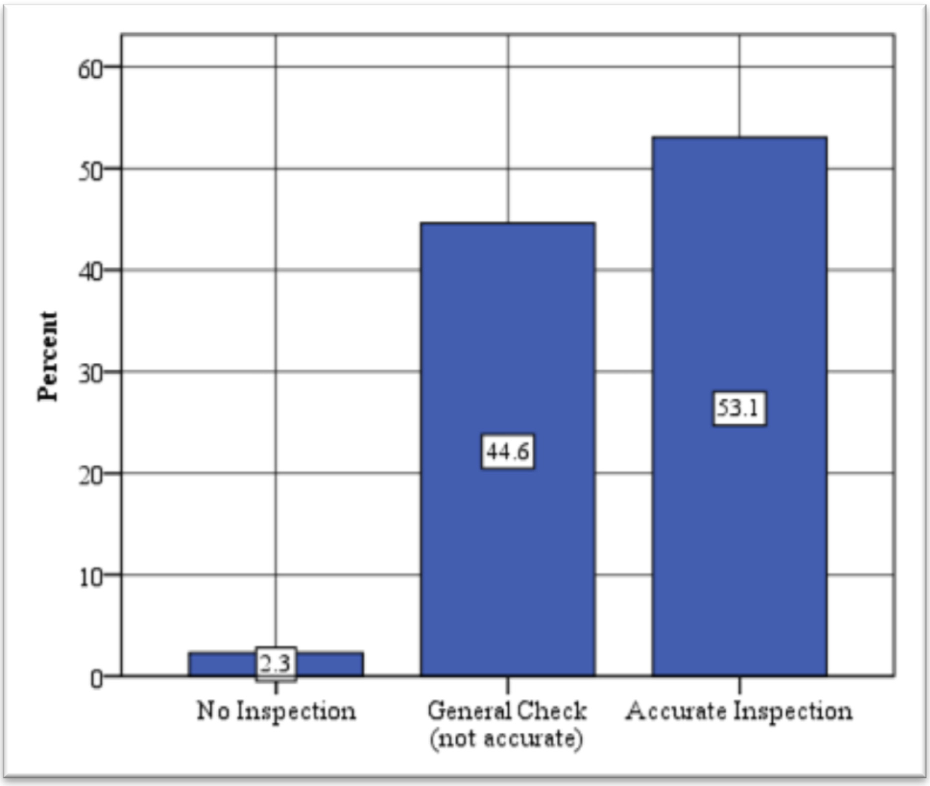


Figure 67: Inspecting quality of materials

9.3.7. Material Shortage

An important factor that may affect purchasing and, consequently, construction logistics is material shortages. N01 and C04 explained material shortages may incur extra cost, cause delay or even stop the progress of work in a project. C04 said:

> *"Material shortages threaten the CPM and you cannot keep your schedule (Relationship OS1). [Also] it costs a lot because you have to pay for labour while they have no job to do. [Moreover] shortages increases the material price and you have to procure materials at a higher cost"* (Relationship OC1).

Cement, concrete and steel are critical materials because, in peak working seasons, they might be scarce (Relationship PO1). N04 and C04 mentioned the shortage of cement. C04 said *"you are in the middle of concrete works when suddenly cement becomes rare"*. N01 and N05 pointed out steel shortages in projects. N05 said: *"sometimes you cannot find a specific size of steel section in the market. So, you have to use the higher size and this increases the costs"* (Relationship OC1). N05 also commented on the shortage of ready-mix concrete: *"sometimes for purchasing concrete, the supplier puts our company on a waiting list. It takes around 20 to 25 days or even more to get concrete".* To avoid material shortages, contractors have to buy and store materials ahead. This increases the size of inventory onsite and incurs more warehousing costs (Relationship OW2).

Several interviewees described the reasons that may cause material shortages. C04 stated:

> *"Financial mismanagement at the macro level causes shortages. In a period, the Government gave mortgages to everybody. So, people started constructing buildings. The demand for materials increased while our resources [supply] are limited. They did not even anticipate importing materials" (Relationship OE1).*

N06, C05, C06 and C18 explained that there are not enough manufacturers in the country for some materials, such as steel. C18 stated *"in our region there is only one brick factory. So, we have to order bricks two months ahead"*. C12 believed *"the machines and plans that some manufacturers use to produce materials are so old. So, the factory cannot work at full capacity"*.

Some interviewees, such as C09 and C13, expressed that some manufacturers or suppliers prefer to export their products because it is more profitable (Relationship OE1). C13 said *"in summer the price of cement goes up and it may be rare. One reason is that they [suppliers] export cement to other countries"*. N01, N05, C05 and C13 also mentioned the relationship between peak working seasons and shortage of materials (Relationship PO1). N05 explained *"in September, October, and November there is a shortage of cement. The reason is that in these months demand is high. Thus, we have to pre-order cement and pay its cost ahead"*. Project location is also important (Relationship PL1). C15 commented on this issue:

> *"In some regions there is a shortage of gravel and sand. Or there was a law that each province can only give cement to the projects that were under construction in that province. We had a project in a region that did not have cement production plants. Sometimes we had to wait two or three month for cement. Because cement producers in other provinces were forced to sell*

cement to projects in that province and if something was left they could sell it to us".

Figure 68 visualises the result of analysis on purchasing agent. The relationship between different agents are set based on what expressed by the interviewees in this section.

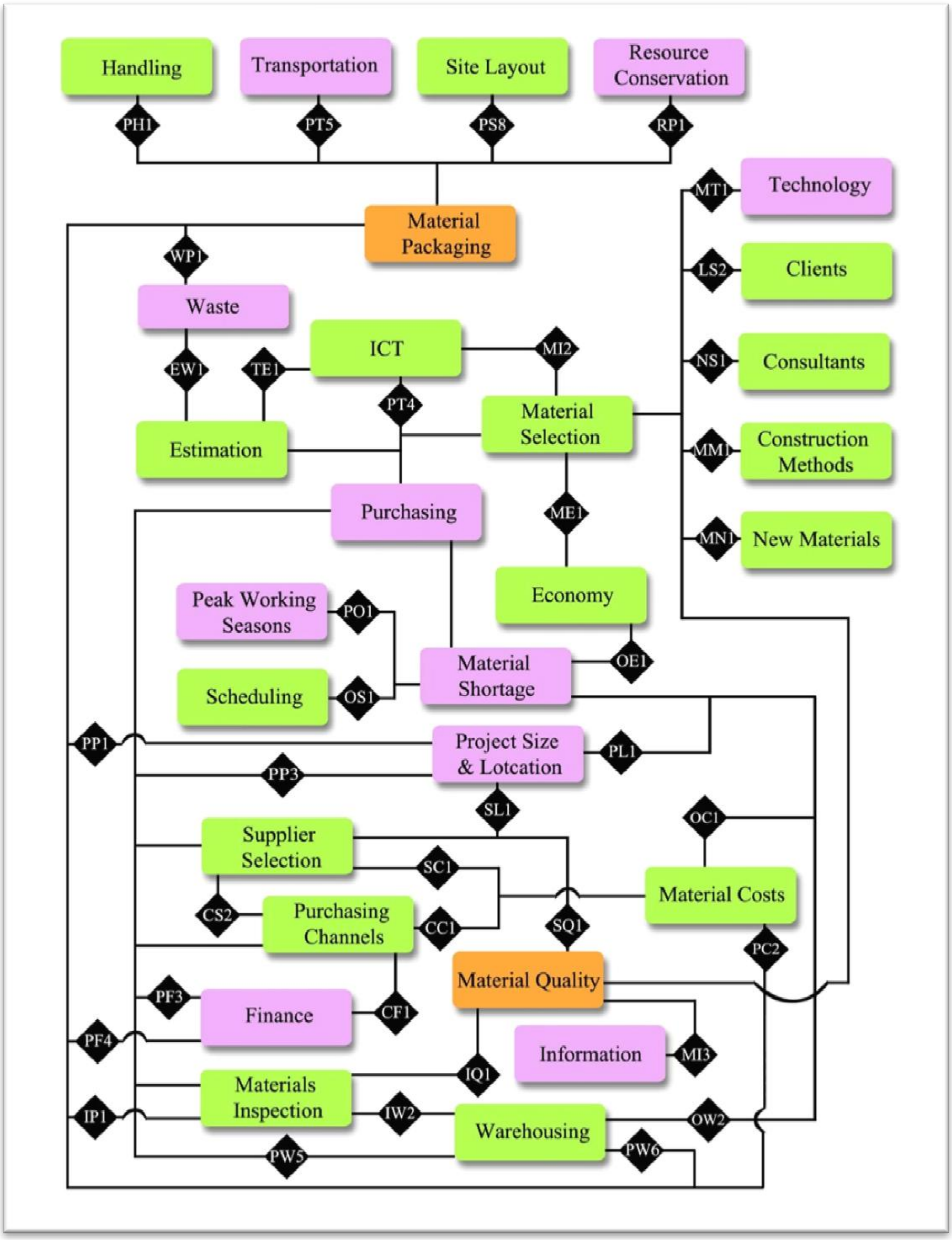


Figure 68: Purchasing agents of the construction logistics system

9. 4. Finance

Finance means managing cash and funds and has a close relationship with construction logistics. Most logistics activities, such as purchasing, transportation and warehousing, incur cost. Effective financial management is required to cover these costs. C17 explained:

> *"You should know the rate that money comes to your projects. You can define a scenario for your cash flow. You should know your income sources such as bill of quantities and your cost such as human resources and procurement".*

The use of ICT in financial management is important because it makes the process of report writing faster, easier and more visual (Relationship FI1). C11 explained: *"we have software that sends estimations to Ms Project. The software produces cash flow and resource consumption graphs"*.

To make sure that all logistical tasks can be carried out without problems, the financial resources of the project should be determined. This section, first, briefly explains the main available financial resources for building projects and, second, explores the impact of the economy and material costs on construction logistics.

The first step for financing the project is to estimate costs (Relationship FE1). Several interviewees emphasised the importance of estimation as it is the only way to understand whether there are enough funds to undertake the project. C11 pointed out the consequence of poor financial estimation for the project:

> *"[Often] the clients' approach to estimation is incorrect. [Based on inaccurate estimation] they carry out budgeting that leads to the creation of a gap between resource allocation and the real situation".*

In terms of financing, projects should be divided into two large groups: (a) public and (b) private. C01, C11 and C18 expressed that there are many financial issues in projects that are funded by the Government. They confirmed that these issues affect the way they purchase materials, pay for transportation and manage their warehouses. C01 said:

> *"The payment from the Government is not constant and continuous. They may give us some money this month and pay nothing next month. The banking incentives are like this too. The banks do not pay the first year. In the second year, they paid us in September. In the third year they paid in February. Their payments are not aligned with the project progress".*

C11 also expressed:

> *"[In public projects,] each year the Government allocates a budget to your project. It means that if your project lasts for two years, you are not sure if the Government will pay for the second year or not".*

C18 mentioned *"the Government payment does not have a logical sequence"*. The main reason is that the Government should prepare the budget bill and send it to the Parliament for confirmation. This may take two or three months and this causes payment disorder in projects. C11 mentioned: *"until June there is no money and the contractor should pay all fees from his pocket"*. C01 confirmed this and said:

> *"Usually there is no fund in spring. From July you can expect getting money from the Government. In February-March the payments are at maximum. But in these cold seasons you cannot execute projects. In some cases the projects are stopped because of bad weather conditions".*

It is important for contractors to know the times they can get money. Based on these times, they can arrange to cover their logistical costs. For example, buying expensive components, such as air conditioning units, lifts and sanitary items, should be conducted in winter, as more funds are available.

In private projects, there are more sources that can be used to finance a project. However, there are still issues that endanger the cash flow of the projects. N01 pointed out clients' lack of liquidity as a serious problem. The clients often get loans to execute projects. The interest rate of loans is high in Iran. N04 commented on this issue: *"the interest rate in private banks is 25 to 30 per cent. We cannot afford it because our profit is not so high that we want to pay 25% to the bank"*. Another problem is that the process of getting a loan may last a long time. N05 stated *"last year it took one month for us to prepare documents to apply for getting a loan. It* *also took two months to get the money. Totally, it caused a three months delay in our project"*.

Getting a loan is not always possible owing to the strict policy of the banks. C01 explained *"no bank gives a loan before completing the first roof of the building. So, you have to pay all cost yourself up to that stage which is difficult for many people"*.

Another source of cash, mentioned by C03, C04 and C13, is to sell some units of the building at a lower price before finishing the project. This method is popular and known as pre-selling the projects. C13 described this in the following:

> *"Some people do not have enough money to execute the whole project but they manage to buy land, pay for the building permit and construct the foundation. After that they will re-sell the project. They will sell one, two, or even 20 units to cover the project's cost".*

C03 also explained his experience of pre-selling: *"if the whole building costs around £5 million we will start with £150,000. Then we will sell the project's units and complete the building"*. However, pre-selling does not always work as expected. C13 stated "*if a recession happens, you will not be able to pre-sell the units"*. C01 added:

> *"If you want to pre-sell your project you should tell the customer that he/she will get the house at a specific date. So, time becomes highly critical. If you miss the handing over date, you should pay a penalty".*

Another source of finance that can be used for buying materials is a barter-like method. In this method, the supplier will get building units instead of cash. N02 elucidated this method:

> *"We buy materials from suppliers that have a portfolio of products. For example, they sell tiles, paint, doors, windows, etc. Instead of cash, we give them our products [building units]. It is beneficial for us because we do not pay cash while we sell our products. It is also attractive for the supplier because he sells his products while receiving a discount on building units from us".*

C04 also gave an example:

> *"Two weeks ago we intended to buy a large volume of stone. We informed the suppliers that we need stone with specific specifications and asked them to provide us with their best offer. We also told them that we will give them our building units for 50% of the total stone price".*

9.4.1. Economy

The economic condition can affect construction logistics. The importance of the economy is explained by C02 *"without considering the economic condition we cannot plan for [construction] logistics. Because our incomes and costs are highly dependent on the economy"*. In this section, the effects of the housing market recession on construction logistics are evaluated. The reason for highlighting the recession is that all interviews were conducted in a recession period in Iran and, thus, the interviewees only focused on that period.

The recession period in the Iranian housing market is independent of the global recession. The period in Iran started at least one year before the global recession. N02, C01, C03, C04, C06 and C18 explained their views about the recession in the Iranian housing market. N02 said *"we have been experiencing a recession each three or four years"*. In a recession period, selling houses is difficult and the rate of building construction is reduced dramatically. However, the prices do not change much because the investors try to keep the building units up to the next boom period. N02 confirmed this and said:

> *"The housing price rarely gets reduced in recession periods. Once prices start to go down the boom period will commence. In a boom period we experience a jump in prices and then prices remain constant up to the next boom period".*

N01 had a different view *"in 2009 the situation has changed a little. In the past, the property price always went up or remained constant. But currently, for the first time, the prices are going down".* However, C04 expressed:

> *"Some people say that the price of buildings is decreased. But I say it is not. Three years ago the price of a unit was £50,000 per square metre. It suddenly went up to £250,000. At present the price has dropped to £100,000.*

> *In comparison to last year, the price is reduced but in comparison to three years ago the price is doubled".*

C13 elucidated *"the best situation is to start a project in a recession and sell it in a boom period"*. The main reason is owing to the suppliers' behaviour in a recession period (Relationship SE1). C01, C06 and C04 highlighted this point. C01 said *"in a recession the suppliers give us more financial privileges such as instalments and credit purchasing"*. He added: *"when we are in a boom period materials demand is very high and dealing with suppliers is hard. But in a recession there is no demand for materials and thus they do everything to sell their products"*. C04 also mentioned that in a recession period the materials price decreases (Relationship EC2). Hence, the total cost of building construction is reduced, while the house prices are constant.

Other relationships of the economy and construction logistics agents, such information (Relationship IE1), material selection (Relationship ME1), and material shortage (Relationship OE1), were explained in the previous chapters. In the next section, material price and the effect of inflation will be discussed.

9.4.2. Material Cost

As explained above, materials are the focal point of attention in construction logistics. The material cost accounts for a large proportion of the total cost of the projects. N01 said *"60% of the project cost is on materials"*. The cost includes extracting, manufacturing, distributing and transportation of materials and components. The relationships of material cost and other construction logistics agents, such as purchasing channels (Relationship CC1), information (Relationship IM1), new materials (Relationship NM1), material shortage (Relationship OC1), peak working seasons (Relationship PC1), material packaging (Relationship PC2), supplier selection (Relationship SC1), and waste (Relationship WM1), were discussed in the previous chapters. In this section, material cost and the effect of inflation on it will be evaluated.

In terms of cost, there are two types of materials: (a) materials that are listed in price indices, such as concrete, and (b) materials that are not listed in the indices, such as tiles. The second group should be purchased from the free market. Yet, the price of the first group is regulated by the Government. Each year the President Deputy for

Strategic Planning and Control produces price indices that are a series of tables which show average prices for materials, equipment and services. Practitioners use price indices to estimate project costs and prepare bills of quantities. The problem with the price indices is that the real inflation rate is not reflected in some material prices in the indices. C07 said "*the material prices in the indices increase by eight to twelve per cent while the real inflation rate is more than 20%"*. Some interviewees explained that the Government does not publicise the real rate of inflation because it may have negative social effects. Unreal price indices means inaccurate data and this will lead to inaccurate cost estimation (Relationship EC1).

In Chapter four, it was explained that the rate of inflation is high in Iran. This seriously affects the price of construction materials. Many interviewees provided several examples about inflation impacts. For instance, C07 expressed *"in 2003 the price of block was £0.13 but now [2009] it is over £0.35"*. C04 pointed out a similar issue about steel rods *"last year the price of steel rods was £0.20 per kilogram. From then it started rising and currently it has reached £0.70"*. A triple time price increase, as C07 stated, makes the purchasing planning very difficult and, consequently, this affects construction logistics.

Price fluctuation is also an issue mentioned by several interviewees, such as N05, C01, C02 and C13. C01 stated *"since four years ago (2005) we have experienced fluctuation in material prices. This makes the contractors confused and they cannot plan for financial affairs"*. Some interviewees explained that they bought steel sections ahead of time because they thought the steel price will rise. However, the steel price dropped suddenly and they lost their capital (Relationship CW2).

To recover inflation, C15 had a solution: *"when we calculate material costs for the next year we add an extra 15% to minimise inflation effects"*. However, even the figure mentioned by C15 does not recover the steel price increase pointed out by C04. C15 confirmed this and added *"for steel, all projects were in trouble. Nobody could procure steel in that condition and many projects were halted"*. The high rate of inflation also amplifies the idea of purchasing and storing materials as soon as possible (Relationship CW2). C03 said:

> *"About stock volume, if the inflation rate is zero nobody turns cash to materials and put so much effort into its maintenance or security. Only in a chaotic market with a high rate of inflation is storing materials beneficial".*

The result of the analysis in this section is shown in Figure 69 which illustrates the relationship between finance agents and other construction logistics agents.

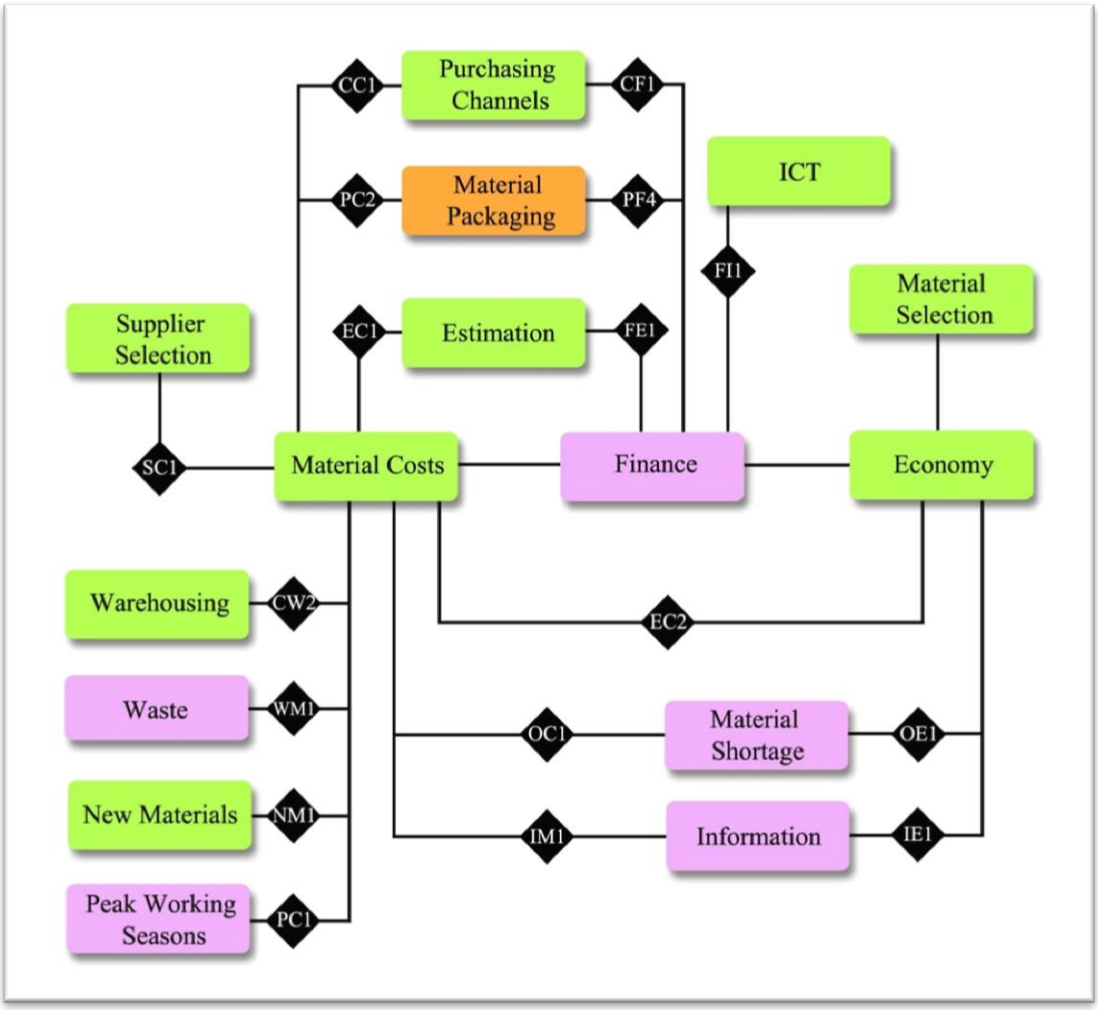


Figure 69: Finance agents of the construction logistics system

9. 5. Conclusion

This chapter discussed the way commercial factors impact construction logistics. In the first section, the role of clients, consultants and suppliers was evaluated. Clients, as the ultimate source of decision making in projects, may be involved in the material selection process or establishing their own material quality standards. Consultants, as designers, have also a direct impact on selecting materials. The role of the supplier is critical and an effective relationship between the contractors and suppliers should be established.

In the second part of this chapter, a general overview of the purchasing process was given. The main steps are: estimation, requisition, selecting materials, selecting suppliers, choosing purchasing channels, and inspection. Each of these stages was covered thoroughly in this chapter and the interviewees' and respondents' views were reflected.

The third part discussed sources of finance for public and private projects. It also explained the effect of the tough economic situation and the recession on suppliers' behaviour, material costs and the housing market. Moreover, the third section highlighted the role of inflation and described how it affects material costs.

Chapter 10

ANALYSIS: MANAGERIAL FACTORS

CHAPTER 10: ANALYSIS- MANAGERIAL FACTORS

10. 1. Overview

This chapter explores factors that are associated with management. One section is dedicated to people who should carry out logistical tasks in projects. The structure that connects these people and the knowledge they require to do their jobs will be described. In the following sections, the importance of information in successful construction logistics will be emphasised. Also, the types of information required for managing logistics and the way information can be managed by utilising ICT will be covered. Moreover, a section is dedicated to timing and logistics scheduling, which is about planning and sequencing orders and purchases. Material delivery matters and problems that endanger the schedule will also be addressed in this section. How to handle and store materials will be clarified in this chapter which is categorised under the material management section. And, finally, in the last section, some logistical problems identified during the qualitative data analysis will be studied from the quantitative point of view.

10. 2. Logistics Organisation

One of the main decisions in managing logistics is how to organise people, tasks and resources. Having an organisational structure for logistics helps the firm to group tasks and responsibilities and also to clarify the relationships of members. Rushton *et al.* (2006) believed that organisational structure is essential if the logistics function is to be planned and operated effectively.

The importance of logistics organisation increases with the size of the project. In large projects, organising people and distributing responsibilities are more critical. This section researches three topics: organising people, organising knowledge and organising other resources. Considering these topics, and according to the information gathered from the interviews, the logistics organisation can be divided into five sections: (1) Logistics Organisational Structure, (2) Logistics Personnel, (3) Logistics Knowledge, (4) Cultural Factors, and (5) Site Layout. In the following parts, each of these sections will be explored and interviewees' views about them will be reflected.

10.2.1. Logistics Organisational Structure

The typical view of respondents was that logistics organisation is a part of the organisational structure of the company or the construction site. C01, C04, C07, C12, and C15 mentioned that their companies have an organisational structure with sections related to some logistics tasks, such as purchasing and warehousing (Relationship OP1).

C015 provided a copy of his company's site organisational structure (Figure 70). The following sections have associations with logistics management: support, supply, health and safety coordinator, warehousing coordinator, and project and quality control. However, there is no specific box for logistics management in this diagram that covers all logistical functions, such as transportation, information flow and site-layout designing. The reason is that, basically, interviewees had primitive perceptions about logistics. They see logistics as equivalent to supply and this is not aligned with the classic definition of logistics presented in Chapter two. Hence, when they spoke about the logistics organisation, they meant people who are responsible for purchasing different materials or components. This perception, which is reflected in the organisational structure, imposes the feeling that the importance of logistics is neglected. When no section is devoted to logistics, there will be no manager as a single point of responsibility for managing logistical affairs. Another obvious issue in Figure 70 is that the relationships between different members are not addressed. For instance, there is no link between the supply section and warehouse coordinator while, owing to the nature of their job, they must work closely together.

The main problem in Figure 70 is that it is not clear who is responsible for logistics. To address this problem, question 8.1 is dedicated to this in the logistics organisation section of the questionnaire. This question aims to show if a team is responsible for managing logistics, one or two individuals carry out logistical management or logistical affairs are done by employees with other jobs in the company. Figure 71 summarised the result of the survey.

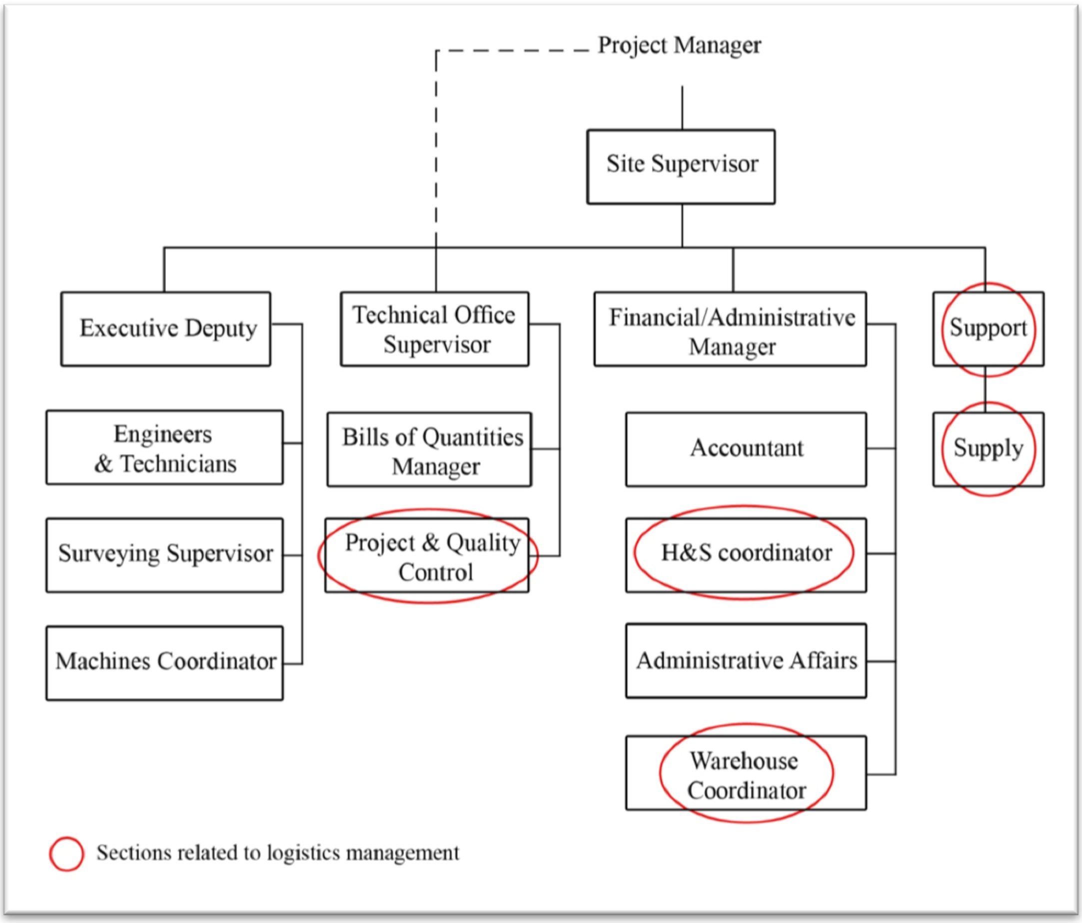


Figure 70: A contractor organisational structure diagram (C15)

Figure 71 shows that in 66.9% of construction companies participating in the survey, there is no dedicated team for logistics. Within those companies, in 6.3% there is not even a specific person to manage logistics. Only 33.1% of respondents expressed that they have a supply and support team in their companies. These teams are usually responsible for purchasing materials, but not all logistics tasks.

Figure 72 clustered answers based on the company grades. The grade one companies (large firms) are more likely to have a team for supply and support, while in companies with grade two, the chance of having one or two people for logistics management is higher. The grade three companies (smaller firms) hold the maximum values among respondents who said the staff with other responsibilities manage the logistics of projects.

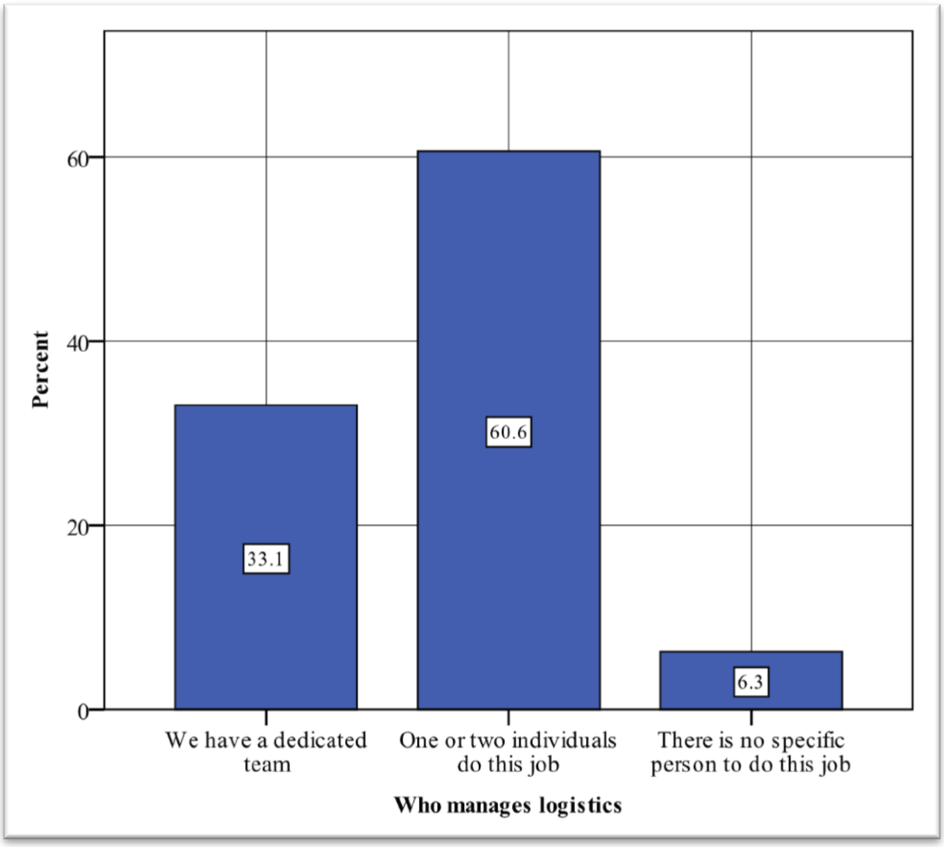


Figure 71: Who manages logistics?

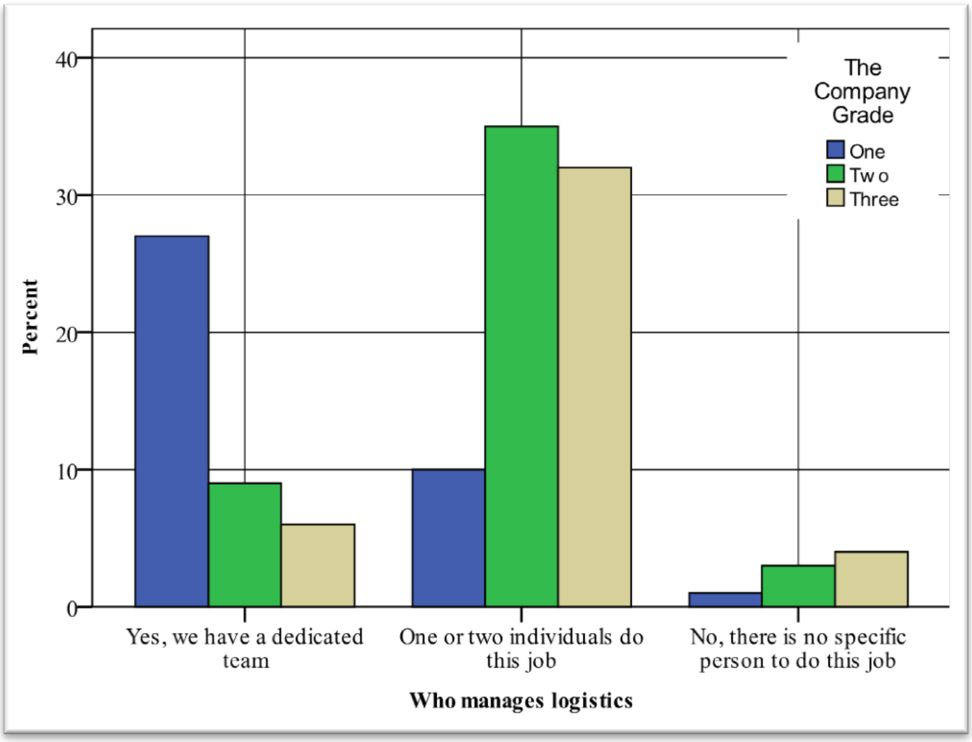


Figure 72: Clustered bar chart for who manages logistics based on the company grades

10.2.1.1. Structure

An important topic in organisational studies is the type of an organisation. Based on data gathered from the interviews, generally, organisations have three types in the Iranian construction companies: centralised, decentralised, and semi-centralised. In a centralised organisation, all activities are managed and controlled by the head office. C07, who used to have a centralised system in his company, expressed that even bills of quantities (interim valuation) were evaluated in the head office. He stated:

> *"Of course it has advantages. In macro-management discourse, the person who is appointed onsite is less experienced than the senior engineer who works in the head office. The senior engineer, only with a glance, can produce a more profitable and acceptable bill of quantities. He can also perform better in documentation and establishing a better relationship with the client through the legal correspondence".*

There are also companies that give decision making authorities to the site managers. A few respondents supported the idea of having an autonomous construction sites. Those who apply this structure indicated that the decentralised structure makes them more agile to respond to problems arising in the site. They believed experienced staff onsite are able to deal with the details of the construction and logistical tasks. Hence, the top managers should be left with strategic decisions at the macro level. C04 clarified the decentralised organisation in the following:

> *"Our site has a similar structure to the head office. The senior project director is responsible for the site. The financial manager, administrative manager and technical office work under the director's authority and everything works smoothly".*

C07 stated that he applies both centralised and decentralised structures in his company and both were problematic. He remarked:

> *"In the centralised option, although the senior engineer is knowledgeable, because he is not physically present on site, he cannot control the logistical affairs properly. Normally, the person who works onsite can better say what should be used and what should be done ... in the decentralised option we*

always feel a lack of control ... so, we decided to work in a semi-centralised way to eliminate weaknesses and utilise the advantages of both methods".

Finding a place in the middle between centralised and decentralised organisation was not popular among interviewees and was only indicated by C07 and C15. C07 continued:

"In a semi-centralised system the connection between the site and the head office exists at a macro management level to establish a system for the work. The site is required to comply with the system established by the head office. In fact site staff should execute the head office standard process. But at the micro management level there is no connection between the site and head office and site staff should deal with details".

C07 makes clear his thoughts by giving the following example:

"In the current system [semi-centralised] bills of quantities [interim valuation] preparation and evaluation are done onsite and the head office does not check and control everything. But a financial summary of the site performance will be checked by the senior engineers in the head office. So, the head office generally oversees the process and does not focus on all details. But changes may be made in items that have heavy financial loads. This is done by cooperation of the site authorities and head office".

In semi-centralised companies, there is a regulatory body which is called the trade committee. The main responsibility of this committee is to generally control the site spending. Its tasks include establishing a financial limits for the site director, making a vendor list, selecting critical materials and components, carrying out high value purchases and overseeing the purchasing process. C15 describes the trade committee in the following:

"About purchasing, we have a trade committee. In this committee a financial limit is defined for the site director. This limit shows the maximum value of money that a site director can spend for a purchase ... If the order value is higher than that limit the purchase should be carried out through the head office".

Hence, in a semi-centralised organisation, the site has a certain level of autonomy to manage their financial inputs and outputs. This also increases the agility level of the project to respond to changes in the market or unforeseen issues onsite while it ensures a level of supervision and control on financial performance of the project from the head office. The semi-centralised style provides codes and standards for the site and asks them to perform in the framework made by the head office and trade committee. Yet, managing day-to-day problems and solving technical issues are left for site authorities.

Although a semi-centralised organisation may look the best option for managing logistics in a project, as most respondents confirmed, the choice of the organisational structure is highly dependent on the size, type and nature of the projects a company undertakes. A critical issue in this structure is that an effective relationship should exist between the head office and the site. This needs a high level of attention when site staff are appointed. In addition to having enough experience, site staff should make decisions promptly, communicate effectively and be accountable to the head office. Finding people with these characteristics may be impossible or costly in undeveloped areas. In this type of organisation, having a dedicated section for logistics management is more essential as the site should undertake more responsibilities. In fact two main success factors of this structure is that the staff should be highly specialised in their jobs and responsibilities should be distributed evenly between employees.

Another important point that was explained by C07, and needs more investigation, is standardisation of logistics affairs. To keep the control over the logistics functions onsite, while giving a level of autonomy to site staff, a set of standard processes should be defined and established. C17 made the following comment about standardisation and documentation:

> *"No work in our company should be done without documentation ... I mean everything is defined and relevant forms and checklists are prepared ... there is nothing that you have to ask questions about from other people. One document should define it necessarily. It does not matter if a document is amended ten times because it has problems or mistakes ... everything you do could be done better".*

C15 expressed how standard processes and relevant forms are prepared in his organisation:

> *"We made all of these forms and codes ourselves and then adapted them to the ISO format. The ISO has a framework. For example, each form should have a number and all documents should be reviewed and evaluated each year to find out if they work properly".*

In general, interviewees believed that standardisation can avoid inefficiencies in construction projects and promote the best way to carry out a task. The question is: do construction companies in Iran standardise the process of logistical affairs in their projects? Are the processes of scheduling, purchasing, warehousing and utilising standardised? Question 8.2 in the questionnaire covers these matters. In this question, the participants were also asked if they obtained ISO (International Organisation for Standardisation) certificates for logistical affairs (Table 16).

Table 16: Logistics process standardisation in the participants' organisations

Responses	Frequency	Per cent
Yes, we got ISO certificate	28	22.8
Yes, but we did not get ISO certificate	26	21.1
No, but we intend to do so	57	46.3
No, it is not necessary	12	9.8
Total	123	100.0

Table 16 shows that 43.90% of companies in the sample established standard processes for logistics tasks. Also, 46.34% were aware about the importance of standardisation. Yet, 9.76% of respondents explained that standardisation is not necessary. More research needs to be conducted on why they think so. In general, data indicates that the majority of construction firms participating in the survey standardised the construction logistics process or intended to do so.

10.2.2. Logistics Personnel

As seen in the previous section (Figure 71), 66.9% of respondents expressed that construction logistics is managed by one or two individuals or people who work in different departments. Therefore, the role of individuals in logistics management should be investigated. This section aims to explore the role of the main logistics personnel in construction projects.

The typical view of respondents is that the site director (supervisor), financial manager, supply and support manager, buying coordinator and warehouse coordinator are the people involved with logistical tasks. Figure 73 is drawn based on interviewee responses and shows the arrangement of logistics personnel. This arrangement may be different depending on the size of the projects and the level of centralisation or decentralisation in a company.

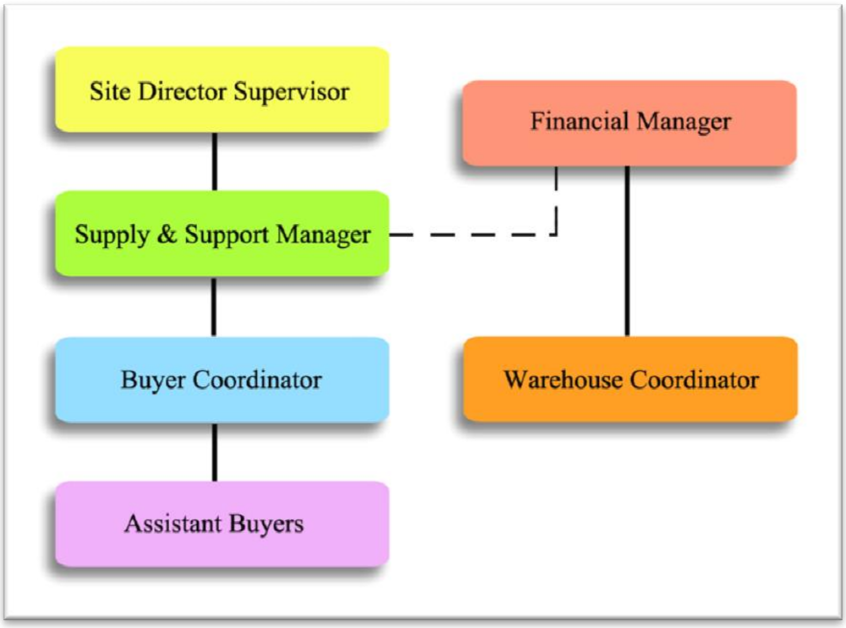


Figure 73: Logistics personnel arrangement

Most respondents indicated that the roles of site directors in logistics management are checking the inventory of the warehouse, asking for required items (preparing the items requisition), overseeing material schedule, keeping the site secure, supervising the whole process of logistics and monitoring the process to the higher authorities via daily reports. N04 clarified the monitoring process: *"We have a site director in our projects. We are in contact with him directly in a daily basis. He reports about different matters onsite to us including the inventory, deliveries, etc"*. C01 also explained the main role of the site director in logistics management as asking for required materials: *"The site director only indicates that for example gypsum powder is finished and we need x volume of gypsum"*.

The financial manager should pay for the cost of purchases, transportation, warehousing and labour. Hence, his main role is to reimburse logistics costs. C15 and C04 expressed that, in their companies, the buyer coordinator and warehouse coordinator work under the financial manager's authority. Hence, in this case, the role of the financial department is extended to supervise the purchasing process and warehouse administration.

Another role that is mentioned by a few respondents is the supply and support manager. C15, C12, and C04 explained that this is almost a new role that has had positive effects on the logistics of projects. C12, who believes the supply and support manager should be employed as soon as possible on site, stated: *"the best thing to do is that in the time of site preparation we appoint a supply manager onsite to register and track all items that are brought to the site"*. C15 also explained that there should be a supply and support manager onsite and said:

> *"We have a supply and support manager who is not necessarily an engineer. The supply and support managers are usually business managers. But in complex projects it is possible that we appoint a civil engineer to help him".*

C15 highlighted the role of the supply and support manager in the following:

> *"This manager is on top of the logistical tasks. All items that need to be purchased should be confirmed by the supply and purchasing manager ... the manager should contact suppliers in our vendor list and gather quotations and find out if the supplier can provide us with the required item and ask about the possible delivery time and date to the site".*

Most interviewees explained that, in medium and large size projects, there should be at least one individual who carries out purchases. This person is often referred to as the buyer coordinator (Relationship PP2). C04 said:

> *"The buyer coordinator is a person who provides different goods for the project ... the buyer coordinator's job is to get quotations from the manufacturers when their products' quality is previously confirmed and choose the best option to carry out the purchase".*

The above quotes show that there is confusion between the role of a supply and support manager and a buyer coordinator. It seems that, in some projects, these two roles are merged together. Yet, based on the interviewee responses, the supply and support manager holds the higher level in the organisational structure. In large projects, there may be several assistant buyers who work under the buyer coordinator's supervision. The main tasks that a supply and support manager or a buyer coordinator should undertake are to (a) receive items requisitions, (b) arrange them, and (c) purchase confirmed items. The buyer coordinator should receive material and machines requisitions from the site director. The requisitions should be arranged and become ready for the project control department to be confirmed. Then quotations should be obtained from the supplier in the vendor list to conduct the purchasing. The process of purchasing was described in Chapter nine.

There should also be a warehouse coordinator in a construction project. He is responsible for receiving incoming loads to the site, storing items in identifiable locations, collating requisitions with the available stock, releasing items to working parties, and issuing an inventory report for the higher authorities on a regular basis (Relationship PW3). The warehousing process will be explored in more detail in this chapter.

To manage logistics effectively, changing the organisational structure in construction projects is essential. Rushton *et al.* (2006) stated forward-looking companies have noticed the need to change their organisational structure to have a dedicated section for logistics. In this research, a structure is defined based on information obtained from the interviews and Rushton *et al.*'s (2006) advice (Figure 74). In the proposed structure, it is attempted to keep the conventional roles and integrate them under the logistics management section. To provide a real basis, the organisational structure presented by C15 (Figure 70) is used as the foundation of the new structure. In the proposed structure, a new section is defined as the logistics manager who designs site layouts (Relationship PS4), administers supplier relationships (Relationship PS6) and deals with site security matters. He is also responsible for making a team to undertake logistics task, such as purchasing, warehousing, transportation and waste management. The logistics manager should supervise the whole process of logistics and provide reports for the site and head office authorities.

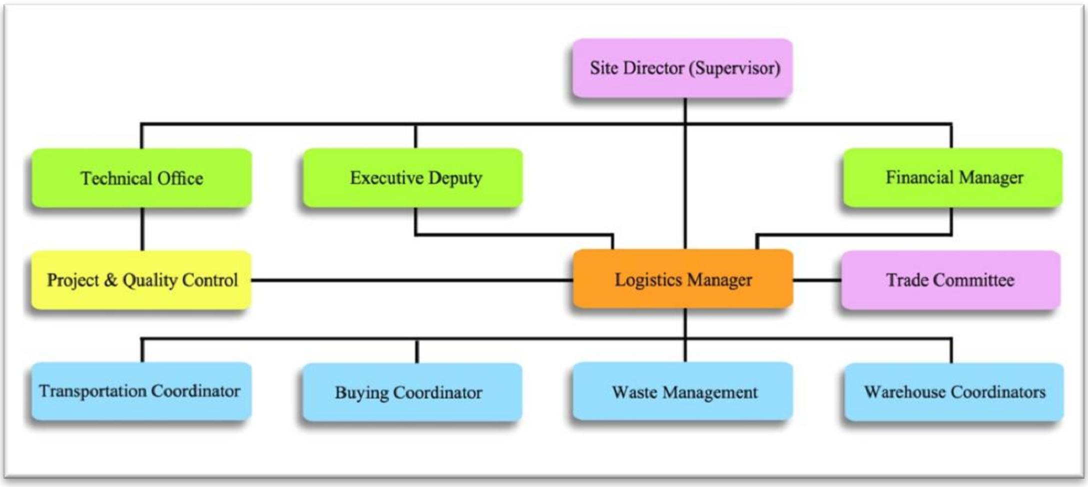


Figure 74: Proposed logistics structure

The onsite logistics manager is in direct contact with the site director, financial manager, and execution deputy. This enables the site director to be aware of logistical affairs onsite by receiving regular reports from the logistics manager. The reports may include information about site layouts, material schedule, orders, purchases, deliveries, space management, inventory, and required cash. The logistics manager is also in contact with the execution deputy which helps him to be aware of the process of construction onsite. Moreover, he is linked to the financial manager to be informed about financial matters (Relationship PF2). The collaboration between the logistics manager and financial manager regulates purchases and payments.

The logistics manager is also connected to the project control unit. This unit develops and control the project schedule. The link between this unit and the logistics manager helps him to be aware of the exact date that items are required onsite (Relationship PS5). There is also a connection between the logistics manager and quality controls unit which ensures that quality inspection is conducted on all incoming items to the site before warehousing. The logistics manager is also in contact with the trade committee in the head office that regulates his performance by establishing standard processes and financial limits. The role of the trade committee was discussed previously and remained unchanged.

Under logistics manager, four roles are defined: buying coordinators, transportation coordinators, warehouse coordinators and waste management coordinators. The description of the buying coordinators and the warehouse coordinators is the same as what was explained before. The only difference is that they are integrated under the authority of a single point of responsibility. The transportation coordinator is defined as a new role and he is responsible for managing the operations of the means of transport, such as trucks, vans, cranes and cars onsite (Relationship PT3). He should provide handling facilities and oversee the handling process to ensure it is safe and efficient. The transportation coordinator is also responsible for arranging deliveries and developing a delivery schedule. He should manage access and egress points, supervise the loading and unloading process, and deal with drivers' issues. Another new role is the waste management coordinator who is responsible for the collection and disposal of waste (Relationship PW4). He should aim to minimise waste through establishing benchmarks, schemes and targets. He may also provide advice for other parties on waste reduction and environmental conservation matters.

The proposed structure is aligned with Rushton *et al.*'s (2006) idea that promotes integration and stresses that logistics should be managed in its own right. This structure sees the logistical tasks holistically and integrates logistics personnel together to provide a foundation for more collaboration. Integration helps the logistics to be planned, operated and controlled as a single entity. In this structure, the connections are clear and this enhances communication among personnel and increases the agility level of the team to respond to changes and crises quicker. With some modification, the proposed logistics organisational structure can be incorporated into centralised, decentralised and semi-centralised companies.

Although having an organisational structure diagram can highlight the roles and relationships, differences between formal and informal organisational structures should be appreciated. In fact, the reality of day-to-day interactions between members of the organisation may be different to what is set out on paper. Therefore, in addition to a hard structure, logistics management requires soft tools as well. In the next section, the effect of personnel knowledge (Relationship PK1) and culture on logistics will be investigated.

10.2.3. Logistics Knowledge

The aim of this section is to find out to what extent construction practitioners are familiar with construction logistics in Iran. The word 'knowledge' is defined by Cambridge Online Dictionary (2010) as "understanding of or information about a subject which a person gets by experience or study, and which is either in a person's mind or known by people generally". In this definition, sources of knowledge are highlighted as experience and study. Hence, the stress in this section is put on interviewees' experience and the level of education and training they attained. Yet, first the researcher should know if interviewees recognise the importance of logistics.

The first problem was that there is no official translation for the term 'logistics' in Farsi which reflects all aspects of the subject. The typical view was that logistics is a word related to military activities. For example, N01 said *"the word logistics reminds me of military matters"*. In most interview sessions, the concept of construction logistics management was defined by the interviewer. The typical approach to logistics was that it is equal to supply and support. Although supply and support are important branches of construction logistics, functions, such as warehousing, site layout designing and security should also be considered. It can be said that all interviewees were familiar with different logistics functions; however, the word logistics, as an umbrella term that covers those functions, was unfamiliar. N01 made this clear in the following:

> *"Every project has logistics and it mostly focuses on supply and support ... of course logistics has been considered to some extent but more efforts are required for optimising logistics tasks".*

The importance of logistics was also confirmed by other interviewees, such as C02, C10, C11 and C15. For example, C10 made the following comment:

> *"Without logistics and support no building will be constructed. Because I, as a contractor, can build the project according to the schedule and CPM only when I receive codified and principled logistics services in the project".*

To obtain a wider view towards the level of construction logistics familiarity among practitioners, question 2.1 in the questionnaire was designed. It is a self evaluation question and asks respondents to assess their knowledge. It should be explained that understanding the logistics definition does not mean that an individual has enough knowledge to manage logistics or conduct logistics tasks properly. Yet, question 2.1 gives a generic indication of respondents' perception towards logistics (Figure 75).

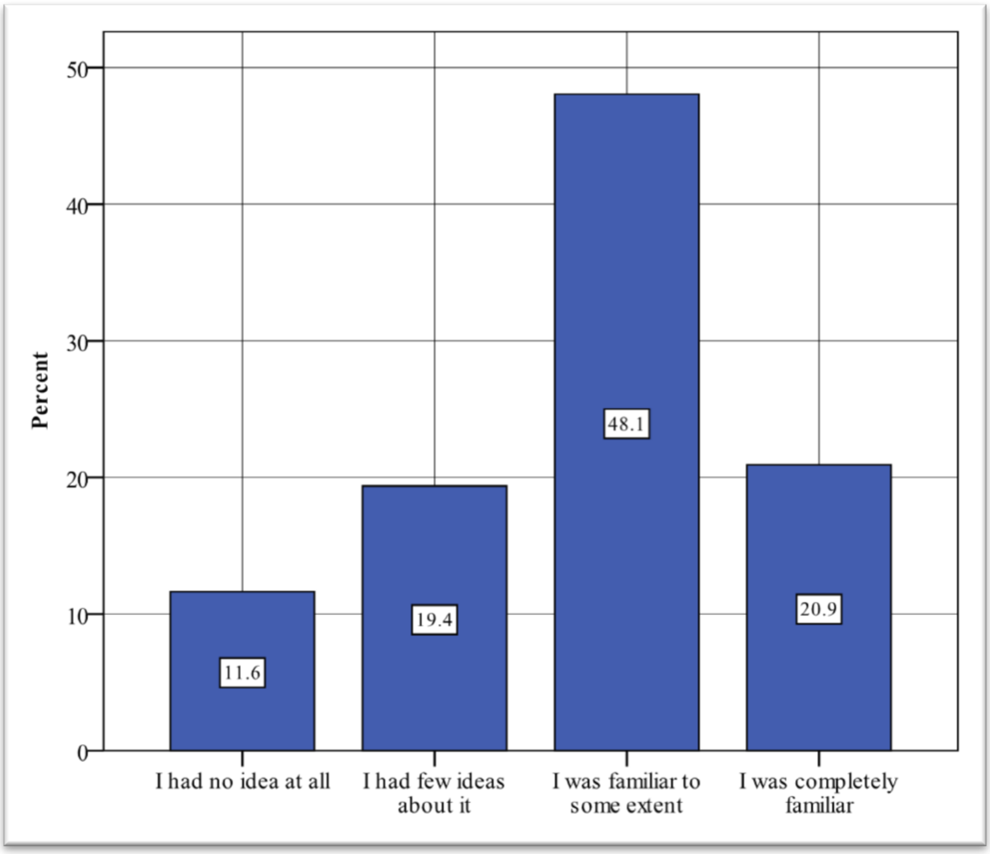


Figure 75: Respondents' perception towards logistics

As shown in Figure 75, 48.1 per cent of respondents explained that they were familiar with the logistics definition to some extent, while 20.9 per cent said they were completely familiar. Only 31 per cent mentioned that they have few ideas or no idea about the logistics definition. This is aligned with the qualitative study result which indicated that practitioners are aware of construction logistics.

Figure 76 illustrates the respondents' perception towards the supply chain concept. In comparison to logistics, fewer people (13.2%) were completely familiar with the supply chain concept. More than 46% of respondents explained that they have few ideas or no idea about the supply chain. This figure is only 21% for logistics. Thus, it seems that respondents' level of knowledge on logistics is higher than the supply chain.

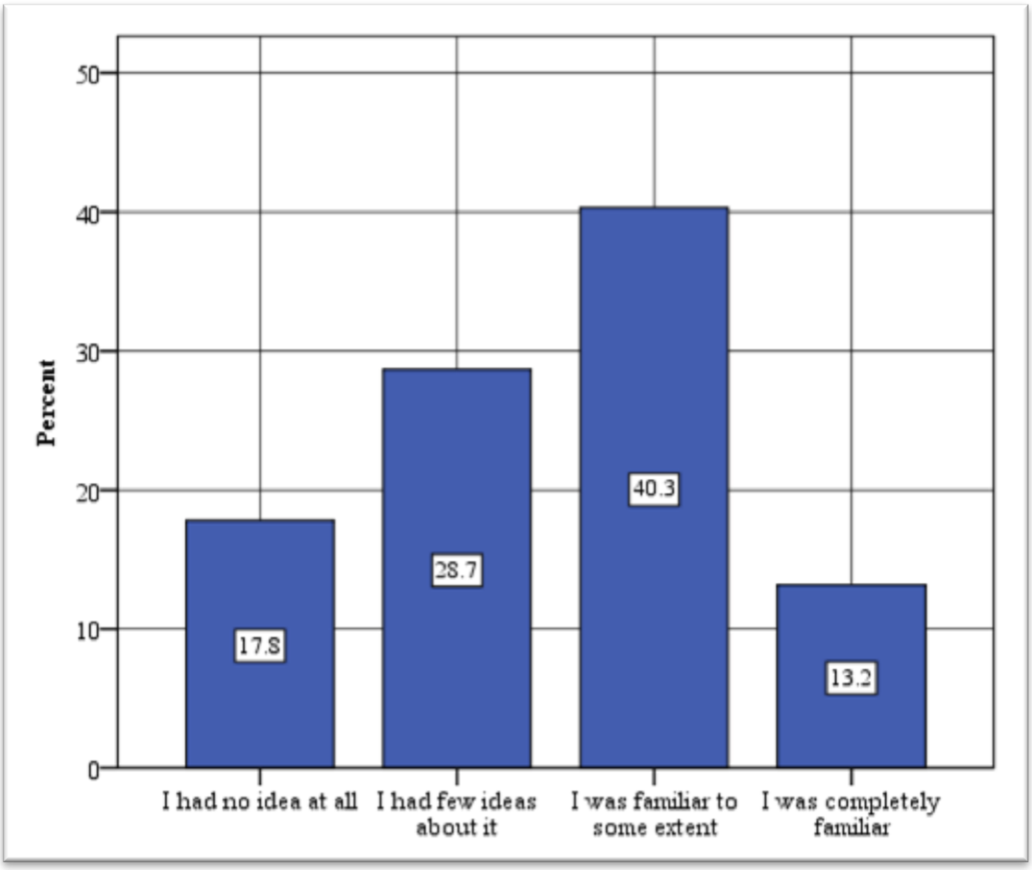


Figure 76: Respondents' perception towards the supply chain

Although most interviewees are aware of the importance of logistics, not enough attention has been paid to construction logistics in terms of training specialised people to conduct logistics functions in projects. The lack of specialised staff has had substantial negative effects on the construction speed, quality and cost. C10 made an interesting analogy and indicated one consequence of poor logistics in projects:

> *"Not only in building construction, but in all other subjects, logistics is highly critical. For example in war, a soldier to be able to fight at the front needs to be supported by 200 people at the back. The situation is similar in construction. Yet, unfortunately we do not have principled logistics systems to supply and support our projects. So, you frequently see in our country that projects last several times longer than what is scheduled or the project is completely stopped".*

One point C10 raised above is that there is a need for a principled logistics system. To establish such a system, two basic elements should be considered: the structure, which was discussed in the previous section, and the staff, which will be covered here. The lack of specialised staff is an issue which is emphasised by many interviewees, such as N02, C02, C03, C10, and C11. C02 said *"we do not have specialised people with high efficiency in logistics management".* The staff that are mostly referred to are financial managers, supply and support managers, buyer coordinators and warehouse coordinators. The interviewees explained that usually people who take on those jobs do not have the relevant education and experience. This is a serious issue that causes problems for the projects. C10 described his problem with an unspecialised buyer coordinator in the following:

> *"A person who is not specialised harms the project from two angles: first, the quality of materials he purchases is low because suppliers can easily influence his judgment and second, he bought materials at a high price. Because the suppliers do not provide a price list and sell their goods at different prices to different people, the more the better ... [for example] I need stone. Initially I have to speak with the buyer coordinator for long hours and explain that because we need stone to cover the parking area, the stone should belong to a specific classification and should be plutonic. After four days of searching for stone he returns with a limestone sample such as Travertine. I told him this is not plutonic and does not have enough hardness to cope with the friction of car tires. He did this because he is not specialised".*

The lack of specialised staff is not only about supply and support managers or buyer coordinators. The site managers have similar problems: C03 expressed *"our site directors and project managers do not have enough knowledge about supply and support"*. This may cause several problems for projects because the site manager as the responsible person onsite does not know how to manage construction logistics. The following quote by C10 shows this clearly:

> *"In many projects our engineers have only five or eight years of experience maximum. They do not have comprehensive information about supply and logistics issues. Sometimes decision making is very terrifying for them because they are not specialised [in logistics]".*

C10 continued:

"I am responsible for controlling the performance of four projects ... I employed young engineers in those projects but I noticed that they are not able to make decisions about logistics. For example one of my engineers with eight years experience was unable to buy 400 square metres of stone. It was around two weeks that labourers were onsite but because there was no stone they could not work ... he could not decide about the stone type and also about the price".

Concluding from C10's quotations, the site directors with a few years of experience do not have enough knowledge about construction logistics. Table 17 is a cross-tabulation of questions 1.5 and 2.1 in the questionnaire. The options of both questions are reduced from four to two for easier analysis. The result is aligned with what C10 said. It shows 22 out of 64 (34.37 per cent) of respondents with 1 to 10 years of experience have no idea or few ideas about the logistics definition, while only 18 out of 65 (27.69%) of respondents with 10 or more years of experience chose similar options. Furthermore, 65.63 per cent of the first group are familiar with logistics to some extent, or completely, while 72.31 per cent of the second group (more experienced) chose those options. This can be a basis for a hypothesis that indicates there is a relationship between the logistics knowledge and job experience. Finding the correlation between respondents' perception about logistics and their level of experience is not the aim of this research and should be evaluated by further studies.

Table 17: Experience and respondents' logistics perception cross-tabulation

		Logistics Perception		Total
		no idea/few ideas	familiar to some extent/ completely familiar	
Experience (years)	1-10	22	42	64
	10+	18	47	65
Total		40	89	129

Another issue is that staff who undertake logistics jobs are required to have two types of knowledge. First, they should be experienced in their fields (e.g. financial management) and, second, they should have enough knowledge about construction processes and materials. A financial manager who is not familiar with the nature of a construction project, even if he is specialised in his field, will be in trouble because he has no idea about the material price, payment methods and market conditions. An expert civil engineer, also, cannot handle complex financial matters. C07 described this issue in the following:

> *"One problem is that the team members who work in the financial department are not specialised to know where the materials are used and how much materials is required. For example in our project in Oroumieh, the area of the site was four or five hectares. You want to know where the cement that arrived to the site is used. The staff working in the financial department cannot provide us with any analysis".*

The following quote by C15 describes the same issue about a project planner:

> *"We prefer to employ civil engineers to undertake different roles. But a civil engineer who is familiar with relevant subjects, for example Primavera [for scheduling]. The reason is that he [the civil engineer] knows the job and materials. [For example] if we employ an industrial engineer [for scheduling] we should [also] appoint a civil engineer to tell him about the construction process."*

N02, also, indicated the knowledge that a supply and support manager must have:

> *"The person who manages logistics must know manufacturers. I mean he should be aware of all supply sources. He should know about the quality [of materials], standards, prices, etc."*

Finding a suitable individual, who has extensive knowledge about construction and also a specialised field such as finance, is difficult. Hence, people should have one of those types of knowledge specified before and be trained for the other one in projects. The question is who is responsible to train people for logistics.

N02, who is a lecturer in a university, said *"both the industry and the universities do not pay enough attention to construction management concepts such as logistics".* C12 confirmed this and added: *"The majority of graduates do not know what to do when they enter a project".* It seems that graduates with construction related degrees have not attained knowledge about construction logistics. N02, C12, and C15 believed that civil engineering and architecture students should study logistics topics. C10 expressed that even independent courses should be established for construction logistics:

> *"There should be separate courses. It is possible that highly experienced people can distinguish logistics weaknesses and find solutions for them but it is based on experience and not knowledge. The courses can provide knowledge for students".*

Question 2.2 in the questionnaire aims to understand what level of logistics knowledge the participants had attained in the university or any other type of educational institution. The results are tabulated in Table 18. Data gathered from the survey shows that a few participants had received enough education about waste management (8%), warehousing (8.73%), and transportation (10.24%). More than 47% of respondents said that they had no education about waste management, while more than 70% of them expressed that no or limited information had been attained in their educational period. The situation is better for construction material specification, scheduling, material protection and site preparation, as respectively 40.94%, 48%, 34.65%, and 22.22% of the respondents had enough education. This is owing to this fact that in the Civil Engineering course synopsis (confirmed by Supreme Council of the Cultural Revolution), construction materials must be taught to all students.

Lack of specialised staff is more crucial for fields, such as warehousing management, purchasing, marketing, and procurement, because there is no established university course to educated students in these fields. Hence, a warehouse coordinator neither has a relevant degree in warehousing management nor a construction related education. C12 stated:

> *"You can instruct people to organise the warehouse in a specific way or define a process for warehousing. But the warehouse coordinator should know the name of materials, their specifications, the way they should be protected, if they are sensitive or not, etc. These are topics that people should learn in the university in addition to warehouse management ... so I always say that if we want to employ a warehouse coordinator he should*

have a university degree. We should recruit an engineer, I mean an educated individual, even if his field of study is not related to his job. If you employ an engineer as a warehouse coordinator he can calculate everything and organise the warehouse neatly. If the warehouse coordinator has a relevant degree, that would be an ideal.

Table 18: Level of education participants received about logistics (F is frequency)

Logistics Fields	No Education		Limited Information		General Information		Enough Education		Total
	F	%	F	%	F	%	F	%	
Site Preparation	21	16.7	37	29.4	40	31.7	28	22.2	126
Supply & Support	43	34.1	35	27.8	34	27.0	14	11.1	126
Transportation	20	15.7	35	27.5	59	46.5	13	10.3	127
Warehousing	54	42.9	33	26.2	28	22.2	11	8.7	126
Handling Onsite	27	21.8	42	33.9	36	29.00	19	15.3	124
Scheduling	15	11.9	22	17.5	41	32.5	48	38.1	126
Construction Materials Specifications	8	6.3	18	14.2	49	38.6	52	40.9	127
Materials Protection	16	12.6	25	19.7	42	33.1	44	34.7	127
Construction Economy	34	27.4	33	26.6	36	29.00	21	16.9	124
Waste Management	59	47.2	29	23.2	27	21.6	10	8.00	125

The above solution may work for people with bachelor degrees in fields, such as general management, economy or business; however, it does not normally work for civil engineering or architecture graduates as these two courses are very prestigious in Iran and few engineers are eager to work in a project as a warehouse manager. To rectify this problem, C07 explained:

"For all logistics services you should recruit educated people [in the relevant logistics field] or if you do not find these people, all staff in the [related] departments should be trained properly".

Hence, as was explained above, internal training provided by the construction organisation can increase the knowledge of personnel. C17, who works for a leading general contractor company, clarified training sources in the following:

> *"We try to have internal training courses ... for example I may have experience [about a subject] or I have learnt something then I will teach and transfer my knowledge to others within the organisation. Also, our colleagues by attending training courses, participating in seminars, and professional courses attained knowledge".*

Therefore, training is a factor that needs much attention to improve the way logistics is done in the projects. Question 2.3 in the questionnaire asked whether the logistics staff had been trained in construction organisations. The respondents' answers to this question are summarised in Table 19. It indicates that the respondents believed only 4.69% of supply and support managers, 3.91% of buying coordinators and 1.57% have a university degree. As expressed before, this is owing to this fact that the Iranian universities do not offer courses in these fields. Yet, there are courses about finance, financial management and accounting. Therefore, the respondents explained 50% of financial managers have a university degree. Table 19 also shows that the respondents thought supply and support managers, warehouse coordinators, and buying coordinators learn their jobs from their colleagues: 67.19%, 65.35%, and 64.84% respectively. Another point in Table 3 is the participation of logistics staff in training courses. A few respondents believe that staff can be trained by attending courses. The lowest figure belongs to the buying coordinators, with 10.94%.

Table 19: Logistics staff's training (F is frequency)

Staff	No Training		Learning from Colleagues		Participate in Training Courses		University Education		Total
	F	%	F	%	F	%	F	%	
Supply & Support Manager	16	12.5	86	67.2	20	15.6	6	4.7	128
Financial Manager	9	7.0	31	24.2	24	18.8	64	50.0	128
Buying Coordinator	26	20.3	83	64.8	14	10.9	5	3.9	128
Warehouse Coordinator	24	18.9	83	65.3	18	14.2	2	1.6	127

As clear from Table 3, learning from colleagues is an important source of learning. The question is: how did the colleagues learn? They learn by doing the job and gaining experience. Thus, experience is a valuable source of learning. C15 illuminated this by giving an example:

> *"We did not know if we have a specific material in warehouse or not. For example the material is required today but it is not available onsite and this stops the project. Finding and purchasing that item from Tehran was time consuming. So, we set a rule that the site director should get an inventory each day to make sure the material that will be required next week is available in the warehouse ... these kinds of experiences have been gathered from different projects and we came to a conclusion that this [the standard process] is the most effective way and so we apply it in all projects".*

Based on the above quotation, the process of learning from experience has four steps:

1- Identifying the problem (a material is unavailable when required)

2- Finding a solution (daily inventory report to the site director)

3- Establishing a standard process (come to a conclusion about the most effective way)

4- Share and apply the standards (apply the solution in all projects)

Establishing a standard process has two parts: defining the standards and standard documentation. Defining a standard process was covered in the previous section in this chapter. Documentation supports the process of logistics in construction projects. To use the potential of experienced people, documentation is a must, since it makes sure that previous experiences can be utilised by the organisation members in the future. C03 said:

> *"For example one truck of gravel arrives to the site. A person can register the entering volume and the volume that is used. At the end we can collate these two figures and find out how much gravel is wasted. We can use this figure in our future projects as a valuable experience".*

Documentation should not be necessarily in text format. C03 explained:

> *"We also use multimedia [for documentation]. We use video recording, photography and editing tools ... we have a documentation department which uses these tools".*

Learning from the experience of others is also an effective way to enhance the logistics knowledge in organisations. One way is to adopt the standards developed by professional bodies, such as the Project Management Institute (PMI). Some leading companies use the Project Management Body of Knowledge (PMBOK Guide) to manage logistics. C17 said:

> *"Owing to the fact that we are a project oriented organisation, we use the procurement management methodology of PMBOK. I mean the stress is put on knowledge of PMBOK".*

Although adopting a standard methodology for managing logistics is an effective way of acquiring knowledge, again it needs training. Learning from others can also be through collaboration with advanced companies. C17 stressed this point:

> *"We documented all activities in the field of procurement ... we learnt this [documentation] from foreign companies when we participated in joint ventures. We got their templates, manuals, and forms ... so they [foreign companies] were our role model and we learnt from them and then utilised this knowledge in our projects".*

Another source of learning is conducting research. However, this way is not popular in the Iranian construction organisations. C03 clarified this in the following:

> *"We do not invest in research in Iran because of several reasons: First there is no security. When we get the desired outcomes from our research, others use these outcomes easily. In Iran most people prefer to be the second person [who develops or uses a new concept or technology] and take advantage from the research conducted by others."*

In conclusion, although the Iranian construction practitioners are familiar with logistics to some extent, there is a lack of specialised staff to conduct logistics tasks. It seems that the practitioners are aware of the importance of logistics and they are able to somehow manage logistics in the projects. Yet, their knowledge mostly relies on experience and not education. Establishing a course about construction logistics, teaching logistics as a module for construction related students, providing training for employees, adopting international codes for logistics management and promoting research are solutions that may be considered by construction organisations to improve the way logistics is managed in projects.

10.2.4. Cultural Factors

Culture shapes the values, behaviours, standards and principles of a society (Relationship CP1). Cultural factors should be considered in construction logistics. Knowing people's culture enhances the understanding of why and how they react to different matters. How to deal with suppliers or workers, how to face cultural issues and how to understand cultural norms are factors that need attention in logistics. In the chapter on the Iranian Building Sector, five strengths and five weaknesses of the Iranian culture were discussed (Table 20). In this section, the comments provided by the interviewees about cultural matters are explained.

Table 20: Strengths and weaknesses of the Iranian culture (Chapter four)

Strengths	Weaknesses
Collectivism and Family	Team-working Inability
Excitement and Joy	Law Aversion
Flexibility and Adaptability	Hypocrisy, Secrecy and Affectation
Positive Attitude towards Education	Criticism and Jealousy
Self-esteem and Self-sufficiency	Lack of Planning and Irresponsibility

The Iranian culture cannot be assumed to be a homogeneous entity. Metaphorically, it is described as being as colourful as Persian rugs. This is owing to the effect of the geographical position on culture (Relationship CP2). Iran has a variety of climates in different regions and this causes cultural differences in the country. C02 provided the following response when asked about culture:

> *"The culture is affected by climate and geographical location ... the nature is the cause of having different cultures. For example, in the desert area because the environment is harsh the people have to be hardworking and sufficient. So the culture is rooted in nature".*

Other interviewees had similar points of view to C02 and spoke about the culture of the different regions in Iran. For instance, some interviewees explained that the Azari people (North West of Iran) are diligent, the people who live in the desert have an economic mind, and the people who live in North strip of Iran are generous. Owing to the fact that construction may take place in different regions, understanding the local culture is important. This can be done by establishing an effective relationship with local people. Geographical location is not the only cause of cultural differences. The attitude of a society to certain matters, such as economy, technology, business and working, may also be a cause of cultural differences. C02 explained different attitudes to economic matters: *"we should know the society's culture. For example, different people may take a different approach to purchasing by credit or cash [some accept it and some do not]. This affects our performance in procuring the project".* N01 also mentioned business culture and expressed that *"our suppliers do not accept returned items. It is a culture that affects the whole supply chain"*. On the working culture, C02 commented: *"because labour is cheap in Iran, people do not use new technology. Some may say that if we use the technology the workers will end up with no job [unemployment]"*.

A few interviewees harshly criticised the Iranian culture in general. N06, C12, and C13 mentioned pretence, jealousy, fakery, skulduggery, unconscionable, and low commitment. For example, C12 said *"we do not have compassion, we are not trustworthy, we are not honest, and we are not committed"*. Some of these general issues have already been explained in Table 20. Other interviewees were against the critics. For example, C05 believed:

> *"In a society, there are different types of people. You see good people and bad people. In terms of suppliers, for example, some of them are responsible and honest and others are negligent and unfair".*

Some interviewees also pointed out more specific weaknesses in culture. N01 expressed:

> *"We have not paid enough attention to material wastage and [our construction site] is a mess and these are cultural issues ... [for example in a site you can see] concrete is poured on the ground. The condition of steel sections and glass are similar to concrete too. A culture should be developed*

> *for labourers, engineers and everybody who works onsite to avoid these issues"* (Relationship CW1).

A typical view of the interviewees was to understand cultural problems and find a way to deal with them. For instance, many respondents spoke about how to make relationships with different parties involved in the project such as suppliers (Relationship CS1). Most interviewees, such as N03, C06, C15 and C16, believed establishing an effective relationship with suppliers minimised the effect of irresponsibility, fakery, and low commitment. C06 stated:

> *"We attempt to have a meeting with the suppliers to reinforce relationships ... we try to keep our relationships fresh and versatile. So, when the suppliers receive our requisition, they will set a priority to fulfil it. We try to establish a continuous relationship".*

N03, also, expressed: *"when you build a friendship [with a supplier], in addition to monetary trust, he will do your job faster and better because you are his friend"*. This is aligned with the collectivist property of the Iranian culture, which was mentioned as a strength in Chapter four. In fact, making strong relationships with suppliers is an interesting example of using the strengths of a culture to cover its weaknesses. A strong relationship with parties can replicate the condition of a family where the families' interest has priority. Beside effective relationships, there are other ways to deal with irresponsible suppliers. C15 commented:

> *"If we feel a supplier is not committed we will stop working with him. [For example] the supplier says I would send your item next week but he does not send it. Or he sends half of the load or low quality material. In this case, the site authorities notice that the item does not have the expected quality and inform us to stop purchasing from that supplier".*

The above quote is about having a vendor list consisting of the specifications of suppliers and their ability. This topic was covered in Chapter nine.

Establishing a strong relationship is not only about suppliers, but also workers and staff. Most interviewees expressed that it is the job of managers to define the role of each individual clearly and inform the staff and workers about their roles and the company regulations. N05 made the following comment:

> *"A manager should set and apply some rules and regulations. The workers and staff should work within that framework. A construction worker in Iran follows his manager and not his conscience. I mean a competent manager can use a worker effectively but an incompetent manager cannot do the same with the same worker".*

Some interviewees thought that, in addition to setting rules, a manager should also create the culture. C12, who is a site director, made this clear:

> *"We should build the culture: for example, I walk in the site and when I see an item left on the ground I will take it and tell the workers that this item has a value. If you waste it, I will have to buy it again. Repurchasing reduces my financial power and then I cannot pay your wages. I build the culture in this way".*

Overall, it can be expressed that cultural factors may affect logistics in different ways ranging from relationships with suppliers to waste production. Each society has weaknesses and strengths in its culture. The role of managers is to utilise the strengths to overcome the weaknesses.

10.2.5. Site Layout

Designing the site layout is one of the early tasks that should be done before site preparation. Anticipating proper storage in the site layout can reduce material waste and designing access routes carefully can reduce time waste (Relationship LW2). The site layout can be affected by material handling methods. Decisions to use cranes, hoists, scaffolds and lifting equipment influence the design of the site layout (Relationship LH1). The amount of space required for storage, offices, and accommodation also affect the site layout design (Relationship LW1).

There is no single site layout because it should be changed periodically, as the condition of the construction site changes. Most interviewees explained that there should be at least a basic sketch as a site layout before the construction process is started. C12 expressed: *"at the beginning of the project, when the client hands over the land to us, we usually prepare a brief plan about the location of offices, construction area, warehouse, etc."* N05 commented on the process of site layout approval:

> *"Before starting the project, the contractor will prepare the site layout immediately after signing the contract. The client should collate the site layout with the master plan to avoid any contradictions. The consultant should confirm the site layout too".*

Yet, in some cases, not enough attention is paid to site layout designing. C03 made this point during the interview: *"our site managers do not have enough knowledge about site preparation and site layouts" (Relationship LK1).* The contractors' abilities to prepare the site was assessed by question 2.2 (the first cell) in the questionnaire. Figure 77 shows that 46.04 per cent of respondents had no or limited education about site preparation. C04, also, explained: *"we have a site layout but it is not clear and accurate".* Inattention to site layout designing may cause problems, specifically for the large size projects. N01 confirmed this and said:

> *"The site layout designing is an important topic. This will be more critical when the site is very large and there are several subcontractors working simultaneously onsite and you should plan in a way to avoid clashes between them".*

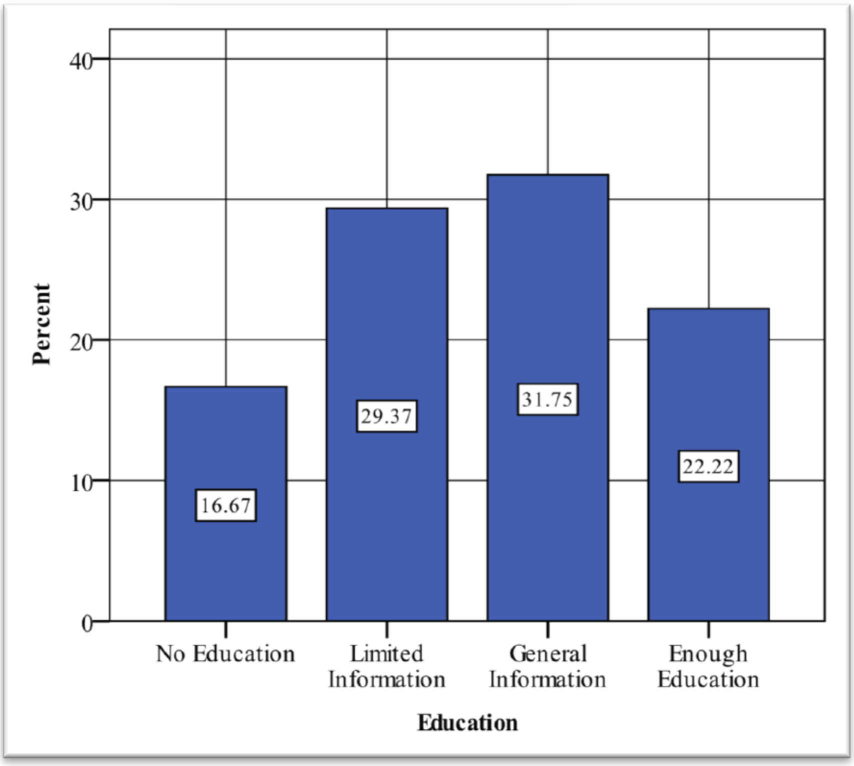


Figure 77: Site preparation education

N01 provided three examples to clarify that inaccurate site layout makes problems for the different parties working onsite:

> *"One example is stone cutting. It produces so much dust. If you have other subcontractors onsite that have problems with dust, this may interrupt their work. So you should think about it. Another example, for mixing concrete you need water. If you pour water from upstream and you have wooden materials downstream you will be in trouble. For example, when you are doing welding and you have inflammable materials beneath, you may damage materials and even you may have a fire onsite".*

The process of site layout preparation has three stages:

1- The client should allocate a proportion of the land for site preparation to the contractor. C12 said: *"we usually ask for a space in the site. He [the client] will give us one hectare for example. In that area we will design the layout"*.

2- The contractor should design the site layout (This will be explored in more depth in the next section).

3- The site layout should be confirmed by the client and the consultant. C15 described that the reason that the site layout should be confirmed by the client:

> *"We develop a site preparation plan. It should be confirmed by the consultant that no structure will be built in the future on the location we are going to use or there is no electricity cable in that location. Then we design a sketch that shows the location of offices, services, batching plant, etc."*

C12 described the situation when a contractor fails to get the client's confirmation for the site layout:

> *"The site layout should be confirmed by the client. Otherwise, you cannot get compensation if the client changes your site layout. This happened to us once. We installed our batching plant but the client decided to build on that area. The client paid us for removing the plant because he had confirmed the site layout at the beginning".*

In Chapter three, it was explained that most site layout researchers have used algorithms to find optimal solutions for site layout. The third stage of site layout design discussed above causes problems for researchers who aim to design an optimised site layout. It means that, even if an optimised site layout is designed, it may be changed by the client and moves far from the optimum state.

10.2.5.1. Site Layout Designing

In this section, factors that should be considered for designing a site layout will be covered. Some interviewees, such as N05, N06, C04, C08, and C12, provided a list of facilities that are needed onsite and should be considered in the site layout. The list has 19 items, including:

- Access routes
- Hoardings
- Security (access and egress)
- Patrol cabins
- Offices
- Canteen
- Accommodation
- Labs (concrete)
- Batching plants
- Fabrication area
- Cranes
- Open storage
- Closed/ Roofed storage
- Silos
- Construction machines service
- Utilities

Some of the above factors are stressed more by the interviewees. These factors are explored in the following sentences. The entrance, exit, and routes should be designed carefully. The way access routes are designed can reduce the time, cost, and labour of unloading and handling of resources. N06 said: *"in an effective site layout, the resources should be easily accessible and also as close as possible to the construction areas"*. C15 continued in similar way: *"the site layout should be designed in a way that reduces transportation distance and cost"*. C09 and C15, for example, pointed out access to cement silos. C09 said:

> *"The way your facilities are restocked is important. I mean for cement silos you should have a suitable route for the truck. So, the place you position the silos should allow the truck driver to move and turn easily"*.

Thus, factors that should be considered for designing routes are having close access to resources, reducing handling distance, and allowing convenient circulation of pedestrians and vehicles (Relationship LT1).

Another facility that must be provided on construction sites are site offices. The type and numbers of offices depends on the size of the project. C12 makes this clear in the following:

> *"Facilities required onsite may change according to the size and financial weight of the projects. For example, once you may have a contract with the value of £500,000 and once the project costs £15 million. In a £15 million project we need more offices. There are more engineers, secretaries, estimators, and planners. So, based on your needs, you define and calculate your space requirements. Sometimes the client asks us to give him office spaces"* (Relationship LP1).

As N06, C08 and C12 pointed out, the critical people that should be provided with office spaces are the site director, project manager, client (representative), financial and administration manager, technical office, consultants, and general staff. The offices may be built by traditional materials and then converted to a residential or commercial building. Yet, most interviewees mentioned that they use temporary structures. C12 clarifies this point:

> *"In Iran usually modular units are used for accommodation [offices]. But we are going to use prefabricated and portable spaces, since they are nicer and more reliable. Meanwhile, transporting and erecting these temporary spaces is easier and can be done without the crane".*

The location of the offices is also important. Some interviewees expressed that the offices should be positioned in a place that is close enough to the site and, at the same time, noise and dust do not bother the staff. N06, also, said: *"it is better to locate the site director's office in a place that has a good view of the site"*. Overall, factors affecting site offices are the size of the project, the client's needs, the contractor's needs, distance to the site, access to the site, and required working conditions.

An important part of site layout designing is to decide on the type and volume of storage space required (Relationship LW1). Determining the volume and type of storage areas highly depends on the types of materials and the logistics schedule (Relationship LS1). C02 stressed the importance of delivery sequence in designing site layout and stated:

> *"We usually know what we need for a project. And we always should store a proportion of materials needed onsite ... [Yet], because we have limited space we ask the suppliers not to send all the materials we need in one batch, since we should allocate the storage, prepare the place and inform the workers [for unloading the materials]".*

Generally, three types of storage area should be considered. C12 explained two of them:

> *"We have open and closed storage area. The closed area is usually used for sensitive materials or small materials with a high risk for theft. The open space is used for machines such as compactors. There are also some materials that need special care such as paint that should be kept in a ventilated place".* There is also the third type that C09 described as *"roofed area for storing materials such as steel"*.

Material handling methods affect the design of the site layout (Relationship LH1). The strategic positioning of the storage areas and fabrication spots reduce handling distances and minimise the chance of re-handling. Determining the cranes' position is also critical and needs much information and experience. Moving a tower crane is impossible during the course of the project and moving a mobile crane is time consuming. Therefore, issues such as access to the materials, loading and unloading areas, spinning diameter, boom length, and maximum weight capacity should be carefully considered. N06 commented on mobile cranes: *"It takes about half a day for a mobile crane to change its position. So we cannot do it frequently"*. About the tower cranes, C04 said:

> *"We have a site plan that shows the location of buildings and routes ... [moreover] we should decide about the position of the tower cranes. The path they move and the area that they feed should be decided. Also, some areas should be anticipated for temporary storage of materials. These areas*

should be close to the routes for easy access. The crane will take the load from these areas and handle it to the point of use".

In all construction sites, there should be a place for fabrication and mixing materials. Suitable grounds for mixing mortar, making steel meshes, welding, steel cutting and concrete mixing should be anticipated. The most important item here is the batching plant as it cannot be moved easily. C09 said: *"for large projects it is better to have silos for storing cement and a batching plant for mixing concrete. It will be cheaper in comparison to ready mix concrete"*. Three points should be considered in the positioning of the batching plant: (a) the noise and dust, (b) distance to the construction area, and (c) the routes that vehicles need to feed the silos and deliver concrete to the construction area. C15 explained *"the batching plant should be positioned in a location where its noise does not bother others"*. C09, also, commented on the position of the batching plant:

> *"In the case that the batching plant is so close to the construction area you cannot build the building easily and you cannot alter the plant location. Hence, the distance of the construction area from plants and facilities should not be too short that it disrupts the work".*

In terms of the site security, N01 said: *"the construction sites usually have patrols that control access and egress points. The site is usually confined by fences and it has a gate. The patrols control everything accurately"*. N05 explained who is responsible for keeping the site secured: *"keeping the site secure and employing patrols are the contractors' role on projects"*. Although the contractor is responsible for site security, the client may set some rules. N01 clarified this in the following:

> *"In a large project the client allocates some spaces to the contractor. The client also decides about working hours and even checks the pedestrians and traffic entering and exiting the site. The larger project, the more accurate controls will be carried out".*

C04 described the way security is managed in his site:

> *"We have a patrol cabin which controls the gate and does not let unauthorised people to come in. Nobody can take out any item from the site unless the site director signs the relevant documents. I mean exit permission*

> *should be attained. When a load arrives to the site the patrols check the truck to identify what the load is. Then, the patrols contact the supply and support office or warehouse and if they confirm the load, the truck can come in to the site. The patrols will guide the driver to the right location".*

Some companies take security more seriously and transfer this responsibility to a specialised firm. C0 indicated this: *"we work with a security company. They are linked with the police and they are not a private firm. I mean they are recommended by the police"*. Keeping warehouses secure is also an issue, as small valuable items or tools may be robbed easily. C02 expressed how he secured the warehouse:

> *"We isolate and cover the underground floor of a building block that has an area of 3000 square metres. It has only one access point and we use it as a secure warehouse".*

In general, keeping the site secure involves fencing, installing patrol cabins and gates, controlling enter and exit points, determining working hours, authorising pedestrians and vehicles going in and out, guarding the site, installing security features, protecting storage areas, and guiding visitors and drivers.

The way site layout is designed is different for urban projects, although there are some similarities. In urban projects, the space is often tight and this makes the site layout designing more difficult (Relationship LP1). The researcher observed that the layouts of urban sites were usually chaotic, while the layout of large sites had better conditions. As clear in Photo 22, there is no sign of organisation in the site. It seems that different items are put wherever there was a space without any plan. This makes the site untidy and increases waste. Even moving in this site was hardly possible.

Photo 22: The layout of an urban project in Tehran

In urban projects, as stated before, the land may be on the north or the south side of the street (Figure 53). This affects the design of the site layout. About the north side projects N03 said:

> *"In urban projects if, for example, the area of the land is 300 square metres, 200 square metres will be constructed and 100 square metres remains. If the land is located in the north of the street, we can use the footpath to make a ramp for the loader for excavating. We, also, build two or three rooms as site office and workers' accommodation. So, the workers can sleep there until we raise the structure. Moreover, we should find a space to store the old bricks temporarily which is again in the footpath".*

For the lands located in the south of the streets, N03 continued:

> *"If we have a land in the south, we build a few rooms in the yard with very thick walls around 10 to 50 centimetres thickness. This helps us to both use bricks for building rooms and store bricks as they are used to build thick*

walls. When the structure is raised, these bricks can be used in the main building or for making a patrol cabin or site office. The bricks should be laid in a way that we can use them when required for the main building".

Storing materials in the street frequently happens in urban projects in Iran. Photo 23 illustrates a storage of bricks out of the site boundaries and in the street. Other materials may be stored outside. For example, C18 said: *"we have to store steel rods in front of the site (on the footpath). We have patrols to watch the rods"* (Photo 24). The municipalities have set rules for storing materials on the street. N03 explained the rule in the following:

"The law says we can occupy two metres of the street [for storing material, etc.] but you cannot exceed even one brick. Also, we should have proper fencing to protect pedestrians and cars from falling down [in the excavated area]". C16, also, commented on the rules and said: *"we should use some [warning] signs. Also we need to cover the face of the building with sack or wooden hoardings".*

Yet, these rules are not practised mainly because of the practitioners' law aversion habit which was expressed in Chapter four as a problem for the Iranian culture.

Photo 23: Storing bricks out of the site boundaries (the land located in the north of the street)

Photo 24: Storing steel rods in the street

Dealing with neighbours is also an issue in urban projects, when the site layout is not designed properly. C16 described the way he establishes a relationship with the neighbours in the following:

> *"In one of my projects, I wanted to build a concrete structure. The length of a steel rod is 12 metres and the width of our site was ten metres. We asked one of our neighbours not to park his car in the street so we can store the rods there. And we had to cut the rods to the size quickly to bring them in. We always have these issues and we get permission and negotiate to solve the problem in a friendly manner".*

Positioning the cranes in urban projects is also problematic and causes health and safety issues for both workers and the neighbours. Many cases were observed where the crane's boom is so long that it exceeded the neighbours' lands (Photo 26). Unfortunately, there is no limitation about the use of crane in urban areas and many accidents have been reported specifically about the cranes collision and collapsing. Figure 25 shows a collapsed train that damaged a neighbouring house.

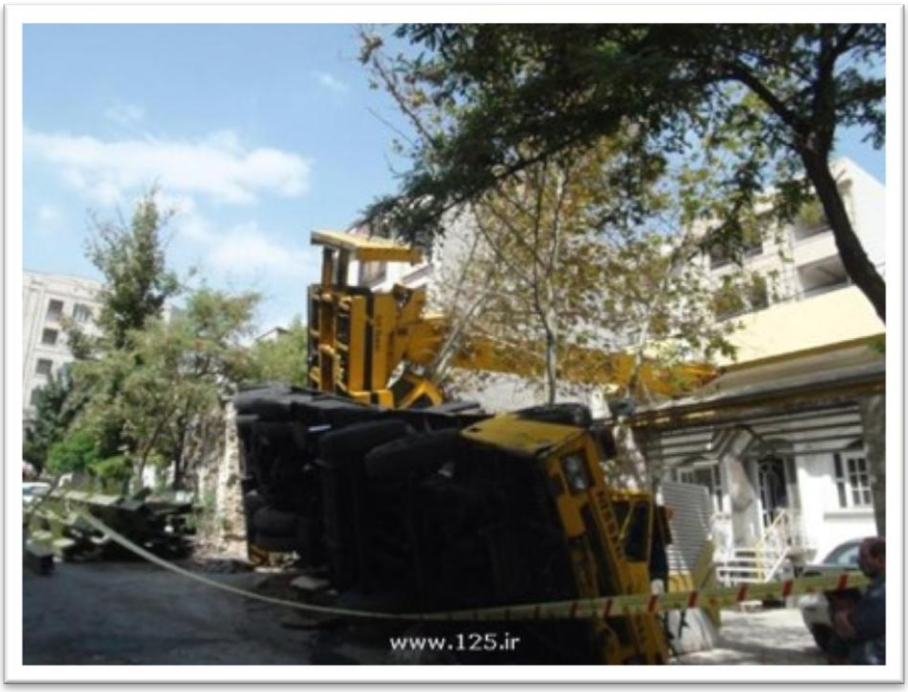


Photo 25: Collapsed mobile crane (Tehran-Fire-Station, 2010)

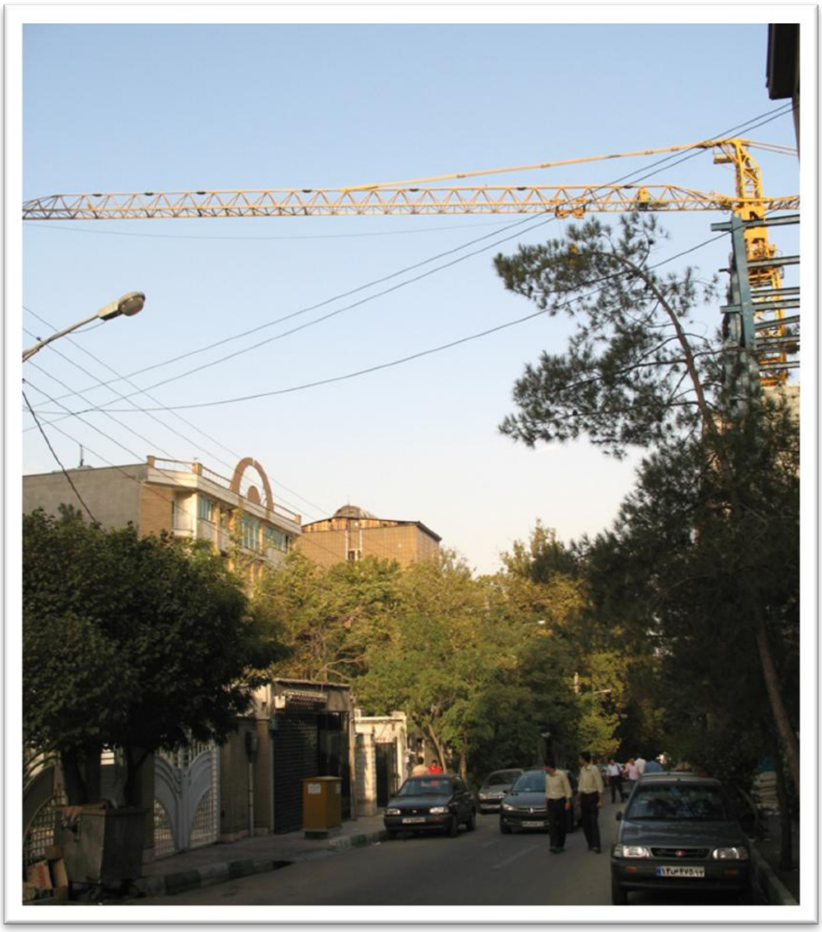


Photo 26: The boom of a tower crane that exceeded the allowed length

At the end of this section, the organisation agents of the construction logistic system is shown in Figure 78. This figure shows the relationships between organisational agents and other agents of the model.

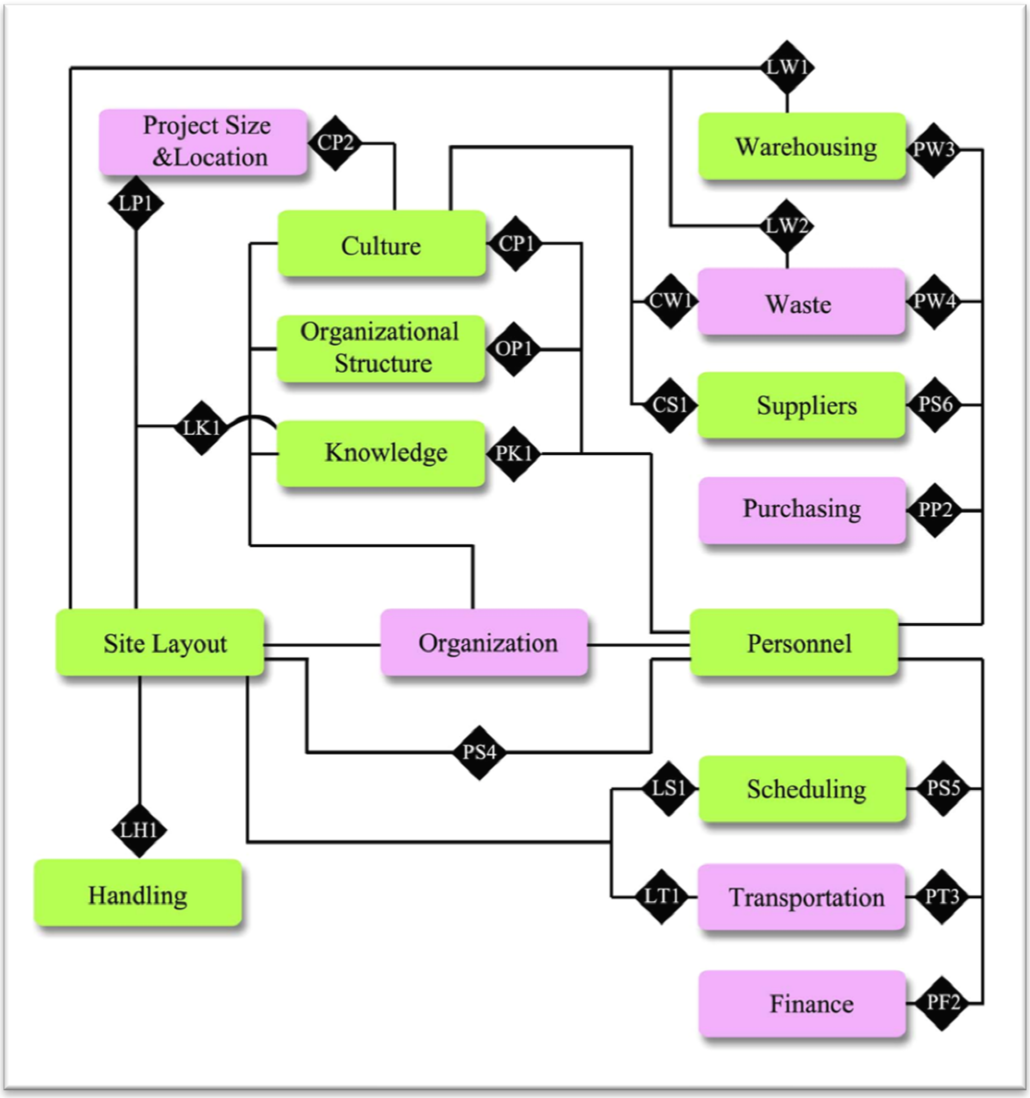


Figure 78: Organisation agents of the construction logistics model

10. 3. Information Management

Prompt and fast access to accurate and reliable information is key for different organisations to achieve success. In the construction industry, the role of information is vital. A typical construction project usually starts with a set of information from a client. The client's information will be processed by consultants to generate data for contractors to construct a facility. In fact, information acts as the glue which binds the different phases of the construction process. In this section, interviewees commented on the types of information they require for managing logistics and the sources that can be attained. Also, there is a subsection which explores how construction firms utilise ICT in Iran for logistics tasks.

The value of information is recognised by the interviewees, such as C03, C08, C11, C15, C16 and C17. C08 explained *"We need information to plan properly"*. C17 continued in a similar way and commented: *"Information is the base of decision making"*. In general, interviewees expressed that the most important information required for managing logistics is marketing information, supplier information, schedule and inventory.

In terms of marketing information, C08 said *"the first thing we should know is the condition of the market. [Also], we should know how many building permissions are issued and how much area is going to be constructed in a year"*. This kind of information helps the firms to anticipate peak construction periods (Relationship IE1). The impact of the economy on logistics was explained in the Finance section of Chapter nine. To obtain marketing information, the companies usually use Governmental publications. C08 said: *"we subscribed to some [governmental] organisations and they send us information about bids, materials, codes, and regulations".* N02, also, explained: *"about the price of land, housing and letting we use publications of Ministry of Housing and Urban Development"*. Although the Governmental publications are the most reliable sources of information, for some respondents they are not accurate enough. For example, C11 stated: *"you need accurate and prompt information ... unfortunately the Iranian organisations provide us with old information dated back to three years ago"*.

Another type of marketing information required is about product specifications and prices (Relationship IM1). Most interviewees expressed that they usually attain this information by contacting suppliers. C16 described the process: *"we first decide on the technical specification of materials we need. Then we start searching for suitable materials by gathering information from suppliers"*. The Governmental organisations, also, provide information about manufacturers and suppliers. N02 made this clear:

> *"Industrial Development and Renovation Organisation of Iran (IDRO) and Ministry of Industry, Mine and Trade have several publications and leaflets*

which provide us with information about manufacturers, their products and their abilities".

However, there is no integrated source for sharing construction marketing information in Iran. C11 highlighted this in the following:

"One of the biggest problems is the lack of an information gathering system about marketing matters. [For example] we bought concrete formwork from X [a German company] a few days ago. All prices are available online in their website. I mean that the company provides us with clear information. But in our country we do not have this transparency. There should be a [Governmental] organisation that provides us with information about prices. A couple of years ago we had a sharp price increase ... Its main reason was the lack of information ... you should have information to distinguish if you carried out a correct purchase or not".

Scheduling also provides information for logistics (Relationship IS1). C17 explained:

"The information tells us the order point and the time the order should be set. It shows when we should order to get the items on a certain date onsite considering transportation and lead times".

The stock information and inventory were critical for many interviewees. N02, C11, C15 and C17 specifically expressed that the stock information ensures that products are ready and available when the different parties want them (Relationship IW1). C17 pointed out this in the following:

"[Stock] information is a key. You should know the rate of consumption of each material in your project ... you may have to balance two projects that you have at the same time. [I mean] sometimes you have shortage in one project and to avoid stopping the work you bring materials from other projects".

Balancing resources in different projects is a subject discussed by other interviewees such as C15, who stressed this in the following:

"When we enter a bid, we take a look at the information we have from other projects. [For example] we see a truck mixer or loaders are free in other

> *projects. By taking a glance we know that we have 100 Tons of scaffolding in a project and there is no need for them in that project. This will affect the price that we offer to the client because we do not need to buy them. If we do not have the items, we should buy them and this increases the costs".*

Interviewees also highlighted the importance of information and communications technology (ICT) in preparing and sharing information. C17, particularly, emphasised the importance of ICT. He explained that his company learned how to utilise new ICT features from international journals and periodicals. The next section will explore ICT in more detail.

10.3.1. Information and Communication Technology (ICT)

The level of ICT utilisation in the construction organisations in Iran is variable depending on the size of the firms (Relationship TS2). Most interviewees were aware about its importance in projects and the impact that it may have on logistics management. Some interviewees expressed that they have an ICT department in their companies. C14 described the responsibility of ICT departments in the following: *"this department offers IT services to all other departments, prepares required hardware and software, and controls wired and wireless communication".*

N03, N05, C03, C06, C08, C11, C14, C15, C16, C17 commented on the importance of ICT for logistics and the way they utilise its power in their organisations. The benefits of ICT utilisation from the interviewees' viewpoint are information accuracy and integrated environment. About accuracy of information, C17 said:

> *"We require different types of reports. Before using IT there were some inconsistencies between the reports produced by different departments. I mean many mistakes could happen. But by using IT the mistakes are minimised and limited to data entry stage only".*

Another benefit of ICT for logistics management is providing an integrated environment that links the different parts of the logistics system together. C08 stated:

> *"Logistics from one side is connected to the financial department, from the other side it is connected to the warehouse, and from the third side it is connected with trading and purchasing. We have software which gives us all*

the information about these issues in one package and is compatible with the trading environment of Iran".

An integrated environment can link several projects of a company together even at the international level. C03 expressed *"in our Venezuela project our IT system is linked to the financial department, procurement department and warehouse. The Tehran office is also linked to them".* In their company, all projects, whether national and international, are linked to the head office. Hence, they can attain information about the financial situation, order conditions and inventory for a particular project accurately and quickly.

According to data gathered from the interviews, the Iranian firms utilised ICT to manage logistics in four ways: (a) documentation and archiving, (b), warehouse management (c) estimation, and (d) communication.

The estimation data, order receipts, schedules, site layout drawings, financial reports, suppliers' information, inventory reports, materials specifications, and delivery reports are logistical documents that were mentioned by the interviewees. This information should be stored, shared and retrieved during the course of a project. C06 and C11 expressed that they prefer to use IT for archiving and documentation because of the following reasons:

- Fast searching feature
- Filtering information
- Effective categorisation of information
- Easier access to information
- Mobile access to information (carrying information on laptops)
- Small space and low weight of information storage (e.g. external hard drives)
- No need to make several hard copies of a document
- Online access

Logistics data are not limited to text documents only and, as C16 expressed, digital photos, videos and voices may be archived in construction projects.

An area that has the potential to receive benefits from utilising ICT is the warehousing and storage process. ICT enables different people to have enough information about the stock levels and inventory in each project (Relationship TW1). C15 said: *"using the warehousing software, the site managers are always informed about what they have and what is required in different projects"*. Some warehouse management software is web-based or is accessible through the companies' portal. For instance, C17 commented: *"we can sit in the head office and obtain real time and up-to-date information about our warehouses in different projects"*. C14 described the process of a computerised warehousing system in the following:

> *"We assign a specific code to each item when it arrives to the site ... then this code and specification of the item [quantity and purchasing documents] will be inputted into the software. The software is a part of our administrative department and they can share information among the people who require it. When an item is needed [by a party onsite] again it is mentioned in the software and its quantity will be reduced from the stock".*

Cost and quantity estimation of materials is another field where ICT can help. Several software packages are available on the market that can be used according to the size and complexity of the projects. As C16 and C17 confirmed, the basic function of all estimation software is to produce organised tables that shows the description, units, amount, cost per unit, and total cost of different tasks (Relationship TE1).

In addition to this, ICT enhances the level of communication between the different parties involved in the project that is key in logistics management (Relationship TS2). C14 believed that *"one basic benefit of ICT is that people can communicate with each other easier and this increases the speed of decision making"*. C17, also, described the way that ICT helped his company to communicate with its international projects:

> *"[when we intend to have a meeting with our site managers abroad] instead of sending eight people there, we can sit in front of a computer in Tehran and have a video conference with the site managers while watching the progress of work using the cameras installed onsite".*

Use of ICT in construction projects may also be problematic. Some interviewees were worried about information security and data loss. However, N03 and C03 stated that there are several solutions for these kinds of problems. C03 said *"in many cases hard copies of important documents were kept"*. N03, also, described that his company defined information access levels for different users. He added *"we take regular backup from our information ... often two copies will be made on DVDs"*.

Another problem is the weakness of the ICT infrastructure and, specifically, internet connections in Iran. C14 expressed that the current ICT facilities are not enough for effective communication. Yet, C06 believed that even the current infrastructure cannot be used by the organisations because, for example, the Government does not allow the companies to use the current capacity of the internet connection. He explained this by using a metaphor: *"we have the roads. But we block them and force people to use a narrow rugged route"*.

C03 and C17 pointed out another issue about the infrastructure. They expressed that there is no standard that obliges all firms to adopt a certain level of ICT in their organisations. C03 said: *"many organisations that work with us have not utilised ICT and they asked us for hard copy of documents"*. C17 discussed the clients' role in using ICT in the following:

> *"We are in direct contact with the clients ... there should be some arrangement that makes the clients up-to-date in terms of ICT. Otherwise, if only contractors adopt ICT it does not help so much"*.

A few interviewees expressed that resistance to change can be a problem for ICT adaptation (Relationship TC1). C17 stated that *"some staff may feel that ICT will take their jobs ... Or some people do not trust in the results produced by the software"*. He continued *"the company is like an old moving train. We should be able to repair this train while it is moving. So, changes and using ICT should be gradually done"*.

Another problem about ICT is that, in undeveloped areas, staff are not competent enough to work with complex software packages (Relationship TK1). C08 highlighted this issue in the following:

> *"In undeveloped regions, employing a competent IT user incurs a high cost ... So; we should make sure that the client has the enough financial power to*

cover these costs. When the client pays the fees irregularly we are not able to employ expensive staff who are able to work with different software".

C08, also, criticised ICT from another angle: *"when everything is in an electronic version if the responsible employee leaves the job the new person will have problems in finding relevant information because there is no hard copy of documents"*. To minimise the effect of the two issues explained by C08, as N05 mentioned, enough ICT training should be provided.

Based on the relationships identified in this section, the 'information' agent of the construction logistics system is developed (Figure 79). Figure 79 illustrates the relationships between 'information' and 'ICT' with other agents of the construction logistics system.

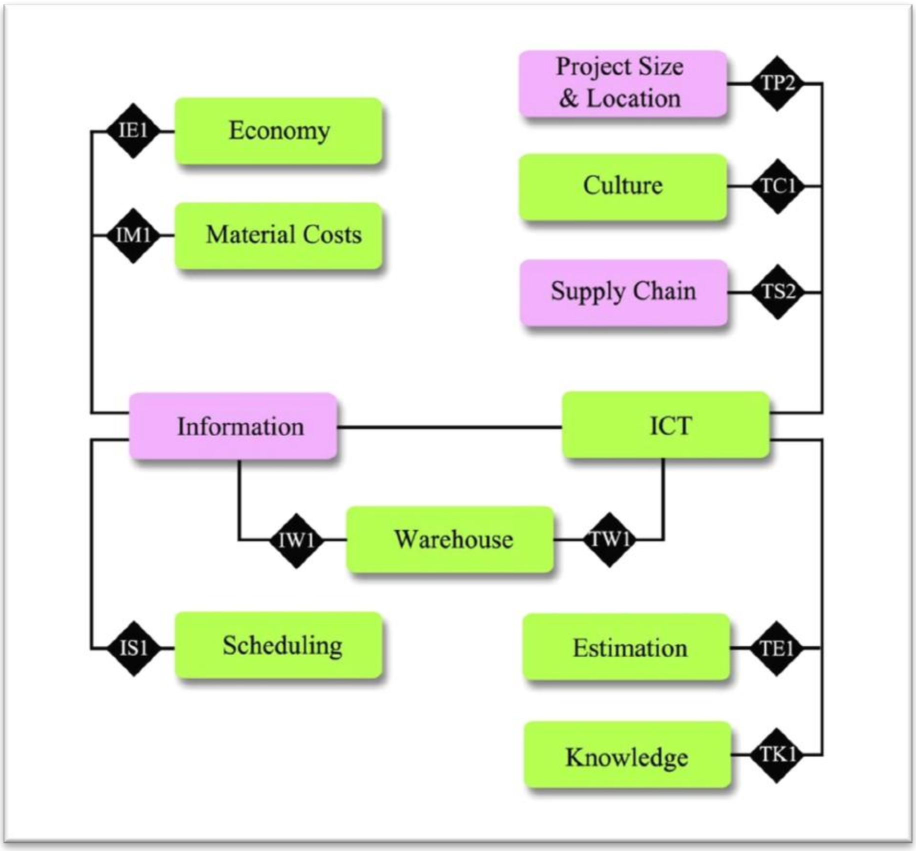


Figure 79: Information agents of the construction logistics model

10. 4. Logistics Scheduling

Logistics scheduling is about having the right materials at the right time. It includes planning for purchasing and delivering materials to the construction site. The relationships identified between scheduling and the other agents of the construction logistics system include information (Relationship IS1), site layout (Relationship LS1), material shortage (Relationship OS1), peak working season (Relationship PS2), personnel (Relationship PS5), purchasing (Relationship PS7), and weather conditions (Relationship WS1). This section first explores the issues related to order time and lead-time, and then material delivery matters will be discussed.

To get materials when they are needed, they should be ordered ahead. N06 said *"the time of purchase depends on the project's schedule"*. Some interviewees, such as C01, C04, C09, C12, and C15, believed that order time should be in accordance with the project schedule. C01 stated *"when the schedule is ready, it is easy to work out the amount of materials needed for each task ... the CPM shows what materials, in how much volume and at what date they should be available onsite"*. C04 also commented *"the project manager takes a look at the CPM and says for example in the next month we should start installing mechanical components. Then he applies for purchasing items"*. C12 described the process in more detail:

> *"The technical office sends detailed materials specification to the project control unit (PCU). The PCU determines the order time based on the schedule, the time materials are required, the project needs and progress of work. The PCU should inform the site supervisor about the purchase and delivery times".*

C15 introduced an effective tool that can be used to determine the order time effectively. He elucidated:

> *"For each project we have a resource booklet. In this booklet it is mentioned that for the first month we need 100 Tonnes of cement and in the second month 1,000 Tonnes of aggregates. This booklet is developed based on the drawings and the project schedule. [For example] when we want to construct the foundations, we calculate the volume of steel rod, formwork, and concrete required based on the drawings. Then we convert these data to graphs (Figure 81). For example we have a graph for gravel consumption in*

each month. We also assign a cost to each item. For example if we need 300 Tonnes of gravel in a month, we assign an average price of £0.25 per kilogram to it and say in that month we should pay £75,000 for gravel".

C15 also provided a table (Figure 80) that shows the amount of some materials which are required each month from the inception to completion of a project. Moreover, he gave a copy of a graph that illustrates the volume of cement required each month (Figure 81).

مصالح اصلی مورد نیاز ماهیانه پروژه

List of Construction Materials for Monthly Usage of the Project

ردیف Row	مصالح Material	واحد Unit	2006-2007	2007 - 2008												2008		جمع کل Total
			(Feb - Mar 07) اسفند	(Mar - Apr 07) فروردین	(Apr - May 07) اردیبهشت	(May - Jun 07) خرداد	(Jun - Jul 07) تیر	(Jul - Aug 07) مرداد	(Aug - Sep 07) شهریور	(Sep - Oct 07) مهر	(Oct - Nov 07) آبان	(Nov - Dec 07) آذر	(Dec - Jan 08) دی	(Jan - Feb 08) بهمن	(Feb - Mar 08) اسفند	(Mar - Apr 08) فروردین	(Apr - May 08) اردیبهشت	
1	شن با ۵٪ پرت Gravel 5% W	ton	_	_	841	1,630	2,171	682	44	1,282	1,425	1,425	142	_	_	_	_	9,642
2	ماسه با ۱۰٪ پرت Sand 10% W	ton	_	_	980	1,899	2,531	795	51	1,493	1,660	1,660	166	_	_	_	_	11,235
3	سیمان با ۵٪ پرت Cement 5% W	ton	_	_	374	724	966	303	19	570	633	633	64	_	_	_	_	4,286
4	آرماتور با ۳٪ پرت Rod 3% W	ton	_	_	142	279	531	300	20	448	498	498	67	_	_	_	_	2,738
5	آهن‌آلات با ۵٪ پرت Steel 5% W	ton	_	_	_	_	_	_	49	49	49	49	49	49	49	49	49	411
6	سیم آرماتوربندی Steel Wire	ton	_	_	1,450	2,840	5,410	3,060	200	4,570	5,080	5,080	680	_	_	_	_	28,370

Figure 80: The amount of materials required each month

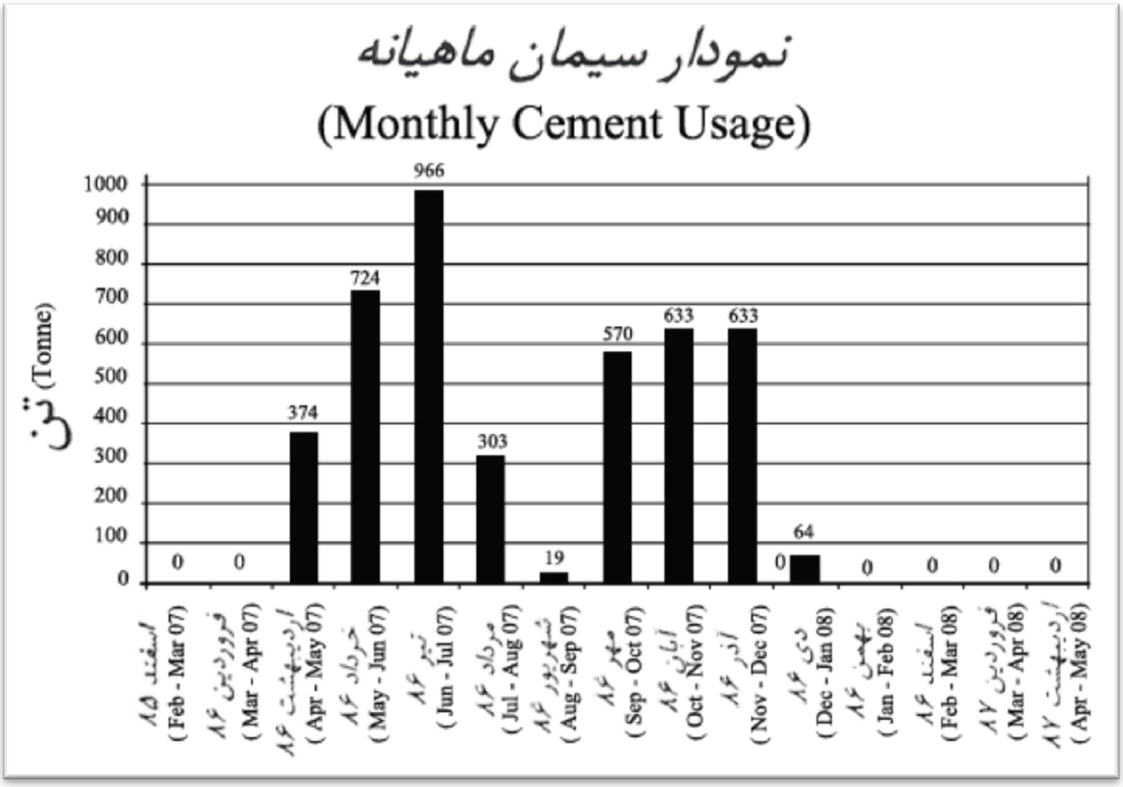


Figure 81: The volume of cement required each month

Determining order time based on the CPM is not always easy to do. N06, C07, C13, and C15 explained that following the schedule is not possible in Iran. C13 said:

> *"We are not successful in following the schedule. Some projects were scheduled to be completed in three years but they lasted around six years ... Different factors such as financial problems of the clients endanger the schedule (Relationship SF2) ... in general following the schedule is very difficult".*

Another threat for the schedule was expressed by N06: "*drawings may be changed during the course of the project and this leads to changes in the schedule and alterations of purchasing time" (Relationship SN1)*. To solve these problems, C07 expressed that the schedule should be updated regularly. C15 said:

> *"If the delay is not so long, we will make the schedule up-to-date. But if a project is delayed for three months we develop a new schedule. We have staff that are responsible to plan and control the schedule".*

However, C01 believed amending the schedule constantly is not feasible:

> *"When a project is in financial difficulties, having an engineer [as a planner] to continuously do corrections on the schedule is useless. We have staff that amend the CPM owing to changes in drawings or mistakes. But it is annoying if you change the schedule every day because of unpredictable events such as financial problems, lack of equipment, material shortage, and inflation. It is not doable".*

Some interviewees, such as N05, N06, C02, and C07 described other methods for determining order time based on experience. N06 expressed *"we anticipate procuring materials on a monthly basis based on bills of quantities"*. N05 stated:

> *"Before starting the project we calculate, for example, we need 30,000 Tonnes of cement in 20 months. So, each month we need 1,500 Tonnes of cement. Based on experience we can say that always 2,000 Tonnes of cement should be available onsite".*

C07 also said:

> *"We develop some tables for the materials we need. For example, four months later you want to do stonework. The type, specification and dimension of the stone should be determined now. This helps us to find sources and gather quotes".*

Some contractors prefer to buy materials as soon as possible if enough space is available to store them. C04 said *"in a chaotic market the winner is the firm that buys materials early. For example, the price of steel was £0.20 per kilogram two years ago and currently it is around £0.7 [per kilogram]"* (Relationship SC2). N04 had a similar experience:

> *"In the previous project I bought eight air conditioning units early when I erected the structure. The reason was that the supplier told me if you buy them now you can get discount but in six months time there is no discount and the price may go up".*

C18 also stated *"we usually buy materials such as cement and steel early. So, our project is never stopped for material shortage or late delivery" (Relationship OS1).*

Some interviewees criticise early purchase of materials. C09 confirmed this and stated:

> *"For example, according to the schedule, I know that I will need isolation in September. I start the purchasing process in August. I do not buy sooner because we do not have enough storage space onsite (Relationship WS2)".*

C01 added:

> *"Some materials such as cement should be always available onsite. So, one or two bunkers of cement are always stored onsite. But for steel sections, the order is exactly based on the specification determined by the consultant. All steel sections should be delivered to the site at a specific time in two or three batches ... or steel rods should be available just in the time needed because they occupy a large space. But small items may be stored onsite for longer" (Relationship WS2).*

C17 also elucidated *"[we do not buy materials early] because this freezes our capital. Furthermore, it needs so much space for storage and we should move towards JIT".* C04 approached the topic from another view: *"it is possible that you buy a material early and then its price decreases".* C08 confirmed this and expressed *"two months ago we intended to buy steel for one or two years' consumption ahead. We were lucky that we did not do so because the steel price decreased"* (Relationship SC2). C04 summarised the problems of early purchasing:

> *"If you want to buy materials early, you should freeze a large proportion of your capital. If you consider the interest rate, you will notice that you do not make profit. [Furthermore,] when you buy early, you should allocate a large space to store the materials. So, you need to build more warehouses and employ more people to manage those warehouses and these incur much cost" (Relationship WS2).*

N01 also believed order time also depends on the space availability onsite: *"it will not be beneficial if you purchase materials before erecting the structure. Suitable storage space should be provided first"* (Relationship WS2). C07 explained *"we check our stock level at specific times and if the stock level is low for a material we arrange a purchase".*

To investigate purchasing time in more detail and understand when the respondents order materials, question 4.1 was assigned to this subject in the questionnaire. As Figure 82 illustrates, the majority of respondents (55.8%) explained that purchasing is conducted based on schedule. It shows that, although following the schedule is challenging, it is still the main tool for determining the order time. More than 40% expressed that they determine purchasing time according to their experience, while only 1.6% start buying materials when the stock is finished. It is interesting that 8.5% of respondents chose the option of buying materials as soon as possible. It shows that, the traditional approach to purchasing time still exists among practitioners.

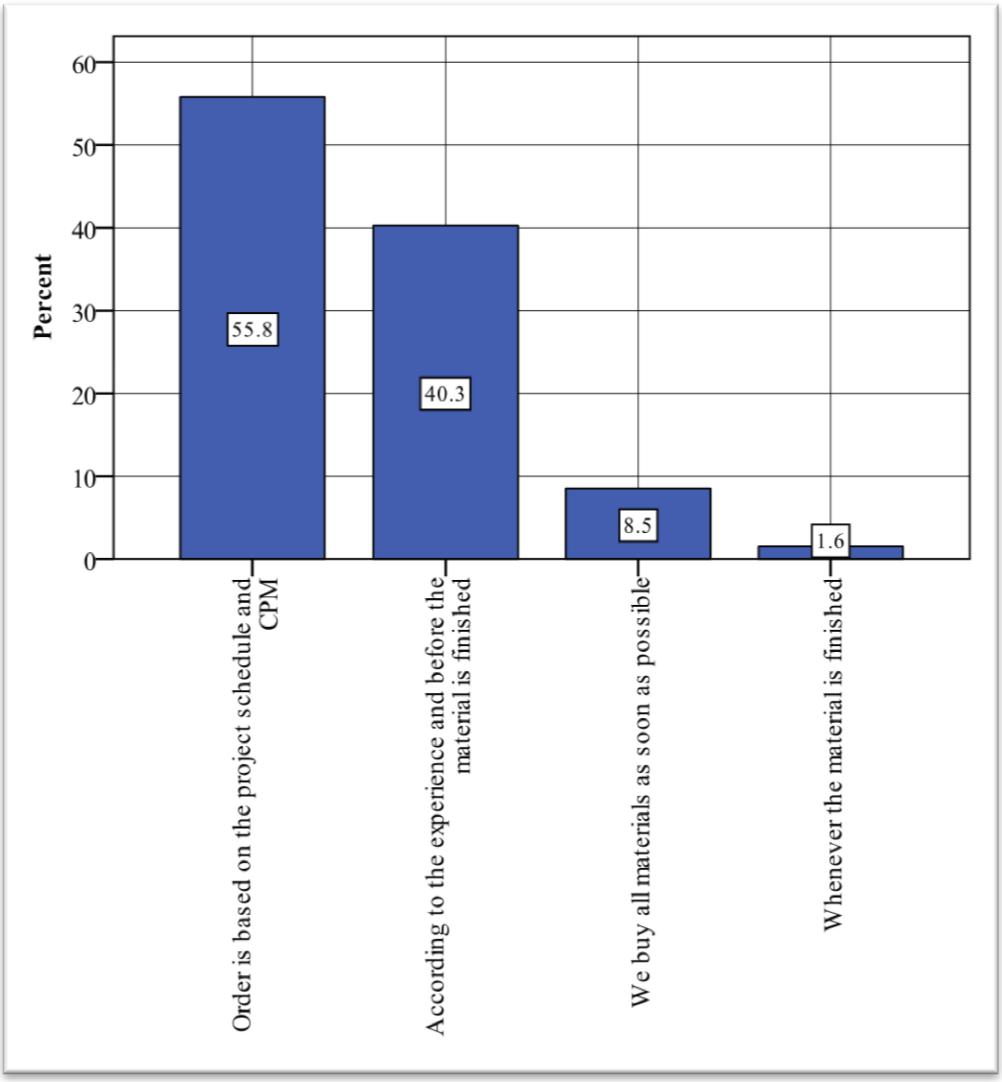


Figure 82: Order time preference

Other factors that affect order time were highlighted by C03 as delivery time (Relationship DS1), indifferences, and the project schedule. N03 and N04 explained that indifferences and low commitment are factors that ruffle the schedule (Relationship SS2). Beside these, C18 expressed the heavy financial load of some items may affect the logistics schedule (Relationship SC2):

> *"For high value items we may experience a delay in the schedule. For example the lift costs around £100,000 or windows cost £170,000 or chillers cost £250,000 each. For these items sometimes we have to stop the project to prepare the money".*

Another important factor that affects the logistics schedule and was mentioned by a few interviewees is lead-time. C02 said *"in some cases the manufacturer tells us that he can deliver the product to the site not sooner than 15 days"*. C13 also gave some examples: *"once the foam manufacturer told us that our order may take 20 days to be met or for ready-mix concrete sometimes we have to wait one or two months"*. To discover more about lead-time, questions 4.2 and 4.3 were dedicated to this subject in the questionnaire. Question 4.2 aims to clarify if respondents consider lead-time in the logistics schedule. The result summarised in Figure 83 shows that more than 80% of respondents consider the lead-time when planning to purchase materials. Moreover, half of the respondents expressed that the numerical data for determining lead-time is accurate. Less than four per cent said that they do not consider lead-time, while 14.7% stated they rarely consider it.

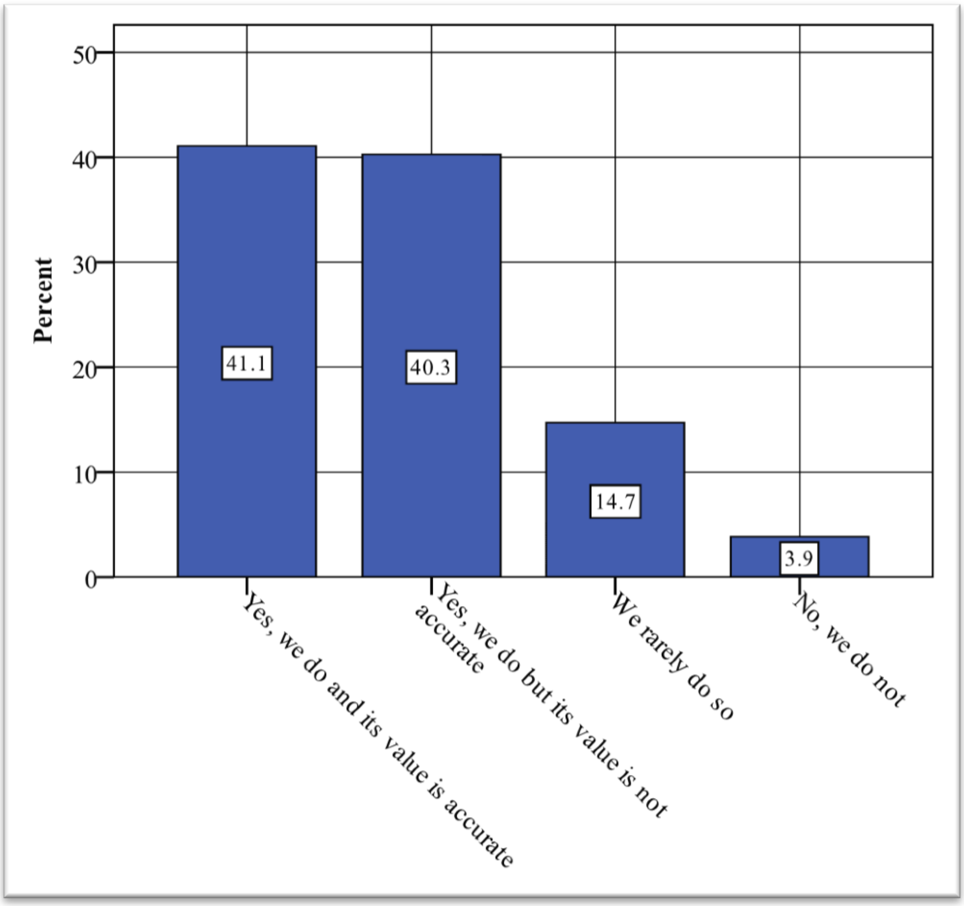


Figure 83: Considering lead-time in logistics scheduling

Question 4.3 aims to understand the main sources that are used by the respondents to find numerical data associated with lead-times. As clear in Figure 84, 75% of respondents rely on what suppliers say about the duration of lead-time. Over 41% explained they use their previous experiences to calculate lead-time. Also, 6.3% stated they guess lead-time value, while 6.3% look for figures in Farsi books and 3.1% search in books in other languages. This seems logical as the value of lead-time may be different from one country to another.

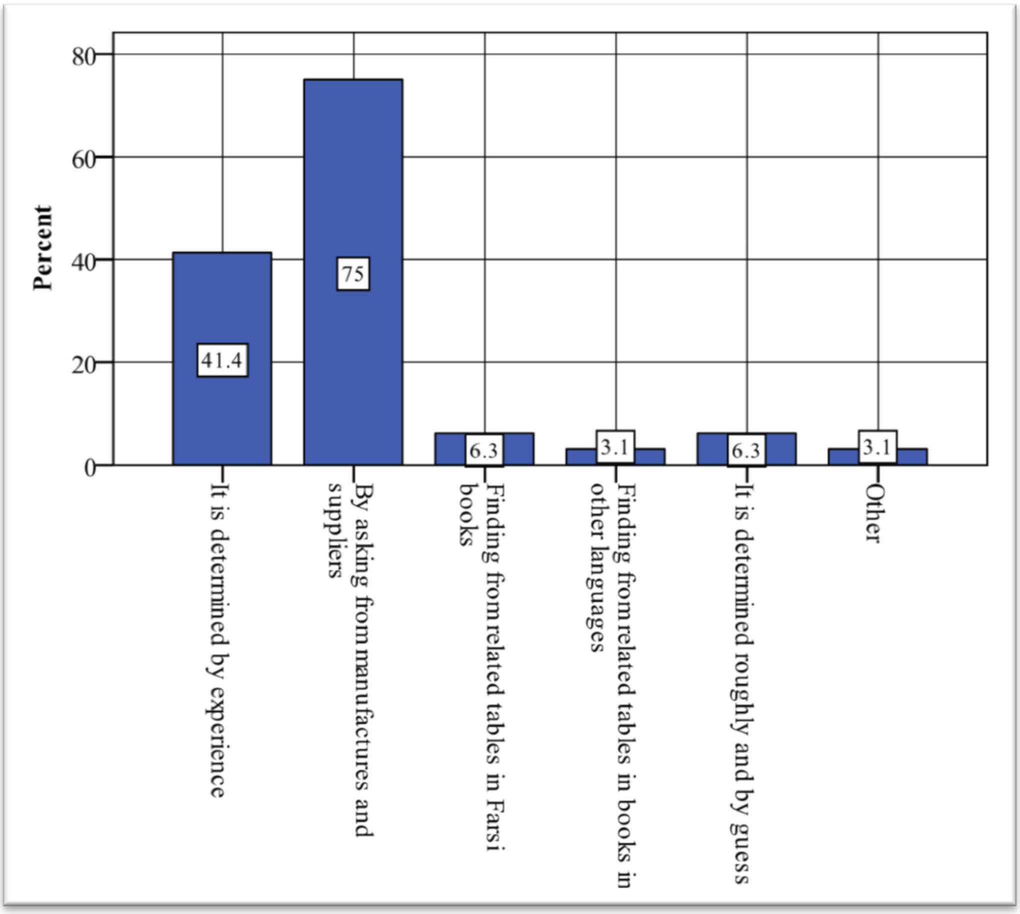


Figure 84: Sources of numerical data for determining lead-times

10.4.1. Material Delivery

The delivery time of construction materials should be based on the project schedule (Relationship DS1) and progress of work. C02 clarified this in the following:

> *"We should manage delivery time to avoid critical situations. By critical I mean materials become out of stock onsite. In critical situations if a problem happens during the transportation process, it will be costly".*

N04 also commented on the delivery time:

> *"If we buy from a local supplier and he has the material in stock, delivery will be done in two hours (Relationship DS2). For example, we call them in the morning and they will deliver the material in the afternoon. But if the supplier does not have it or we need a large volume, depending on the market conditions, delivery takes at least 24 hours".*

Delivery time planning is more important in peak times. N01 and C05 explained that, in some seasons, the drivers and vehicles will be very busy. C05 made this point clear: *"the end of spring is the season for harvesting wheat. In this time it is very hard to find a free driver"*. N01 also added "*in wheat harvesting season the drivers may charge you twice the normal price. So, we try to avoid these times for transporting materials to the project"* (Relationship DP1).

Late or early delivery of material is a serious issue that was pointed out by many interviewees. Late delivery may cause delays (Relationship DS1) for the project and incur cost because the workers cannot work without materials while they should be paid. Early delivery may cause problems because the site is not prepared to receive materials. In some cases, there is not enough storage space (Relationship DW1) or enough workers to unload the materials. To measure how often late or early delivery happens in Iranian building projects, one question was dedicated to this topic in the questionnaire.

Figure 85 illustrates that more than 31% of the respondents experienced early material delivery in their projects, while more than 61% said early delivery rarely happens. The issue of late delivery (Figure 86) is more crucial. All respondents explained that they experienced late delivery in their projects and nobody chose the 'never' option. More than 56% stated that late delivery happens in construction projects often or very often. Hence, delivery timing is a factor that should be improved to minimise its negative consequences on the project.

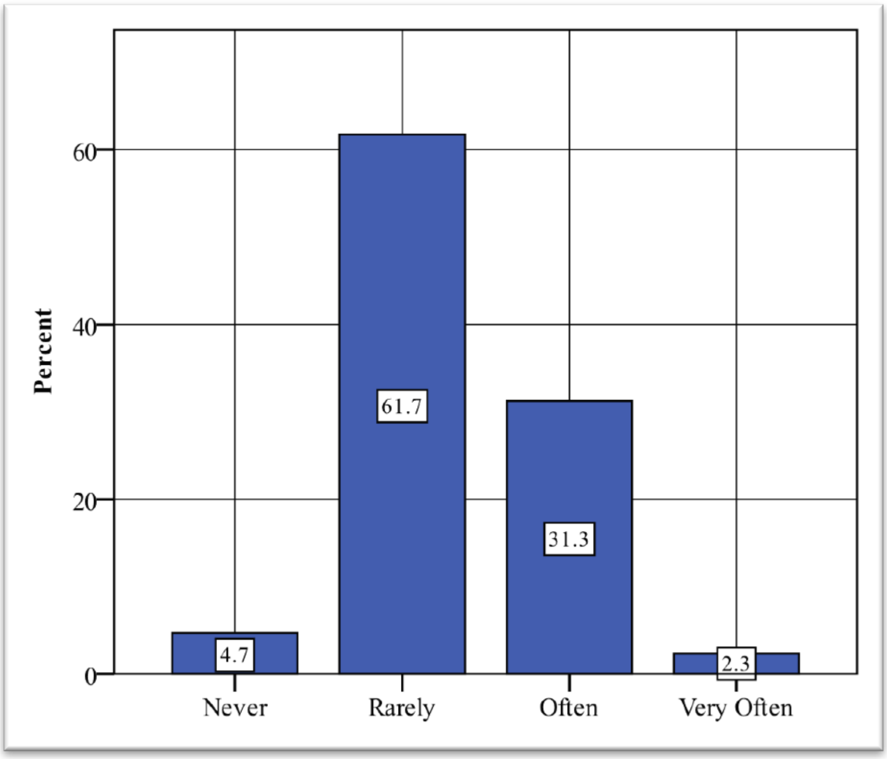


Figure 85: Early delivery of materials to the site

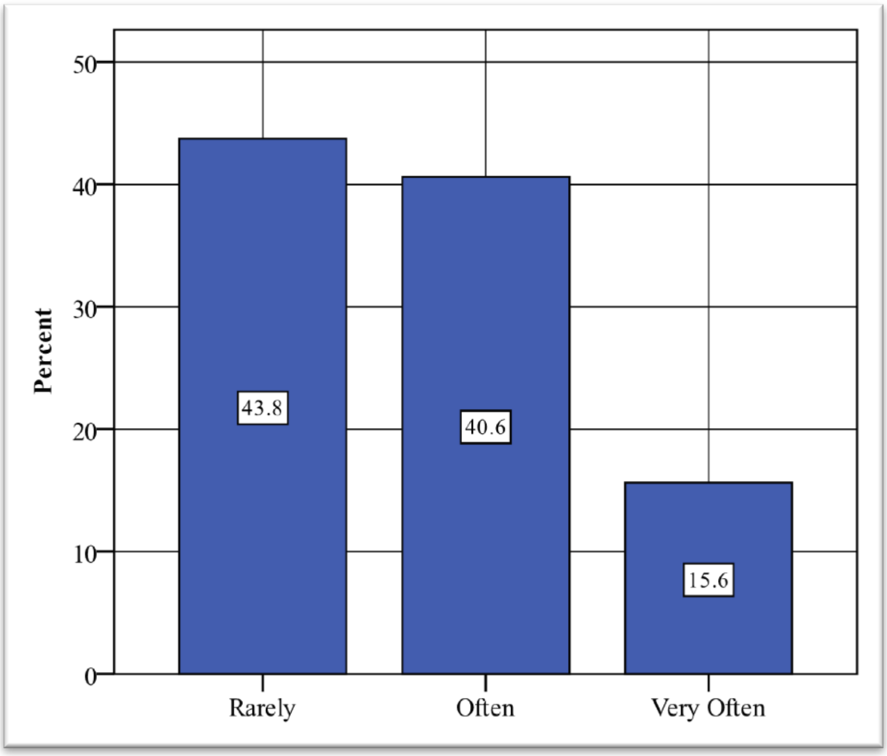


Figure 86: Late delivery of materials to the site

One approach to delivery timing is JIT, which is recommended in several publications (Agapiou, Clausen, Flanagan, Norman, & Notman, 1998; Strategic-Forum-for-Construction, 2005; CITB-Construction-Skills, 2006). Most interviewees were not familiar with the JIT and have not applied this concept in their projects. C17 stated:

> *"We have not applied JIT in our projects yet. But we can do it in a period of five to ten years. First we should learn how to do it from the leading [international] construction companies and then utilise it in our projects".*

When a short description of JIT was provided by the interviewer, some interviewees expressed that it can be done for steel sections. For example, C16 elucidated:

> *"If you pay the cost for the trailer to wait, you can unload steel sections with a crane and erect them immediately. This requires accurate planning. The sections should be marked to be installed into the exact place and the layout of sections on the trailer should make this possible. I mean the steel subcontractor should know which sections should be put on top and which sections at the bottom [on the trailer] to avoid problems in the unloading stage".*

C01 also commented on JIT: *"steel rods should arrive to the site when they are needed. They should not be stored onsite for a long time. But small materials may be stored longer and their delivery is less critical".*

Another important topic explained by several interviewees, such as N01, N04, C05, and C17, is sequencing the deliveries. In most cases, the whole load should not be delivered to the site at once because of space limitations. In other words, deliveries should be carried out in a logical sequence (Relationship DS1). Proper sequencing of deliveries of construction materials can save money and time by reducing storage space, waste and the amount of re-handling of materials. C17 expressed *"for example 200 items should be delivered to a 1000 hectare site ... these should arrive to the site at different times in a way that supports construction functions"*. C04 gave an example:

> *"We want to buy bricks. First we calculate the total numbers of bricks required which are 180,000. Then we tell the supplier that we need the*

bricks in October and ask them to deliver a proportion of the load each fifteen days".

C02 also described his experience:

> *"Owing to limited space I could not receive 15,000 square metres of tiles at once. So, I asked the supplier to send 1,500 square metres of the tiles each two days. Because I should have the time to define the storage, anticipate a suitable space, prepare the site and inform the site about the delivery".*

C01 explained a similar situation:

> *"When we buy materials we tell the suppliers to send us the loads in several batches. For example, if we need 2000 square metres of tiles, we will ask the suppliers to divide them into four parts and then deliver them at specific times".*

The information provided in this section is summarised in Figure 87. It shows the complex relationships of scheduling agents of the construction logistics system.

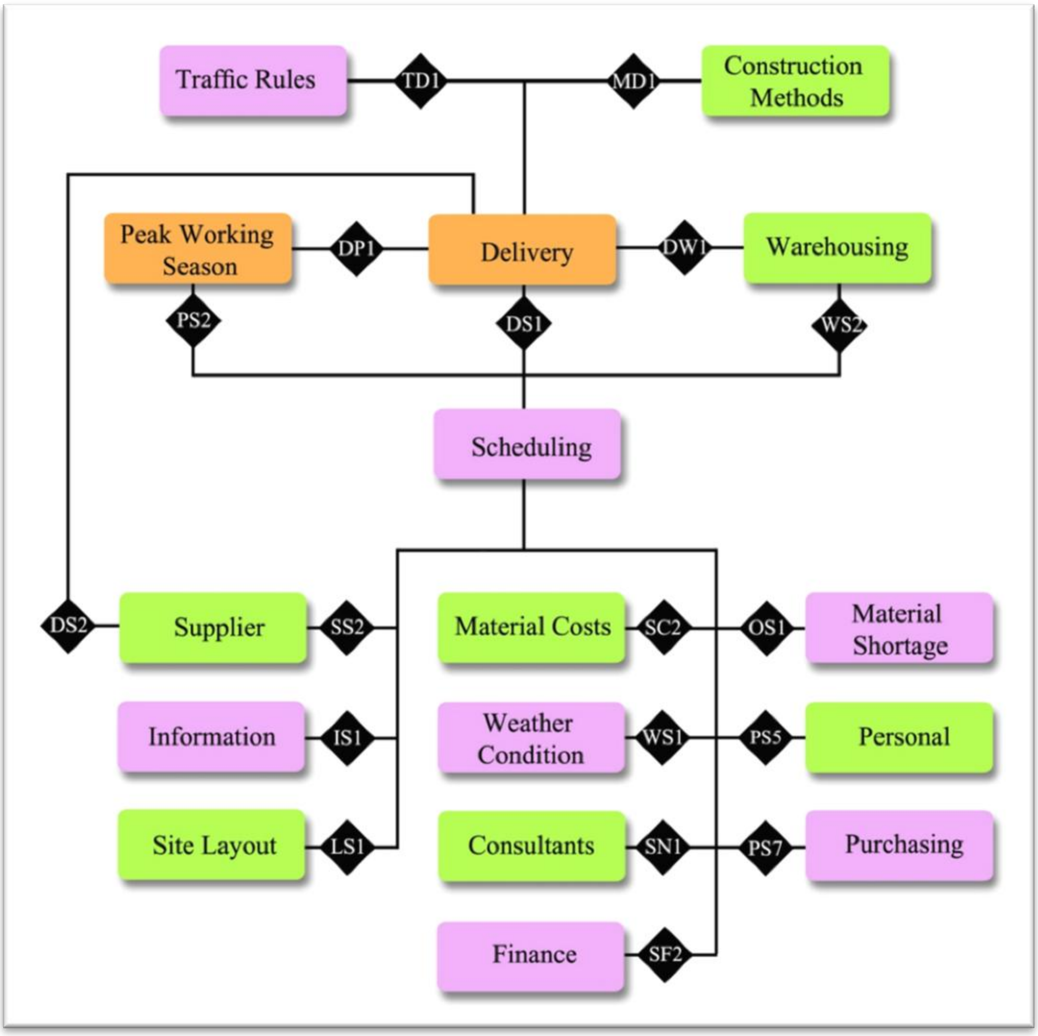


Figure 87: Scheduling agents of the construction logistics system

10. 5. Material Management

Material management is about the flow and movement of different items in construction sites. In the literature review (Chapter three), the topic of 'material management' was divided into three sections of delivery, warehousing and handling. In the analysis stage, material delivery was explored in the scheduling section. Hence, material handling and warehousing will be studied here.

10.5.1. Material Handling

Construction material handling includes lifting, carrying, pushing, or pulling materials manually or by using special equipment. Handling depends on the type of materials and construction methods that are used in a project (Relationship HC1). The handling strategy and types of equipment required vary for different structures and buildings. N01 said *"for steel structures we use cranes but for concrete structures because the structure is raised gradually we do not necessarily need a crane"*. In the previous chapter, the association between handling and factors such as site layout (Relationship LH1), new materials (Relationship NH1), offsite and prefabrication (Relationship OH1), material packaging (Relationship PH1), and waste (Relationship WH1) were explained. This section explores unloading, horizontal circulation and vertical movement of materials onsite.

The handling of materials onsite is in two directions: (a) horizontal and (b) vertical. Horizontal movement involves unloading, carrying, pushing and pulling materials from the unloading point to the warehouse or from the warehouse to the point of use. Vertical movement means lifting materials from the nearest place to the building on ground level to the higher floors of the structure.

10.5.1.1. Horizontal Movement

When materials are delivered to the site, they should be unloaded by labourers. Unloading is often done manually without enough attention to health and safety issues (Photo 27). Yet, for sensitive materials, special care is necessary to prevent damage. C16 stated *"the clay blocks should be unloaded one by one because they break easily"*.

Photo 27: Dangerous unloading of materials (throwing out heavy cement kerbs)

An important point about unloading is that enough labour should be available to unload materials. The drivers are often precipitous and do not like to wait too long to unload materials. This issue becomes worse when the materials are delivered late at night (Relationship HD1). N04 expressed *"in many cases the drivers arrive very late at night. At that time we do not have enough labour to unload the materials"*. N03 also explained:

> *"Cement, bricks, stone, etc. usually arrive at 00:30 or 01:00. At this time we cannot handle them to the storage area because it bothers the neighbours. Some neighbours do not tolerate even the two or three hours that it takes to unload the materials and they complain to the police. So, we have to work two or three hours and take a rest and continue the job in the morning".*

Some interviewees expressed that they employ specialised workers for unloading materials (Relationship HP1). C02 said:

> *"We found out that it costs more and takes longer if our workers unload the materials. So, we use specialised workers. They unload a truck only in 30 minutes while our workers do the same job in four hours. The drivers are also happy because they do not have to stop for four hours to unload the materials".*

When materials are unloaded, they should be delivered to the warehouse for long period storage or to somewhere near the point of use for short period storage. Then they will be handled gradually to where they are required (Photo 28). The distance between the place materials are stored and where they should be incorporated into the building should be optimised (Relationship HW1). If materials are stored very close to the building, they may cause obstacles and disrupt the circulation of staff and materials. If materials are stored very far from the building, it will take too much time to handle them to the point of use. C02 confirmed this and said *"if the handling distance is very long, handling time will be increased. This time is wasted as it is not considered in the schedule".* C02 also commented on handling distance: *"in large projects the handling distance is between 500 to 1000 metres. So, we use vans and trucks to handle materials"*.

Photo 28: Materials temporarily stored near the building to be handled to the point of use gradually by means such as a wheelbarrow

Long handling distances may increase re-handling. Many interviewees explained that poly-handling is a problem that happens frequently in building projects in Iran. This is the issue that has been discussed in several publications (CITB-Construction-Skills, 2006; Sullivan, Barthorpe, & Robb, 2010). C04 described the handling practice: *"when materials are unloaded we use a forklift or something similar to put the materials on a deck to be towed by a tractor"*. C16 also stated *"first we unload and store materials in the nearest place ... then we handle them to the point we want"*. Based on what was explained by the interviewees, at the beginning of the handling process, materials should be unloaded. Then materials should be handled to a place for temporary storage using equipment or manually. From the storage point, materials should be loaded on to a vehicle or other means and delivered to somewhere near the building. At that stage, again materials should be unloaded and handled to the point of use. This process involves poly-handling of materials which can have negative consequences. Sullivan *et al.* (2010) explained poly-handling increases the likelihood of material damage, while it wastes the working time of skilled labourers. Several interviewees confirmed the relationship between re-handling and waste. C04 said "*during the loading, unloading, handling, and storing, a large proportion of materials will be wasted (Relationship WH1). Re-handling is not desirable at all*". C02 also commented:

> *"Wrong distribution of materials onsite leads to a cost increase (Relationship HF1). For example, materials which are stored in a location by mistake. We should pay a cost to re-handle them to the suitable place".*

The machines that are used for horizontal distribution of materials are cranes, tractors, trucks, hiabs, dumpers and forklifts. C15 stated:

> *"We usually use a hiab. It lifts the load and puts it on the vehicle's deck. Sometimes we use other types of cranes to lift the load and put it on a deck towed by a tractor. We use forklifts for loads on pallets but it is rare. Dumpers and trucks are frequently used too".*

C05 expiated an issue with the hiab:

> *"The problem is that the whole length of a hiab cannot be used for loading. I mean some space should be allocated to install the crane at the back of the vehicle. So, the length of the deck in a hiab is shorter than a normal truck. Thus, if you have long components, such as steel sections, you cannot handle them with a hiab".*

10.5.1.2. Vertical Movement

Vertical movement is mainly about lifting materials to the higher levels of the building. The role of machines is more important in vertical movement. Machines that are used for vertical movements are lifts, winches and cranes. The choice of machine depends on the size and height of the projects (Relationship HP2). C03 stated "*for high rise buildings we use tower cranes but for other projects I recommend lifts and winches*". In small projects, as N01 mentioned, materials are handled by winches (Photo 29) and lifts instead of cranes. C02 said *"a winch can be used up to 14 storeys"*. C16 added *"we handle materials to somewhere near the building and put materials in a basket and lift them up using a winch. The loading capacity of a winch is around 300 kilograms"*. C18 also clarified why winches are preferred in small projects:

> *"It is not always possible to use a tower crane. Sometimes you do not have enough space to install it and sometimes the height of the building is short and there is no need for a tower crane. So, in some cases we use two, three or even four winches simultaneously".*

Photo 29: Use of a winch to move materials vertically

For large projects and high rise buildings, tower cranes are used (Photo 30). N01 stated *"tower cranes can be used for six-storey to fifty-storey buildings. If more than one crane is used in a site, a safety distance should be considered between the two cranes to avoid any clash"*. C04 also expressed:

> *"For large projects lifts and winches are not suitable because they have a low loading capacity ... The loads are usually placed in two sides of the crane and large volumes of materials will be lifted at once to the floor needed".*

N06 pointed out the factors that should be considered when a crane is to be used: *“power, installation method, boom length, gradient, allowed weight, wind effect, and traffic of the site location”*.

Photo 30: Using a crane bucket to move aggregate to the higher floors

Another mean that is used for working at height and delivering and installing materials to upper floors is scaffolding. N04 explained that no attention is paid to health and safety issues regarding scaffolding, and working on scaffolds is very dangerous for the workers. C02 said *“we had a situation that a worker fell from the scaffold. But hopefully nothing happened to him”*. As clear in Photo 31, the type of scaffolds used in Iran is not secure at all. There is no stair or ladder and workers have to climb up the structure to reach the working level. Moreover, as N04 mentioned, the working platform is not fixed to the ledges and may be displaced owing to wind or a worker’s negligence. Also, there is no fencing and this increases the risk of falling owing to vertigo and unsteadiness. Furthermore, safety equipment is not provided or is not being used by the workers. N04 made this clear in the following:

"Workers do not use safety tools when they are on scaffolds. Two days ago I noticed a worker on a scaffold who did not wear a safety belt while it was available. They cannot work when fastened to a belt because it limits their movement".

Photo 31: Scaffolds as a risky means for working at height

10.5.2. Warehousing

Warehousing is an essential task in construction logistics. Although modern logistics promotes minimising, or even eliminating, material stock, many construction materials should be stored onsite for variable periods before incorporating them into the building. Warehousing is necessary because, in construction projects, the demand for some materials is usually continual. For example, cement is required for the foundation, structure, tiling, and finishing. Hence, there is a continual demand for cement in different stages of the construction and, therefore, it should be stored onsite. Furthermore, some materials have long lead-times and should be ordered early. These materials may be stored onsite for a period of time to avoid delays in projects (Relationship WS2). The risks of material shortage (Relationship OW2) and suppliers' indifferences (Relationship WS2) are other reasons that can be used to justify having an onsite warehouse.

In previous sections and chapters, some relationships between warehousing and other agents of the construction logistics system were identified, which include material costs (Relationship CW2), delivery (Relationship DW1), handling (Relationship HW1), information (Relationship IW1), ICT (Relationship TW1), material inspection (Relationship IW2), site layout (Relationship LW1), construction methods (Relationship MW2), consultants (Relationship NW2), material shortage (Relationship OW2), project size and location (Relationship PW1), personnel (Relationship PW3), purchasing (Relationship PW5), material packaging, (Relationship PW6) and waste (Relationship WW1). This section discusses the warehousing process, storage spaces onsite and material maintenance. However, before covering these topics, a short review of having long-term or short-term storage will be provided.

The time period that materials are stored onsite is critical. The longer the period, the more warehousing cost should be paid (Relationship WF1). Furthermore, storing materials for a long period increases the risk of waste owing to depravation (Relationship WW1). C09 explained:

> *"I try to have materials at least one week before use. This one week is my safety factor against unpredictable issues such as material shortage etc ... I had bought the steel sections that I needed in October two or three months ahead".*

SFfC (2005) stated that materials are often stored onsite for long periods of time. This issue exists in the Iranian building sector as well. Some interviewees expressed that they have to store materials onsite for long periods. The main reasons for long-time storage are the high rate of inflation, the risk of material shortage and suppliers' indifferences. C02 said:

> *"If we know that the price of a particular item will rise in the near future, we will purchase our need (Relationship CW2). Otherwise, we do not spend capital on it and purchase it based on our experience and in the stage it is required".*

C17 had a similar view:

> *"Based on our experience, materials, such as steel rods and cement, are critical. So, we store as much as we can. If in theory we need two silos to feed the batching plant and 10,000 tonnes of cement is required, we have to store three times more because the cement supply may be disrupted ... I mean Murphy's Law frequently happens in Iran. It means that anything that may go wrong will go wrong".*

C17 continued:

> *"We have warehouses in all of our projects. For example, we knew that for a project we should work on a job for twenty years. We had closed, opened and semi-opened warehouses ... everything was automated. For example, in the warehouse you could search for an item in the software and it could tell you that item's location (Relationship TW1)".*

C03 believed the idea of long time storage is due to inflation on material costs (Relationship CW2): *"the main reason for long time storage is inflation (Relationship CW2). If the inflation rate is zero, nobody converts cash to materials and then puts so much effort to maintain them"*.

A group of interviewees were against storing materials for a long time. They expressed that long-time storage of materials may cause problems, such as space shortage, waste increase, cost increase, cash flow issues, routes blockage, re-handling, fire and theft risk increase, and materials depravation. C04 mentioned *"there is no need for long time storage since suppliers deliver materials on time. So, you do not have to buy materials six months ahead and store them onsite"*. C04, C07, C08, C09, C17 criticise long term storage and explained several reasons against the idea. C07 said *"in one of our projects there is no space to purchase materials ahead"*. C04 also mentioned space limitation and added:

> *"More materials onsite means that we have to build more warehousing spaces. We should also define a system for warehousing and employ warehousing staff. We have to pay staff to control enter and exit of items ... we also have to insure the warehouse against fire. So, we have to pay extra money and it is not worth it".*

In addition to insurance, extra money should be paid to install features such as security systems, enter/exit controls, identification system, fire alarm, and fire distinguishers to keep the warehouse safe (Relationship WF1). C04 explained another reason to reject long-time storage:

> *"For some materials the guarantee period may be expired if they are stored for a long time. For example, the air conditioning units have an eighteen-month guarantee. If you buy and store them for two years, the guarantee will be expired".*

He continued: *"there is no point in storing some materials or components. For example, heavy vehicle tires after staying 18 months in warehouse will be spoiled"* (Relationship WW2). C17 also mentioned *"the stock should not reach the point that causes problems for the cash flow and incurs unnecessary storage costs. The capital should not be stagnant in warehouses"* (Relationship WF1).

Question 7.3 in the questionnaire measures which materials and components were worth being stored onsite for six months or more, from the respondents' point of view. Figure 88 summarises the result of the data gathered from the questionnaire survey. Only 19.8% of respondents chose the 'none' option. It shows that the position of the industry is far from the point where the JIT principle can be applied. Aligned with the result of the qualitative analysis, 54% of respondents expressed that steel sections are worth being stored for long periods. Electrical components, tiles, mechanical components, and stone are the other items worth storing for a long period, as they were selected by 30 to 40 per cent of respondents. Steel, tiles and stone are items that are not so sensitive to the weather conditions. Electrical and mechanical components are quantifiable items that do not need a large space for storage and can be kept in one room in the basement.

However, materials, such as paint, gypsum powder, doors, and bitumen, that are sensitive to moisture, sunlight and high or low temperatures cannot be stored for long periods and, thus, less than 18% of respondents chose them. Bricks, windows, gypsum and cement boards, bitumen, and gypsum powder are bulky materials and need large storage spaces. Hence, respondents are not willing to keep them for a long time onsite. The cement situation is unique as more than 20% of respondents were keen to store it for long periods while it may be depraved after three months. This is owing to the price fluctuation and possible shortage in the market.

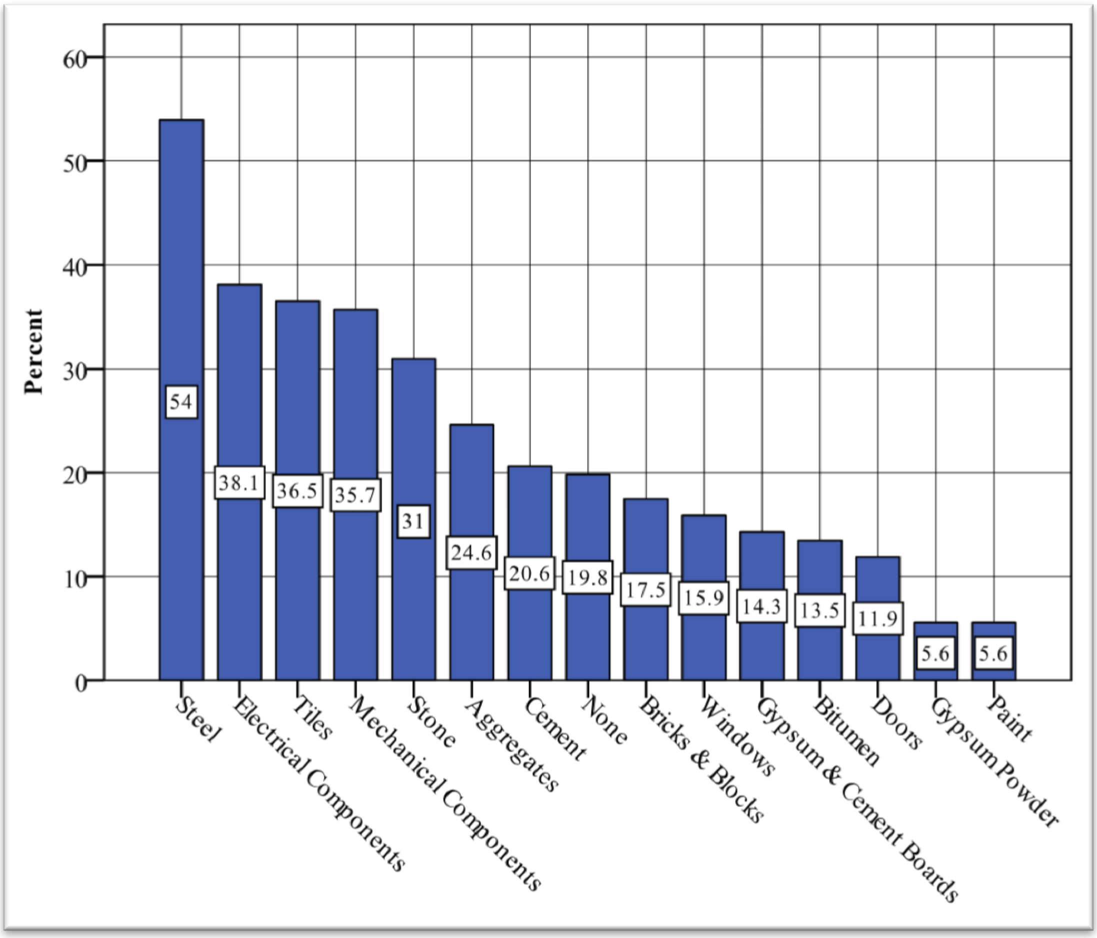


Figure 88: Which materials are worth being stored onsite for six months or more

10.5.2.1. The Warehousing Process

The process of warehousing in the Iranian construction projects is too basic. C03 said *"even in large and national projects we do not have standard processes for warehousing materials and tools"*. C07 also explained:

> *"One weakness is that in our projects the warehousing process is done traditionally. Yet, in modern projects the site supervisor, for example, asks about the amount of steel rods size 12. [The warehouse staff] will respond that 120,000 Tonnes were entered to the site and X amount is consumed in that location so the available stock is Y".*

After purchasing an item, it will be handed in to the warehouse and will be registered manually in an inventory book. Then it will be retrieved when required by different trade contractors for incorporating in to the building. C04 described the process:

> *"When the buyer coordinator purchases the items, they will be delivered to the warehouse. Then a receipt should be issued [by the warehouse coordinator] that shows a certain amount of materials entered to the site (Relationship PW3)".*

The receipt should include information, such as the item description, quantity, date of purchase, date of delivery, the supplier name and a traceable label (Relationship IW1). As discussed in Chapter three, in addition to the above information, the warehouse management system (WMS) may include handling details (the time and location the materials are needed) and health and safety information (Sullivan, Barthorpe, & Robb, 2010). There is usually a coding system used by the warehouse coordinators to label each item. This is aligned with what Sullivan *et al.* (2010) recommended as a standard product description among parties involved in the project. In some projects, enter and exit of materials is carried out with help from software (Relationship TW1). C14 said *"all of our items have a unique identification code. These codes are generated using software that keeps the stock records as well"*.

Many interviewees, such as N01, N05, N06, C07, C09, and C15, explained that much attention should be paid to inventory. C07 said *"the more time we spend on inventory and stock control, the less waste and theft we will have onsite"*. N06 explained *"everything that enters to the site should be registered in the warehouse inventory (Relationship IW1). It should be incorporated into the building or returned to the central warehouse of the company"*. C17 expressed:

> *"Each load comes with some documents that include information about the load. This information should be inputted manually into the system when the load arrives to the site or even sooner. After receiving the load the system produces a receipt".*

The site authorities should have enough information about the inventory. The warehouse coordinator should inform the site supervisor about the stock level by producing daily and monthly reports of items that are purchased, stored and consumed (Relationship PW3). The report should include information about the item description, available stock, the amount purchased, and the amount consumed (Relationship IW1). The site supervisor needs this information because he must ensure that resources are ready to start activities that are planned in the schedule. Inventory information may also help higher management levels of the company to distribute resources evenly in different projects. N01 said:

> *"The amount of available materials onsite is known by the warehouse coordinator. But the site supervisor should check the stock at regular time intervals. It is possible to define an indicator for stock levels and make the coordinator responsible for keeping the stock level over a certain amount".*

C09 also described the stock indicator (Relationship PW3) in the following:

> *"I determine an indicator for each material and inform the warehouse coordinator about it. [For example], for cement the indicator is 20 Tonnes. When the stock reaches that indicator, the warehouse coordinator should inform me to buy more. The indicator is determined based on the market conditions and material price".*

Some companies put more stress on ICT implementation in the warehousing process (Relationship TW1). For example, C03 stated *"in one of our projects the warehouse, financial department and head office are connected together via online software. So, you can check the inventory of materials in each site".* However, inventory control is not straightforward in all cases. C07 stated:

> *"Some materials such as plumbing fittings are easy to control. [For example,] eight of them used and two remain. But some materials should be weighed such as gravel and cement. We are working on these types of materials to find a way to control the quantity of them onsite".*

C15 pointed out some problems of a poor inventory:

> *"There was some issues ... for example they [site staff] did not know if they had a material in the warehouse or not. For example, we need an item today but it is not available in the warehouse. Finding and ordering that item was*

time consuming ... and this disrupted the project progress ... [to avoid these issues] it was decided that the site supervisor should become informed about the inventory on a daily basis".

The final stage of warehousing process is retrieval. When a material is needed, the trade subcontractor should ask the warehouse staff to retrieve it. The warehouse coordinator should identify the item and give it to the subcontractor. As C15 mentioned, in the retrieval time, a receipt should be generated by the warehouse coordinator that includes information about the item description, the item label (code), quantity, recipient name, and date of retrieval (Relationship IW1).

Gopalakrishnan (2010) pointed out seven principles that should be considered for successful warehousing practice. Among those principles, close distance to the work area, ease of handling, security and proper containers were considered by the interviewees, while easy identification, safety and tidiness were not covered. To understand what warehousing systems are predominantly used in building projects in Iran, question 7.1 in the questionnaire was asked. Figure 89 illustrates the result of the descriptive analysis.

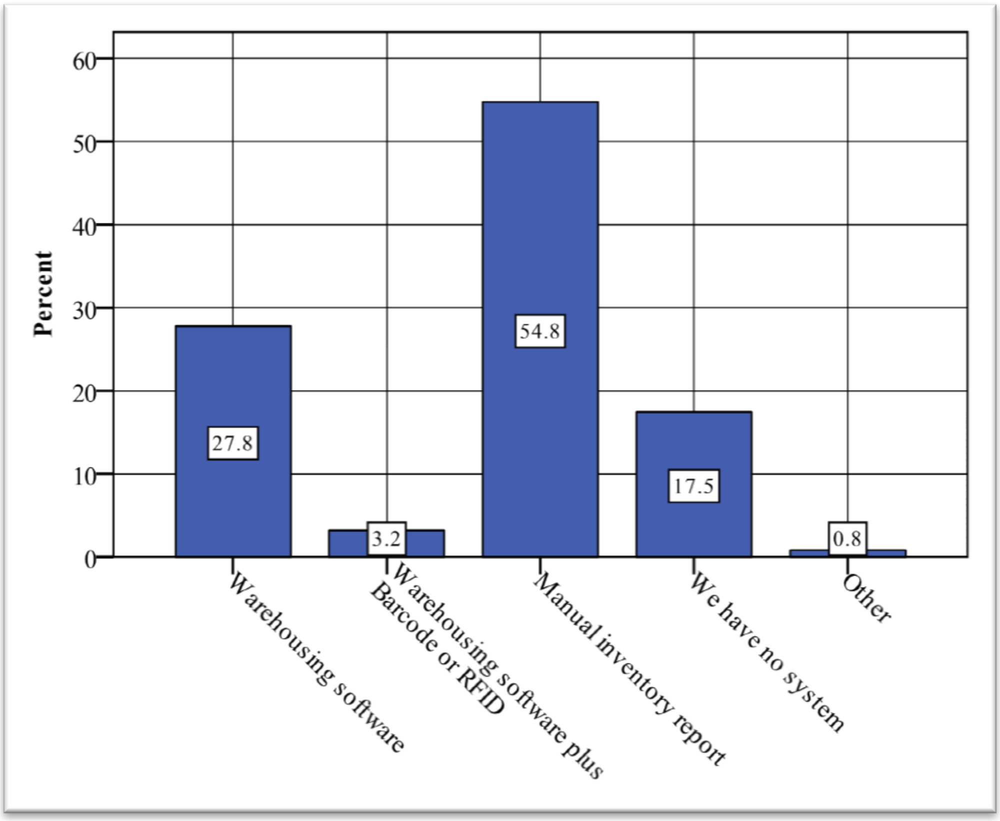


Figure 89: The choice of warehousing systems by the Iranian practitioners

Figure 89 shows that around 55% of respondents use manual methods to control the enter and exit of materials in the warehouses, while less than 28% utilise specialised software for managing warehousing tasks. Application of new technologies, such as barcode system and RFID, is rare, as only 3.2% explained they use them in their projects. More than 17% mentioned that they do not have any form of warehousing system. Considering Photos 32, 33, 36, 39, 40, and 41, which show the disorder, disorganisation, and mess in most warehouses visited, this value is less than what was expected. One reason is that many contractors have a system on paper, but they do not have capable staff and enough time to utilise the system.

10.5.2.2. Storage Space

The storage spaces should be seen and anticipated in the site layout (Relationship LW1). C12 said *"when the land is handed to us we draw a plan ... in that plan we anticipate [for example] 12 times 30 metres of closed storage and 20 times 40 metres of open storage".* Many photos were taken of storage spaces in different projects. In most cases, the onsite material storage spaces were dirty (Photo 32) and disorganised (Photo 33) with poor lighting and no marking. This leads to inaccurate inventory information, material wastage, re-handling and waste of time.

Photo 32: Dirty site owing to poor warehousing practice

Photo 33: Disorganised onsite warehouse

The warehouse may have indoor and outdoor spaces. Sensitive and high value materials should be stored in indoor spaces (Photo 34) and large materials that are less sensitive to environmental impact should be stored in outdoor spaces (Photos 35 and 36). The terms open and closed storage were frequently used by interviewees to highlight storage type. These are similar to the semi-permanent storage and staging area explained by Thomas *et al.* (2005). C12 described storage types in the following:

> *"The closed storage is used for materials that are vulnerable to the environmental conditions such as welding electrodes or small materials that may be stolen easily. The open storage is used for bulky materials and machines such as compactors or materials such as paint which should be stored in a ventilated space".*

Photo 34: PVC pipes are properly stored and categorised by size in an indoor storage space

Photo 35: Clay brick stored in the outdoor space

Photo 36: Gravel, sand, bricks and blocks are stored in the outdoor space

C15 provided a document that described the four types of storage spaces in his company:

1. Surrounded open storage for heavy and bulky materials such as steel sections.
2. Closed storage without roof for materials such as timber.
3. Closed roofed storage with shelves for storing spare parts, electrical and mechanical components.
4. Silo for storing cement and similar materials.

N01, C02, C03 and C18 stated that, to have secured closed storage, in most projects, after erecting the structure, the building basement will be converted to the project warehouse. Photo 37 shows cement and gypsum powder bags that were stored in the basement of a building. Other floors can also be used for storage. N01 said *"when we build the structure small size and high value items will be stored in the floors. We do not leave them in the site because they may block the routes or be stolen"*. C02 described this in more detail:

> *"We isolate the building basement with the area of 3,000 square metres. It has only one access point and we use it as a warehouse. There is no need to store bulky materials such as tiles, cement and gypsum powder in this place. Yet, the lift motor should be stored here to be protected against rain, sunlight, and other risks. For example, lift rails, fire detectors, electric sockets, taps, pipes, and plumbing fittings should be stored in a suitable place like this".*

Photo 37: Cement and gypsum powder bags stored in the basement of a building

The warehouse is usually divided into sections. For instance, in Photo 38, the first floor of the building is dedicated to the polystyrene wall units. C18 said *"for each material we allocate a specific location. For example, pipes are in one room and tiles in the other room"*. C02 also stated *"we divide the warehouse into several sections. We have a section for PVC pipes (Photo 34) or a section for inflammable materials such as isolation, bitumen and fuel"*. C03 added:

> *"For large projects we define warehouse sections for different types of materials. For example, we have different storage spaces for electrical components, sanitary units, tools, etc. But for small projects we usually have one single space for storage".*

Photo 38: A section in the first floor of the building is dedicated to polystyrene wall units

The storage spaces and sections change according to progress of the projects. This is close to the random location storage philosophies explained by Tompkins and Jerry (1998). In earlier stages of the project, open storage is required, while in later stages close storage is needed. C03 explained:

> *"We can see the transformation of storage spaces in different stages. For example, the mechanical components warehouse transforms to sanitary items and then to electrical components storage".*

In Chapter seven, it was explained that material storage may be challenging in urban projects owing to space limitation (Relationship PW1). N03 said *"warehousing in urban projects depends on site location, the street width, the land dimensions, entrance condition, and land position [north or south side of the street]"*. Space limitation in urban projects forces the builders to store some materials in the street (Photos 39, 40 and 41).

Photo 39: Aggregates and block stored on the pavement

Photo 40: Storing materials on the pavement and street in Tehran

In Photo 39, aggregates, blocks and a modular office unit are placed on the pavement. Photo 40 illustrates cement bags and steel rods stored in the street without proper hoarding. Photo 41, as C18 mentioned, shows that steel rods, because of their length, are usually stored in the street.

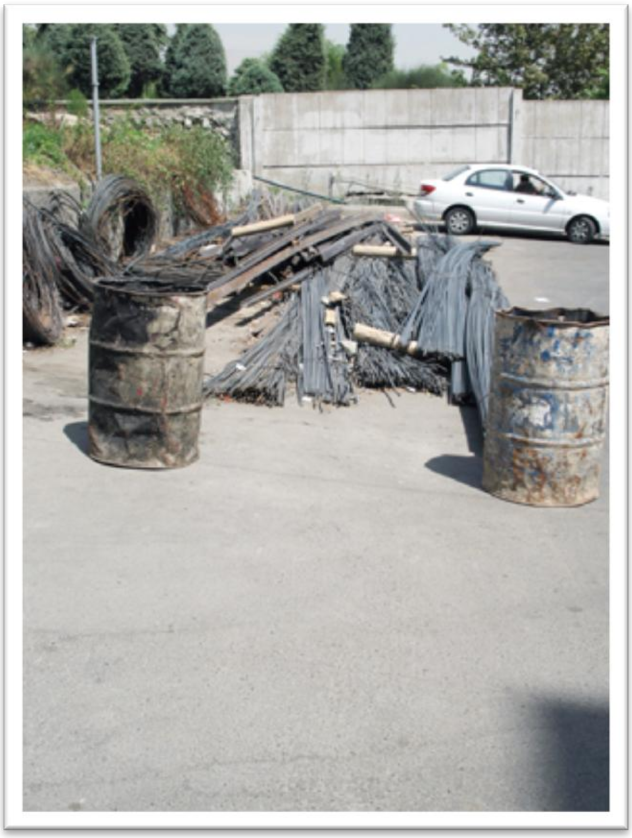


Photo 41: Steel rods stored in the street

N03 and C16 explained that there are regulations enforced by the municipalities for occupying the street that may be variable in different regions and cities (Relationship PW1). N03 expressed:

> *"Usually between one and half to two metres or one third of the pavement width or one third of the street width can be allocated for material storage. But you should use hoardings to prevent people and cars from falling down. Materials such as bricks (Photo 39), steel rods (Photo 41), and joists are unloaded and stored in the street. But you should somehow deal with the neighbours".*

C16 confirmed this and added *"we are allowed to use one third of the street width for material storage temporarily. Yet, it should not exceed 24 hours"* However, in most cases, materials remain on the street for several days or months, up to the time that neighbours complain in municipality. The negative consequences of storing materials in street are endangering street users' lives, damaging the street and pavement, blocking the road, causing heavy traffic, and increasing the risk of material theft. N01 made the following comment about storing materials on the street:

> *"Contractors store materials in a way that incur the minimum cost. When you walk in the City [Tehran] you can see that building sites occupy pavements and streets as much as they can (Photo 39-41) ... [For example,] steel rods are stored in the street which is specifically dangerous at night for pedestrians and drivers".*

A few interviewees, such as C02, C11 and C14, discussed the concept of a central warehouse. Some large construction companies have spaces (usually in the suburb of large cities) dedicated to material storage. These storage spaces are called central or head office warehouses which feed a portfolio of the company's projects. Critical materials, components, tools and plants are stored in central warehouses and transported to the sites when they are required on a JIT basis (Relationship DW1). From this view, the function of the central warehouse has similarities to the consolidation centre, and central warehouses have the potential to be converted to a CC. C14 described the central warehouse in the following:

> *"Beside onsite warehouses for projects, our head office has a warehouse too. Each item that is purchased should be handed to the central warehouse and then the financial department will make the payment. The central warehouse [like other warehouses] issues a receipt when it gets the item and another receipt when the item leaves the warehouse ... to transport loads from the central warehouse to the onsite warehouses we have a special form that should be filled out by the central warehouse coordinator and the procurement officer".*

C11 also explained:

> *"One of our staff is responsible for checking all warehouses for unused materials or free tools. He can arrange delivering these items to the other projects where they are needed or return them to the central warehouse".*

The similarities between a central warehouse and a CC motivated the researcher to ask question 7.2 in the questionnaire. The aim of this question was to know if the respondents are familiar with a CC and if they use similar facilities, such as a central warehouse in their projects. Table 21 summarises the data gathered from question 7.2. As a CC is a new concept, it is not surprising that the majority of respondents (46.4%) expressed they have not used a CC in their projects. However, more than 41% stated that they use a similar facility and it had a positive effect on the construction process. This does not mean that a CC is widely used in the Iranian building projects, but it is an indicator that shows there are facilities, such as a central warehouse, that has the potential to be converted to a CC.

Table 21: Using consolidation centre or similar facilities in projects

Responses	Frequency	Valid Per cent
Yes, it has positive effects on the construction process	52	41.6
Yes, but it does not have positive effects on the construction process	15	12
Yes, but it has negative effects on the construction process	0	0
No, we do not have it	58	46.4
Total	125	100

10.5.2.3. Maintaining Materials

During the period materials are stored in the warehouse, they should be looked after carefully. Poor material protection in warehouses may damage materials and components and leads to waste increase (Relationship WW1). Materials, such as cement, gypsum powder, plaster boards, steel sections and aluminium, are sensitive to moisture. Some materials, such as bitumen, insulations and paint, are inflammable and should be stored in a well ventilated space. Other materials, such as PVC pipes, plumbing fittings, glazing, wires, tiles and stone, may be deformed or broken at high pressure when large numbers of them are piled on each other. To avoid these problems, a suitable space should be provided for materials according to their nature, specifications, and safety requirements. N01 believed not enough attention has been paid to material maintenance in the Iranian building projects. He said:

> *"In many cases you can see that materials are left exposed to sunlight or bad weather conditions (Photo 42). [For example,] steel sections and cement are exposed to moisture, wind and dust ... or paint is exposed to water and sunlight ... [for example] concrete formworks, although they are not categorised as materials, they are tools that should be used several times. The contractors should regularly check, clean and lubricate them ... but in some projects you can see that they are stored in a way that will not be functional for the next job ... these are irregularities that we have not paid attention to".*

Photo 42: Gypsum powder bags left outside of the onsite warehouse

C03 explained *"the topic of materials maintenance is expressed in the fifth issue of National Building Code. For example, the code describes how to store and maintain* *cement ... but to what extent contractors obey these rules is questionable"*. The National Building Code consists of twenty technical pamphlets published by the Ministry of Housing and Urban Development. The fifth issue of the code is dedicated to construction materials, which includes introduction to building materials and elucidation of different materials' standards. In terms of maintaining materials in warehouses, a few tips are provided for cement, aggregates, and timber only. For instance, for cement, it is recommended that:

- Loose cement should be stored in silos.
- In regions with 90% or more humidity, packed cement should be consumed in six weeks and loose cement (in proper silo) in three months.
- Conglomerate cement should be sent to the lab for quality tests before use.

These general tips are not enough and practitioners have to rely on their own experiences and studies. N05 said *"we have a pamphlet that explains how to maintain cement onsite. For example, you cannot pile more than five tonnes of cement"*. Another issue, as C03 mentioned, is that in many cases the contractors do not obey even these simple rules. C01 stated:

> *"In undeveloped areas, the contractors did not have access to silos and bunkers. So, they built a chamber and then pumped cement in it. In this method, about 17 to 18% of cement will be wasted" (Relationship PW1).*

Some interviewees also described similar stories for gypsum powder. C01 and C05 mentioned gypsum sensitivity to moisture and confirmed that it can be stored in proper silos for two or three months. C05 added *"we try not to keep gypsum in the warehouse. I mean we will send gypsum bags to the point of use immediately after delivering to the site"*. On gypsum powder that comes in bags, C01 also said:

> *"If the height of gypsum powder pile exceeds 20 rows, specifically in humid regions, the first two or three rows at the bottom will be depraved. So, wooden pallets should be used. These are issues that people learn during the work".*

C15 stated health and safety issues, and the expiry date of materials, should be considered when they are being stored. He also added:

> *"All items in the warehouse should be inspected and checked in predetermined intervals. I mean at least each three months the stock should be checked. If materials are damaged or depraved, they should be delivered out of the site" (Relationship WW1).*

After removing the damaged materials, their descriptions and quantities should be deleted from the inventory.

Based on what was discussed in this section, the material management agent is developed (Figure 91). It shows the network of relationships between different agents of the material management with other agents of the construction logistics system.

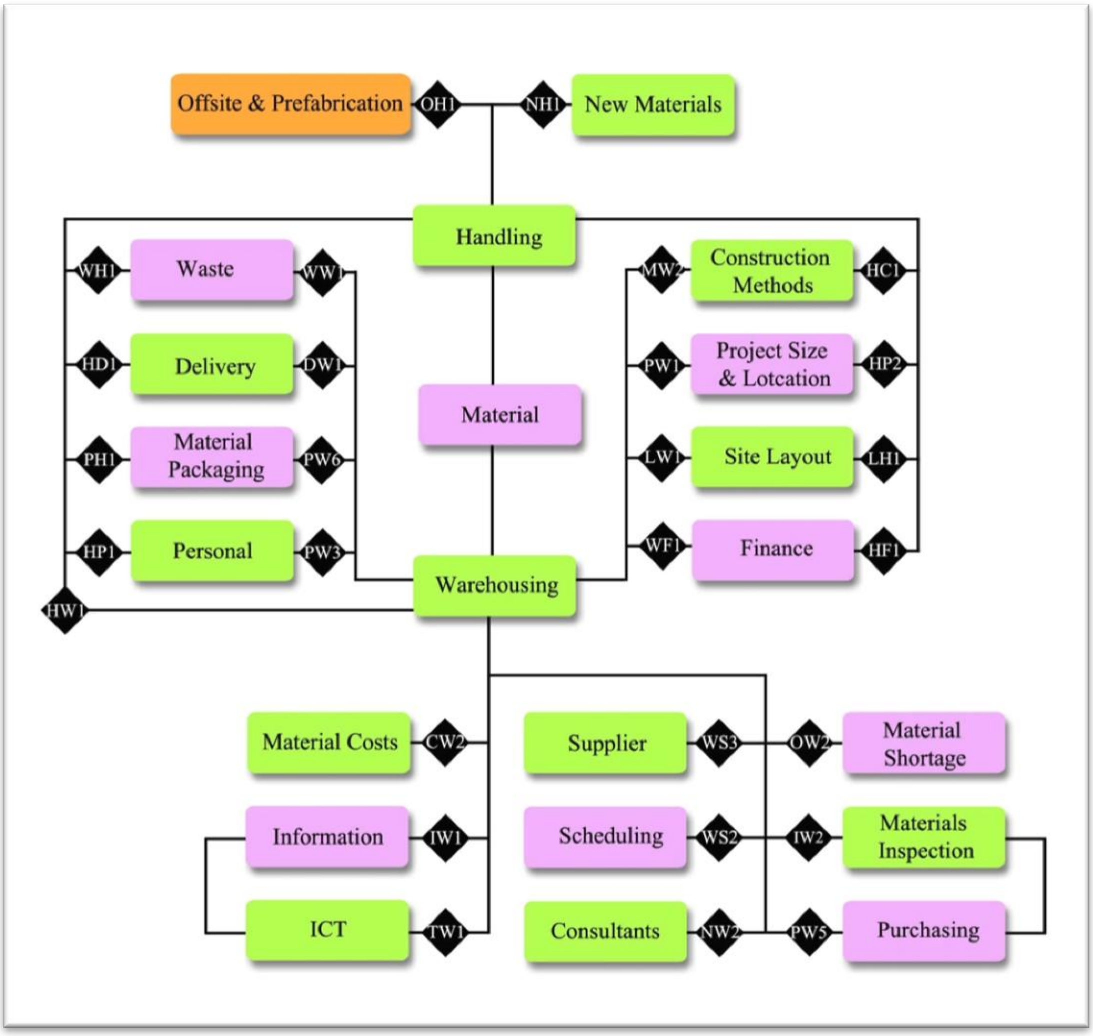


Figure 90: Material management agents of the construction logistics system

10. 6. Logistical Problems

During the course of qualitative data analysis, several logistical problems were identified. For instance, C02 explained about poor financial planning, and the lack of experts in construction logistics. C04 and C10 pointed out suppliers' indifferences. C10 also mentioned late delivery and the poor logistics knowledge of young engineers. Ten logistical problems, which were identified throughout the QDA, were selected to conduct the quantitative study. The aim was to rank logistical problems in the Iranian building projects based on their importance. To do so, the Relative Importance Index (RII) method was utilised. The RII for each problem is calculated using the following formula:

$$RII = \frac{\sum_{i=1}^{4} W_i X_i}{\sum_{i=1}^{4} X_i}$$

Where:

$W_i = Weight\ assigned\ to\ i^{th}\ response$

$W_i = 0, 1, 2, and\ 3\ for\ i = 1, 2, 3, and\ 4\ respectively$

$X_i = Frequency\ of\ the\ i^{th}\ response$

$i = Response\ category\ index$

$i = 1, 2, 3, and\ 4\ for\ Not\ Important, Important\ to\ Some\ Extent, Important,$
$and\ Very\ Important\ respectively$

The result of the calculation is shown in Table 22. The table indicates that financial problems and poor logistics scheduling are the most important logistical problems, while early or late delivery and weaknesses in transportation infrastructure are less important in comparison to other problems. An interesting point is that, according to Table 22, the low level of logistics knowledge among practitioners and the lack of experts in construction logistics have a higher rank than the unpunctuality of suppliers and material shortage. This highlights the important role of logistics knowledge in managing construction logistics.

Table 22: Ranking of logistical problems in construction projects in Iran

Rank	Problems	RII
1	Financial Problems	2.50
2	Poor Logistics Scheduling	2.31
3	Low Level of Logistics Knowledge among Managers and Engineers	2.27
4	Lack of Experts in Construction Logistics Management	2.21
5	Estimation Mistakes	2.06
6	Inappropriate Warehousing and Material Protection	1.90
7	Unpunctuality of the Suppliers	1.84
8	Construction Material Shortage	1.68
9	Early or Late Delivery of the Materials to the Site	1.67
10	Weakness of Transportation Infrastructures	1.48

The logistical problems which were ranked in Table 22 may have different negative consequences for the projects. Based on the qualitative data analysis, five major consequences of poor construction logistics were identified. These consequences were listed in Question 10.2 in the questionnaire. The aim was to understand to what extent poor logistics management can cause problems in construction projects. To rank these consequences based on their importance, the Relative Important Index (RII) was figured out, using the following formula:

$$RII = \frac{\sum_{i=1}^{5} W_i X_i}{\sum_{i=1}^{5} X_i}$$

Where:

$W_i = Weight\ assigned\ to\ i^{th}\ response$

$W_i = 0, 1, 2, 3\ and\ 4\ for\ i = 1, 2, 3, 4, and\ 5\ respectively$

$X_i = Frequency\ of\ the\ i^{th}\ response$

$i = Response\ category\ index$

$i = 1, 2, 3, 4\ and\ 5\ for\ Very\ Few, Few, to\ Some\ Extent, much, and\ very\ much$

The result of the calculation is presented in Table 23. Cost increase, delays, and waste increase are the most important consequences of poor construction logistics, while, according to the respondents’ view, poor logistics does not necessarily lead to poor quality construction and low level of health and safety.

Table 23: Ranking of poor logistics management consequences in construction projects in Iran

Rank	Problems	RII
1	Project Costs Increase	3.41
2	Delays	3.30
3	Waste Increase	2.98
4	Low Quality Construction	2.69
5	Low Level of Health and Safety	2.34

10. 7. Conclusion

This chapter discussed five topics. First, the importance of logistics organisation was highlighted and the effect of the organisational structure on construction logistics was explained. Furthermore, issues related to centralised, semi-centralised and decentralised organisations were specified and a new structure introduced that includes a logistics manager. In terms of logistics personnel, the role of site supervisors, financial managers, supply and support managers, buying coordinators, and warehouse coordinators were described and it was indicated that there is a skill shortage in construction logistics. In many cases, personnel have not received enough training and education to carry out their jobs and they have to learn by experience. Additionally, the impact of culture on construction logistics was explored. The purchasing behaviour, level of trust, attitude towards waste, the sense of responsibility, and building friendships are the cultural matters that were studied. It was mentioned that each culture has strengths and weaknesses that should be known for managing logistics. Organising the site was also an important subject which was covered in this section under site layout. Interviewees' experiences were explained in that section and the process of site layout designing was discussed.

The second part of this chapter explored the role of information in construction logistics. Material specifications, technical data, inventory, and marketing information were topics that were reviewed in that section. Moreover, the role of ICT and the way it is applied in construction logistics were discussed. The role of ICT in improving an integrated environment, documentation, archiving, warehouse management, estimation, and communication was highlighted in this section.

The third part was dedicated to order time and the delivery of construction materials and components. In that section, a discussion about early or late ordering of material was presented and the different methods used by the interviewees for determining order time was described. Also, some issues, such as material shortage, suppliers' indifferences, and client's financial problems that may endanger the logistics schedule, were considered. Delivery matters, such as JIT, sequencing, and early or late delivery, were explained and the results were complemented by descriptive statistics.

Material management was the topic of the fourth part which investigated the handling and warehousing of construction materials. In this part, information was provided about handling methods, handling equipment, handling distances, horizontal movement, vertical movement, and the way practitioners decide on choosing a handling strategy. Moreover, the importance of an onsite warehouse was emphasised and the advantages and disadvantages of long-time storage were made clear. In that section, statistical data was explained about the materials that are worth being stored onsite for a period of six months or longer. Moreover, warehousing processes were described and the ways materials are received, registered, stored and retrieved were expressed. Furthermore, different storage spaces were discussed and the methods for reporting and managing an inventory were clarified. A short section was dedicated to a central warehouse and it was explained that it has the potential to be converted to a consolidation centre. In addition, the conditions of material protection in construction projects were explored. It was expressed that not enough attention is paid to maintenance of materials and tools and this leads to waste generation and cost increase.

In the final part of this chapter, the results of a quantitative analysis of identified logistical problems were explained. According to the data collected through the survey questionnaire, financial problems, poor logistics scheduling and the low level of logistics knowledge among construction experts are the most important problems that affect construction logistics in the building projects in Iran. Experiencing these problems in the projects leads to poor construction logistics practice that has negative consequences for the projects. Based on the calculated Relative Important Indices, the most frequent consequences of poor construction logistics are project cost increases and delays.

Chapter 11

SYNTHESIS: CONSTRUCTION LOGISTICS MODEL

CHAPTER 11: SYNTHESIS-CONSTRUCTION LOGISTICS MODEL

11. 1. Overview

This chapter introduces and expresses the construction logistics model that is developed based on the qualitative data analysis (QDA). First, the holistic approach of the research and the way the model was developed is discussed. Then, different elements of the model are described and how the model works is elucidated. Finally, the expert feedback on the model and its functionality is reflected.

11. 2. The Construction Logistics Model

As explained above, this research takes a holistic and systemic approach to construction logistics. According to this approach, construction logistics is a system that consists of subsystems and agents that are interconnected to each other. These connections, that are called relationships, are as important as the agents of the system. To visualise all the elements of the construction logistics system, a conceptual model was designed that enables practitioners to obtain a panoramic view of all aspects of construction logistics as a single entity. The model was designed in a way to be informative and easy to use. Hence, it uses boxes and lines to represent different components of the construction logistics system. It should be explained that the proposed model was not developed based on a mathematical algorithm. In contrast, the conceptual model was created through an evolutionary process of qualitative data analysis. In other words, qualitative information formed the agents, relationships and boundaries of the model.

The purpose of this research was to develop a descriptive conceptual model that illustrates the construction logistics system in Iran. To design the model, information collected from the interviews was studied qualitatively and the results were explained in the analysis chapters. During the course of the QDA, in addition to discovering and categorising the agents of the construction logistics system, the relationships among those agents were also identified. The subsystems of the construction logistics model were presented in previous chapters. This chapter integrates all the subsystems and presents the whole construction logistics model on a single sheet. In the presented model, all the subsystems and agents of the system are shown without sacrificing the relationships among the agents. In the following sections, different elements of the model will be introduced and how the model works will be described. Furthermore, the feedback provided by three construction experts on the proposed model will be reflected.

11. 3. Elements of the Construction Logistics Model

The construction logistics model has four elements: (1) blue ovals, (2) rectangles in different colours, (3) dotted line branches, and (4) relationship diamonds (Appendix seven). The blue ovals are the subsystems of the construction logistics system. They are the main categories or parent nodes that emerged from the QDA. The subsystems are connected to each other in the form of a tetragonal to make an integrated system. The rectangles are agents of the system, which were referred to as child nodes in the QDA. Three layers (Tiers) are defined for agents, according to their importance, which are differentiated with different colours. The layers show the hierarchy of the nodes that are extracted from the QDA. The rectangles are in purple, green, and orange. The purple rectangles are in the first layer (Tier one) that are directly divaricated from the subsystems. The green rectangles (Tier two) are child nodes of the purple rectangles and parent nodes of the orange rectangles. Orange rectangles are in the last layer (Tier three) and do not have any child nodes. The black dotted lines are the branches of the system that connect agents to each other and to the subsystems. In other words, these lines illustrate which agent belongs to which category. To show the relationships, solid black diamonds are positioned on the black lines. There is an identification code for the relationship between each two nodes that are linked together. This code is written in the middle of the diamond shape (Figure 91). Using these codes, the reader can access the description for each relationship, which is tabulated in Appendix eight.

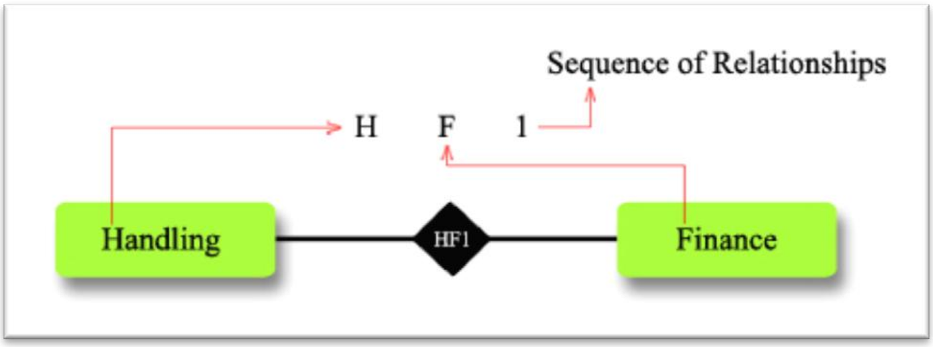


Figure 91: Labelling relationships

The table in Appendix eight supports the construction logistics model (Appendix seven) and provides a brief explanation for all relationships. In total, the table covers 137 relationships that are sorted alphabetically based on the relationship codes. For each relationship, the name of the two nodes is shown in the table and a short description on how these two nodes are related to each other is provided. For example, for Figure 91, Table 24 is presented that describes the relationship between ‘Handling’ and ‘Finance’.

Table 24: An example of a table that describes the relationships between two nodes

Row	Relationship Code	Node 1	Node 2	Description
22	HF1	Handling	Finance	Wrong distribution of materials onsite leads to cost increases because extra money should be paid to labour to re-handle materials to the suitable places.

11. 4. How the Model Works

The model shows factors that affect construction logistics in building projects in one picture. This enables the reader to understand the aggregate behaviour of the whole system without focusing only on one specific aspect of the system. In other words, it helps the practitioners to consider all the factors that may have any impact on construction logistics in the time of decision making. By focusing on each agent, the practitioners can see all the relationships associated with it. These relationships show how the agent affects, and how it is affected by, other agents. In other words, by focusing on a specific agent, the practitioner is able to find out what is the impact of that agent on the system, and what is the impact of the whole system on the agent. This means that no agent in the construction logistics model can be dealt with in isolation. Therefore, any change and modification in one agent of the system will alter the behaviour of the whole system.

To clarify how the model works, giving an example is helpful. The ‘Supplier Selection’ agent is chosen to describe the model function. As clear in Appendix seven, the ‘Supplier Selection’ agent is categorised under the ‘Purchasing’ agent. The ‘Purchasing’ agent belongs to the ‘Commercial Factors’ subsystem and is a parent node for ‘Supplier Selection’. Appendix seven shows that the ‘Supplier Selection’ agent has five relationships with 'Material Costs' (SC1), 'Material Quality' (SQ1), 'Project Size and Location' (SL1), 'Purchasing Channels' (CS2), and 'Suppliers' (SS1). It means that these five agents should be considered as affecting factors. The relationships between the agents are described in a table (Appendix eight). To access the description, the unique code of each relationship should be searched for in the table, which is sorted alphabetically. For example, the relationship CS2 with 'Purchasing Channel' is associated with the following description in the table:

> *Selecting purchasing channels highly depends on the amount and volume of materials required. For small volumes, usually retailers and suppliers are selected, while for large volumes and bulk ordering, manufacturers are the better choice.*

Hence, the purchasing channel is a factor that affects the way suppliers are selected. Another example is relationship SS1 that links 'Supplier Selection' and 'Suppliers'. The description in the table indicates:

> *Selecting suppliers may be based on previous collaborations and keeping long-term relationships.*

Thus, the length and type of relationship is a factor that should be taken into account when a supplier is to be selected to procure the project.

An important point that needs explaining is the compatibility of the model. As the construction logistics model is designed based on the complexity mindset, it does not have a constant form. The model can be used, reviewed and modified by users based on their experience, changes in the market, emerging new technology or economic conditions. It can be modified easily to add or delete agents and relationships. To insert an agent into the system, the user should find a proper subsystem and add the agents to it. Then, he/she can set the relationships of the new agent with the other agents of the system and label them with a unique code. Description of relationships can be expressed in the attached table for each label. In this way, the model keeps its evolutionary character and becomes adapted to changes enforced by the environment. Since the data was collected from medium and large size organisations, it can be argued that the created model is most relevant to similar sized organisations.

However, there is no reason why the model cannot be utilised in a simpler format by small organisations.

11. 5. Validity of the Construction Logistics Model

This section reports on the credibility of the developed model and illustrates the feedback, comments and suggestions that been received from participants. As stated in Chapter six, the results of the qualitative study should be presented to the interviewees to receive their feedback on the credibility of the final product of the research. Credibility means to distinguish if the results of the research are trustworthy from the perspective of the interviewees. Utilising response validation techniques, the interviewees were contacted to participate in a ten-minute telephone interview. Owing to the fact that there was a two-year gap between the interviews and the model formation, ten participants were accessible and among them, only three were willing to comment on the model. N01, C05, and C17 agreed to make comments on the model.

The construction logistics model, as the main product of this research, was presented to the three interviewees to check validity. The model was sent to the interviewees via email as a Portable Document Format (PDF) file which included both the model graphic and the table. The respondents were advised to view the model on a computer and not to print it owing to its size. At the beginning of the interview, the model was introduced and the way it works explained by the researcher. After evaluating the model, the interviewees were requested to answer three questions that are stated in the following:

1. Is the model understandable and easy to work with?
2. Are you interested to use the model to manage construction logistics in your projects?
3. What are the strengths and weaknesses of the model?

The comments and feedback received from the interviewees are summarised for each question in the following sections:

11.5.1. Is the model understandable and easy to work with?

N01 expressed that the model can be used in the real world. He added the model is organised very well. Yet, some changes are required to somehow make it more user-friendly. C05 said the model looks logical but it is very complex and it is hard to work with. He indicated that it takes time to become familiar with the model and, in practical situations, there is no time to focus on a model for a long time. C05's view is a common problem of any new tools and applications, because often people are resistant to change. Yet, after becoming familiar with the new feature, they will use it with minimum issues. C17 explained that he likes the model and, despite its complexity, it is not difficult to follow. He mentioned that the table attached to the model is useful and, that without the table, the model is difficult to understand.

11.5.2. Are you interested to use the model in your projects?

N01 indicated that the model can be used in practical situations and emphasised that it is good practice to apply an academic product in the industry. He added that the model can provide the practitioners with the information needed to make logistics decisions. C05 expressed that the model can be applied easily, because it does not need expert people to use it. He stated that the model is a helpful tool for staff that are not experienced and can be used when the main decision makers are absent or busy. C05 also said that the model should be adapted to small or large projects. C17 answered positively to the second question and explained that the model can be used after some modifications. He mentioned that the adaptability of the model to different situations by adding or eliminating agents and relationships is a notable ability that increases its chance to be successful in practical situations.

11.5.3. What are the strengths and weaknesses of the model?

The interviewees also commented on the strengths and weaknesses of the model. N01 explained that the main advantage of the model is that it gathers the knowledge of experienced people in one place. He also pointed out the large size of the model as a disadvantage and mentioned that more relationships can be added to the model. Reducing the model size increases the level of confusion when a user attempts to follow a relationship. On new relationships proposed by the practitioners, the model allows adding or deleting components. The way a new agent can be added to the system was described above.

C05 expressed that the descriptions provided in the table are real and look practical. He also indicated that considering factors, such as culture, that relate to the special situation of the construction industry in Iran is an advantage of the model. However, he believed, in some cases, it is difficult and time consuming to follow the relationships. To minimise the difficulty of following relationships, the distance between lines were increased. Also, branches are shown with dotted lines which differentiate them from relationships. Furthermore, in Appendix nine each agent and subsystem is drawn separately (subsystems and agents close up) with its branches and relationships. Using this tool, the user will be able to find the affecting factors on each agent more easily without following lengthy relationship lines.

C17 stated that the best point about the model is that it is designed according to experts' views and that is why it is rational. Yet, he said that it is a little confusing to switch between the model and the table, and the model should be digitalised to be acceptable to the industry. Converting the model to software was the best suggestion received. The model has the potential to be considered as the base for developing a software package for managing logistics in building projects.

Interviewees also provided other suggestions to improve the model. N01 implied a short definition of logistics, the way the model works and some application examples should be added to the model's documents. C05 explained that a Farsi version of the model should be produced and a manual should be developed to direct the user on how to use the model. C17 also expressed that the label of some agents such as 'Purchasing Channels' and 'Culture' required more description and clarification. The issue of making terms clear and providing definitions was raised because the interviewees did not have access to the full version of the thesis. It can be concluded that, to apply the model in practice, a manual should be developed to describe how the model works, how new elements can be added to it, and what is the exact definition of each term. The point raised by C05 about translation is so critical. The model and its associated documents should be translated to Farsi to be utilised by a wider range of practitioners in the industry.

11. 6. Conclusion

The conceptual model developed in this research is a holistic approach to construction logistics (Appendix seven). Instead of a mathematical equation, the model relies on practitioners' advice and experience. It consists of four elements that are: subsystems (tetragon), agents, branches and relationships. The model is also accompanied by a table which provides descriptions for the relationships (Appendix eight). By focusing on each agent of the model, the user can identify the factors that affect that agent. Moreover, the user can understand the impact of the specific agent on other agents and also on the whole system. The model can be modified by the user to add or eliminate agents and relationships and, thus, it can be adjusted to different conditions and situations. The final construction logistics model was presented to three experts to evaluate its credibility. The interviewees' comments and suggestions were positive and raised important points that should be taken into account in the future development of the model. The main advantage of the model, as expressed by the interviewees, is that it was developed based on the real situations of the building sector in Iran that were described by the experts. Yet, some modification is required to make the model user friendly and easier to use.

Chapter 12

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Chapter 12

CONCLUSIONS

CHAPTER 12: CONCLUSIONS

12. 1. Overview

In the previous chapters, a literature review was carried out and the results of the QDA and the questionnaire surveys were discussed. The final chapter of the thesis summarises what has been done and explains how the research objectives were met. Furthermore, the main contribution to knowledge will be highlighted and some recommendations for further research will be provided. At the end, some guidelines are offered for conducting research in the area of construction logistics management.

12. 2. Research Summary

12.2.1. Literature Review

The first stage of the research involved reviewing the available literature to refine the research questions. The aim of the literature review was to enhance the researcher’s understanding about logistics and construction logistics and to identify arguments, strengths, weaknesses, and issues in the previous research. The five objectives of reviewing literature in this research were: (a) becoming familiar with the logistics terminology, (b) describing and evaluating the literature on logistics, construction logistics, and complexity, (c) studying the Iranian building sector, (d) reviewing methodologies used in construction management research, and (e) identifying the gap in the existing body of knowledge. The focus of the literature review was on the five aspects of: general logistics, construction logistics, the Iranian building industry, complexity theory, and research methodologies applied in the construction management field.

12.2.1.1. Logistics Management

Logistics is rooted in military science and encompasses moving, equipping and accommodating military forces. In the business sector, it involves supplying raw materials, managing materials and distributing the final product. Generally, material flow and information flow are the focal point of attention in logistics management. In fact, logistics management aims to use the required information to ensure prompt and continues materials flow from the source to the end customer. Some functions of logistics are: logistics network designing, supply and demand planning, sourcing and procurement, transportation management, fleet management, material handling planning, warehousing management, inventory management, labelling, packaging, administrating third party logistics services providers, order fulfilment, and customer service. The logistics system should be considered as an integrated entity. This enables an organisation to carry out a trade-off analysis to achieve value through the whole supply chain. The supply chain is a network of suppliers and customers that are linked with the main organisation. Managing the supply network involves making decisions about (a) location, (b) production, (c) inventory, (d) transportation, and (e) information (how to gather, process, and share information). The difference between SCM and logistics management is that the focus of logistics is on a specific organisation, business or project, while SCM aims to deal with the whole network that may encompass several independent firms. This is aligned with the unionist view which sees SCM as an umbrella term that includes logistics.

12.2.1.2. Construction Logistics

Logistics management has been sporadically applied in construction owing to some characteristics of the industry, such as single product, temporary location, indirect employment, fragmented supply chain, and adversarial relationships among parties. According to the literature, the most important functions of logistics in construction projects are: planning and scheduling, site layout designing, purchasing, delivery and transportation, handling, warehousing, and waste management. In terms of scheduling, five strategies are recommended by the literature that are: (a) maintaining buffer stocks on site, (b) matching the pace of work, (c) just-in-time ordering, (d) just-in-time delivery, and (e) programming the procurement process. All of these strategies can be applied in a project for different types of materials. The next logistics function is site layout designing, which involves assigning access, egress and traffic routes, providing enough and suitable storage spaces, positioning administration buildings, providing welfare facilities and equipment, and considering the services locations and site boundaries. Purchasing encompasses identifying supply sources and the acquisition of resources. The literature usually encourages practitioners to reduce the numbers of suppliers and to establish long-term relationships with them. In terms of delivery and transportation, factors such as project location, access to the site, delivery channels, delivery capacity, allowed delivery hours, delivery slots, vehicle capacity, travel distance, and waiting times for unloading should be addressed. Warehousing is an important function of construction logistics that may incur high costs for the project. The storage spaces are divided into three areas: (a) semi-permanent storage, (b) staging area, and (c) workface. Easy identification, being close to the work area, ease of handling, security, and tidiness are some factors that should be considered for setting a successful warehousing policy. An efficient handling strategy should attempt to reduce the number of handling operations. Handling equipment, availability of labour, material size, weight, bulkiness, and packaging are some aspects that should be considered for setting a successful handling strategy. Waste generation is a serious issue in the construction industry. There are two ways in which wastage can be reduced in construction projects: (a) minimising waste generation and (b) improving waste management practice onsite.

There have been researchers who have attempted to produce a model or framework for construction logistics. The works of Agapiou *et al.* (1998), Muya (1999), Sobotka (2000), Hill and Ballard (2001), Strategic Forum for Construction (2005), and Fang and Ng (2008) are commendable. The most notable research was conducted by Hill and Ballard (2001), which introduced ten principles for successful logistics management: (a) design for production, (b) rationalise the supply side, (c) manage processes (not functions), (d) establish standard processes for construction logistics, (e) define supplier standards, (f) measure performance, (g) continuous improvement, (h) reduce the component count, (i) share information, and (j) throughput (not storage). The problem with most research cited above is that they focused on a single or a few aspects of construction logistics and did not approach the topic holistically. This is the gap that was identified in the literature and this research aims to fill this gap by developing a holistic conceptual model for managing logistics in building projects.

12.2.1.3. The Iranian Building Sector

The third literature review chapter discussed the Iranian culture and the specifications of the building sector in Iran. Collectivism and family, excitement and joy, flexibility and adaptability, positive attitude towards education, and self-sufficiency are the strengths, and team-working inability, law aversion, hypocrisy, criticism, jealousy, and irresponsibility are the weaknesses of the Iranian culture. The role of the construction industry is important in Iran and accounts for about nine per cent of Gross Domestic Product (GDP) of the country. The Ministry of Housing and Urban Development (MHUD), President Deputy Strategic Planning and Control (PDSPC)-Technical Affairs Office, municipalities, and the Iranian Construction Engineering Organisation (IRCEO) are the four main institutions that regulate the construction industry in Iran. Time overrun, cost overrun, delay, and low productivity are some issues of the Iranian construction industry that are caused owing to material shortage, poor weather and site conditions, equipment breakdown, design deficiency, lack of proper tools and equipment, lack of inspection, absenteeism, accident, improper plan of work, repeating work, changing crew size and labour turnover. In the building sector, the main challenges are the sharp rate of population growth, the risk of earthquake, and the turbulent building economy. The Government has established six strategies to deal with these challenges: (a) Maskan-e-Mehr Scheme, (b) Public-rent Housing Scheme, (c) Mass-produced Housing, (d) supporting new methods of building, (e) renovating old buildings against earthquake, and (f) Rural Housing Development Scheme.

12.2.1.4. Complexity and Management

Today’s organisations are characterised by high technology, high speed, high change, high unpredictability and high stress. In these conditions, the Newtonian style of managing organisations which asserts systems can be reduced to their parts and elements does not work any more. An alternative is the complexity mindset that accepts change, uncertainty and unpredictability as norms in today's life of organisations. According to the complexity mindset, organisations cannot be reduced to their parts without considering the interactions, irregular patterns and nonlinear behaviours of their elements. This research considers construction logistics from an organisational perspective and attempts to approach it from the complexity mindset. Construction logistics is considered as a complex system because (a) the inter-relationships and interactions among the agents of the system are as important as the agents themselves, (b) the agents of the system have a degree of freedom to respond to changes, (c) the whole system can learn from the environment and adapt itself to the changes, and (d) the logistics system is a part of a construction project that is a complex environment. The complexity mindset helps this research to study the relationships between the agents of the system and their interactions with the system's environment. It also contributes to taking a holistic view towards the system and considering the impact of environmental factors, such as the economy and culture, on the construction logistics system. To attain a deeper understanding of the system, a model was developed to transfer meaning by using an informative diagram.

12.2.2. Methodology

This study utilised a multi-strategy research methodology that means using both qualitative and quantitative approaches. The qualitative part focused on describing and interpreting the construction logistics system by gaining input from experienced practitioners. A set of twenty four in-depth interviews (over 1660 minutes) were carried out with practitioners in Iran who had 594 years of experience in total. Interviewing was continued up to the point where the desired level of data saturation was achieved. The grounded theory approach was adopted to analyse the qualitative data gathered from interviews, which involves classifying and organising data through the creation of themes emerging from the interview transcripts. The quantitative part complemented the findings of the qualitative study through conducting a questionnaire survey and using descriptive statistical analysis. The questionnaire was designed based on the results of the qualitative data analysis. The survey aimed to utilise a relatively large sample to understand what people know about construction logistics and how they manage logistics in their projects. The questionnaire consisted of 30 questions that were categorised under ten sections. A total number of 135 completed questionnaires were received. The gathered data was analysed using SPSS and the results were incorporated into the analysis chapters in a way that complements the qualitative outcomes.

The first round of the QDA (open coding) led to the formation of 41 nodes. Some nodes, such as purchasing, warehousing, and transportation, were referred more frequently than others and formed larger nodes. In the next stage of the QDA, larger nodes were divided into smaller nodes and smaller nodes were merged into the other nodes. Finally, all the nodes were categorised under four general groups of (1) environmental factors, (2) commercial factors, (3) operational factors, and (4) managerial factors.

12.2.3. Analysis

12.2.3.1. The Effects of Environmental Factors on Construction Logistics

Owing to the fact that Iran is located in a special geographical location with diverse weather conditions, the impact of the environment on logistics should be considered. Four environmental factors that were studied in this research were: (a) resource conservation, (b) project size and location, (c) weather conditions and geographical position, and (d) construction peak working seasons. In terms of resource conservation, interviewees described three strategies: (1) to establish a code of practice on how to deal with natural resources, (2) to change the way that resources are delivered to the sites by providing proper packaging, and (3) to promote recycling. The size and location of the project is another environmental factor that affects construction logistics. Working in urban areas, outside cities, and undeveloped regions requires different logistics strategies. For example, in urban projects, storage space is limited and, therefore, in these projects the importance of packaging is higher. Alternatively, in undeveloped regions there may be skill, equipment and material shortages. Additionally, adverse weather conditions should be considered in logistics planning. When the temperature is very high or low, materials may be melted or frozen. Moreover, the peak working period should be considered in the schedule to minimise the impact of issues, such as labour and material shortage, price increase and suppliers' indifferences. Peak working time is often in summer, but it may be different for regions with a hot climate.

12.2.3.2. The Effects of Operational Factors on Construction Logistics

The operational factors that were covered in this study include technology, transportation and wastage. The technology section is about new materials and construction methods. The logistical advantages of using new materials were explained by interviewees as: light weight, flexibility, proper packaging, and high durability. There are also disadvantages such as high cost and unfamiliarity of labourers with new materials or construction methods. Some popular new materials are foam (polystyrene) sections, plasterboards, light blocks (Lika) and prefabricated steel joists. In addition, the choice of construction methods affects some aspects of construction logistics, such as site layout design. The reason is that the components required to build steel or concrete structures are different. For concrete structures, the most important elements are concrete and steel rods while in steel structures, steel sections are used to build beams and columns. Use of prefabricated materials and offsite construction is rare in Iran because of the lack of interest in clients, unfamiliarity of the contractors, transportation issues, and lack of special handling equipment onsite.

Another operational factor is transportation. This should be considered early and in the material selection stage. Road freight is the dominant form of construction materials transportation and its cost may be calculated based on the price index, weight/distance or a quote provided by the driver. A cost trade-off should be conducted between the material price and the cost of transportation to procure the material with the best value. Traffic regulations, such as heavy vehicles movement limitations in urban areas, is an issue that should be considered in transportation scheduling. Moreover, transporting very tall, very wide or very heavy loads need special arrangements with the police and local authorities.

The amount of wastage generated in the Iranian building projects is very large. Around 60% of questionnaire respondents explained that the amount of waste generation is high or very high in building projects. The reasons explained for this problem by the interviewees were poor loading and transportation, poor handling, poor storage, cultural matters, poor packaging, low price of construction materials, lack of training, and lack of motivation for contractors. The result of the survey showed that cultural matters, workers' unawareness, and wrong loading and unloading methods are the most important reasons for generating waste in building projects. The waste produced during demolition and excavation is also important. The old building’s materials, such as door and window frames, steel sections, and aluminium sections, can be sold, while bricks can be reused in the new building.

12.2.3.3. The Effects of Commercial Factors on Construction Logistics

The commercial factors include the supply chain, purchasing, and finance. The main supply chain members that were discussed in this research are clients, consultants and suppliers. The contract that binds the supply chain members affects some construction logistics aspects, such as purchasing, material selection, site mobilisation, material delivery, material scheduling, finance, logistics organisation, and construction methods. According to survey data, the most popular form of contract in the building sector in Iran is the traditional method, as 58% of respondents use it in their projects.

Clients, by confirming bills of quantities, selecting materials, and setting quality standards affect construction logistics. Hence, clients' changing decisions on these aspects is an issue that can cause logistical problems for the projects. Consultants are also influential in construction logistics, because they should choose materials and construction methods. They can propose standard sized components when they are designing the project to reduce the variety of materials onsite. The role of suppliers, as material providers, in construction logistics is critical. An effective relationship should be set between contractors and suppliers. In the survey, around 45% of respondents were keen to have long-term relationships with suppliers. The benefits of having a long-term relationship with suppliers are payment instalment, credit purchasing, purchasing via phone, receiving special discount, service priority and getting help to deal with unanticipated issues. However, more than 18% of respondents stated that, in a competitive market, there is no need to establish long-term relationships with suppliers because there are always suppliers who can procure materials with lower costs.

Purchasing should be based on the construction stage, project size, availability of cash and availability of space for onsite storage. In small projects, when the onsite stock goes below a certain level, the construction manager will be informed by the foreman to buy more materials. Yet, in larger projects, purchasing should be conducted by the site staff or the head office according to the schedule. First, the amount of needed materials should be estimated and then a requisition should be prepared by the site supervisor. The requisition should be checked by the Project Control Unit (PCU) and sent to the buyer coordinator for gathering quotes. Then materials should be selected according to the client's expectation, available budget, price, quality, technical regulations, new technology, and packaging. The quality of materials can be ensured by collecting and testing samples or buying products that are certified by the Institute of Standards and Industrial Research of Iran (ISIRI). Also, attention should be paid to packaging because proper packaging may decrease waste, increase quality, make transportation easier, and provide a more organised working space. Packaging also has a negative side because it increases the amount of debris onsite and also causes environmental issues. After selecting a material, a supplier should be selected from the vendor list to procure the project. Utilising a vendor list minimises the risk of indifference, having low quality material, and delivering wrong quantities to the site. The results of the survey showed that 73% of respondents had a vendor list, but they also considered alternatives. Some criteria that can be used for establishing a vendor list are: service quality, price, payment privilege, commitment, delivery speed, distance to the site, and a long-term relationship. The questionnaire respondents selected supplier commitment as the most important criterion that should be considered in vendor list preparation. In terms of purchasing channels, retailers, agents, manufacturers, and mercantile exchange are used by the interviewees. For small volumes, usually retailers and agents are selected, while for large volumes and bulk ordering manufacturers and mercantile exchange are the better choices. All materials and components arriving to the site should be inspected before storage in terms of quantity and quality. Around 78% of questionnaire respondents expressed that they carry out accurate quantity inspections, while 53% said accurate quality inspection is conducted in their projects. A factor that endangers the purchasing process is material shortages for materials, such as cement, concrete and steel. Material shortage may be due to a lack of enough manufacturers, exporting products to other countries, peak working seasons, or project location in an undeveloped region.

Financial factors also affect construction logistics. Contractors should be aware of timing and the amount of payments made by clients to arrange purchasing materials and services required. In public projects, contractors encounter many challenges as finance sources are limited. Interviewees explained that the payment from the Government is not continuous and does not follow a regular sequence. For private firms, the main finance sources are banks. However, the interest rate of loans is so high in Iran that the process of getting a loan may last a long time. Hence, sometimes clients and contractors have to use other sources, such as pre-selling units and bartering building units with materials. The impact of economic conditions, such as a recession, on construction logistics is considerable. The interviewees explained about the unavailability of cash and changes in the suppliers' behaviour in a recession period. Another factor is the inflation rate as this affects construction materials' prices. The material cost includes the extracting, manufacturing, distributing and transportation of materials and components. Materials costs are calculated based on the price indices booklet that is published by the government for specific materials. The problem with the price indices is that the real inflation rate is not reflected in some material prices in the indices.

12.2.3.4. The Effects of Managerial Factors on Construction Logistics

The managerial factors that affect construction logistics are organisation, information management, scheduling, and material management. The logistics organisation includes: (a) organisational structure, (b) personnel, (c) knowledge, (d) culture, and (e) site layout. In terms of structure, contractors may be centralised, decentralised, and semi-centralised. Each of these structures has its advantages and disadvantages, but the issue is that, in many cases, no section in these structures is dedicated to logistics. Around 61% of the survey respondents expressed that they do not have a team for managing logistics and usually one or two individuals carry out logistics tasks. To manage logistics effectively a new section should be added to the structure for a logistics manager to design site layouts, administer supplier relationships, and deal with site security matters. Besides structure, establishing standard processes for construction logistics tasks is important. For instance, there should be a document that expresses a standard process for purchasing materials. Less than 44% of companies which participated in the survey stated that they had established standard processes for logistics tasks.

The people who should be fitted into the logistics organisational structure were pointed out as the site director (supervisor), financial manager, supply and support manager, buying coordinator and warehouse coordinator. The respondents' knowledge of construction logistics was not very high and 31% mentioned that they have only a few ideas or no idea about logistics. Enough training has not been provided for construction logistics and there is a lack of specialised staff for undertaking logistics roles. This is more crucial for certain fields, such as warehousing management, purchasing, marketing, and procurement, because there is no established university course to educate students in these fields. Hence, logistics personnel should learn how to do their jobs through experience or getting help from colleagues. Cultural factors should also be considered in construction logistics. How to deal with suppliers or workers, how to face cultural issues and how to understand cultural norms are factors that need attention in logistics management. For example, in terms of the relationship with suppliers, the interviewees' typical view was that, by establishing a friendly relationship with suppliers, the risks of irresponsibility, fakery, and low commitment will be reduced. Organising spaces onsite and designing site layout were also covered by the interviewees. Proper locations should be allocated to facilities, such as offices, accommodation, batching plants, cranes, storage areas, security, routes, and hoarding.

The role of information as the base for making logistics decision was covered by interviewees. The most important logistical information is market data, product specifications, schedule, and inventory. The importance of ICT was also appreciated by the interviewees. The benefits of ICT utilisation, as expressed by the interviewees, are information accuracy and an integrated environment. In relation to logistics, ICT can be used for documentation and archiving, warehouse management, estimation, and communication.

Another managerial factor is logistics scheduling, which means planning for purchasing and delivering materials to the site. One of the tools that can help in logistics planning is the resource booklet that shows the amount of materials which are required each month from inception to completion of a project. In terms of purchase timing, 55.8% of respondents explained that purchasing should be conducted according to the schedule. In addition to the project schedule, factors such as delivery time and indifference affect order time. The delivery time should also be based on the project schedule. Late or early delivery of material is a reoccurring problem in Iran, as 31% of the respondents had experienced early delivery and 56% of them had experienced late delivery. An important point about delivery time is that the whole load should be delivered to the site gradually and in a logical sequence. Sequencing can save money and time by reducing storage space, waste and the amount of materials re-handling.

Material management encompasses handling and warehousing and is the main concern of construction logistics. Material handling depends on the type of materials and construction methods and involves activities, such as lifting, carrying, pushing, or pulling materials manually or by using special equipment. After unloading, materials should be delivered to the onsite warehouse for long period storage or to somewhere near the point of use for short period storage. Handling can be done in horizontal or vertical directions. In horizontal movements, materials should be placed in a pre-planned location to minimise poly-handling. In vertical handling, the role of machines, such as cranes and winches, is important. The choice of machine depends on the size of the projects, height of the building, weight of materials, available space, the project location, and site traffic.

Warehousing is one of the main functions of logistics. It is necessary to have storage space in projects, because the material demand is continual, some materials have long lead-times, and there is a risk of material shortage and suppliers' indifferences. Storing materials onsite is not wise, because it raises warehousing costs and increases the risk of material depravation. However, owing to economic issues such as inflation, some practitioners prefer to buy and store materials early. The warehousing management system that is used in building projects is basic, as around 55% of respondents used manual methods to control enter and exit of materials to or from the warehouse. An important point about warehousing is that the site directors should be always informed about the stock level. The warehouse coordinator should prepare an inventory report and notify the site director about items' descriptions, available stock, the amount of purchased materials, and the amount of consumed materials. In terms of space, four storage types may be considered onsite: (a) surrounded open storage, (b) closed storage without roof, (c) closed roofed storage with shelves, and (d) silo. During the warehousing period, enough attention should be paid to material protection by complying with material protection codes. Poor material protection may damage materials and components and leads to waste and cost increase.

In the QDA, ten problems were identified that affect the construction logistics practice. To distinguish which problem is the most important, the survey respondents were requested to rank these logistical problems. The results showed that financial issues, poor logistics scheduling, and low levels of logistics knowledge are the most important logistical problems respectively. These problems may have several negative consequences for the projects. The survey also demonstrated that cost increase, delays, and waste increase are the most important consequences of poor construction logistics.

12.2.4. The Construction Logistics Model

Using diagrams and models is an effective way of visualising the configuration of complex systems. The model developed in this research helps to obtain an image of the whole process of construction logistics in building projects. It is designed based on qualitative data gathered from interviewing experts. The model has four parts: (a) subsystems, (b) agents, (c) branches, and (d) relationships. The model can be used as a decision making tool for managing logistics in building projects. Utilising the model, the practitioners are able to consider the factors affecting a specific agent. They also can study if any change happens to one agent, how other agents and, consequently, the whole system will be affected.

The final model was shown to three experts to attain their feedback on three points: (a) if the model is understandable, (b) if the experts are willing to use the model, and (c) what are the strengths and weaknesses of the model. The experts' feedback was positive and no major drawback was raised by them. Most comments were about the use of the model and not the content. They described the model as logical, organised and compatible with real situations. However, they explained that, to utilise it in practical situations, the model should be presented in a user friendly manner and possibly converted to a software package.

12. 3. Meeting the Research Objectives

The aim of this research was to develop a conceptual model based on the current practice of construction logistics in building projects which is adapted to the economic, cultural, technological and environmental specifications of the construction industry in Iran. The study achieved its aim by conducting qualitative research and using the in-depth interviewing method. Through the QDA, factors affecting construction logistics in Iran were identified. All the findings were gathered together to produce a conceptual model that appreciates the specifications of the construction industry in Iran.

The three objectives of the research have also been realised:

1. *To distinguish social and technical factors which affect the process of construction logistics in building projects in Iran.*

   This objective was met through reviewing the literature and adopting a complementarity methodology approach. To attain a thorough understanding of the construction specifications in Iran, the available materials were studied. Also, literature about the Iranian culture and economy were reviewed to become familiar with social aspects of the country. The complementarity approach of the study mixed the qualitative and quantitative methods. The qualitative data from interviewees helped to identify factors that affect construction logistics. The quantitative survey enhanced the understanding of these factors from a wider perspective. Furthermore, it assisted in finding out the knowledge level of the Iranian practitioners about construction logistics. The qualitative study also contributed to recognising logistical problems and challenges in the Iranian building sector. The quantitative study was used to rank these problems according to their importance.

2. *To identify how the above affecting factors are linked together.*

   This objective was achieved through the qualitative study which facilitated the research to comprehend and describe the process of construction logistics practice. In the analysis stage, a modified grounded theory approach was adopted to focus more on the association of factors with each other. The result of the QDA enabled the study to discover the relationships that link the affecting factors together.

3. *To develop a holistic conceptual model that visualises the agents and relationships of the construction logistics system while appreciating its properties as a complex system.*

   The third aim of the research was realised through the literature review and creation of a diagram to visualise the qualitative data. The literature review enabled the research to evaluate previous attempts to make models or frameworks for construction logistics. It also helped to obtain knowledge about complex systems, their properties and the way they can be managed. Boxes and lines were used to create a conceptual model based on the result of the QDA. The subsystems and agents form the structure of the model, while the relationships shape a network that make these elements connect together. The final model is holistic and integrates logistics functions together. This helps to understand the aggregate behaviour of the system, which is one of the main properties of complex systems. The model is also flexible to changes in the environment and can be amended by adding or eliminating subsystems, agents, and relationships.

12. 4. Original Contribution to Knowledge

This research has contributed to the existing body of knowledge and provided the following insights:

1. The research has increased the understanding of construction logistics in Iran by describing the current practice of logistics management in building projects.

2. The study has revealed the logistical challenges and problems that practitioners may encounter in building projects in Iran. The way experts deal with these challenges were also discussed. These problems were ranked based on their importance by using a quantitative method.
3. The research has generated a detailed understanding of factors that may affect the logistics practice in building projects, and includes environmental, operational, commercial, and managerial factors. In addition to conventional logistics functions, such as purchasing, transportation, and warehousing, the impact of other factors, such as culture, organisational structure, ICT, inflation, technology, project size and weather conditions, were also studied.
4. The research has provided descriptive statistical data about different aspects of construction logistics, such as logistics and supply chain knowledge, logistics education and training, logistics organisation, frequently used purchasing channels, logistics scheduling, contracts, vendor list criteria, material delivery, material inspection, warehousing, and waste. This is the first statistical analysis of construction logistics in Iran that gives a wider view about the current conditions of logistical affairs in building projects.

5. The main contribution of this research is the development of a holistic conceptual model for managing logistics in building projects. The model is compatible with the technological, cultural, economic, and environmental conditions of the Iranian construction industry. Moreover, it was developed based on the holistic approach towards construction logistics and considers both agents and relationships of the construction logistics system.

12. 5. Recommendations

The research, by conducting twenty four interviews and gathering 135 completed questionnaires, has attained a general understanding of construction logistics practice in building projects in Iran. According to the shortcomings and issues that were identified during the course of the research, the following recommendations are presented that may improve the performance of construction logistics in Iran:

- The low level of general logistics knowledge among managers and engineers in Iran is an issue that was raised by both the interviewees and the survey respondents. This problem should be addressed by educational institutions through providing modules about logistics subjects. Also, there is a lack of experts for different construction logistics functions, such as procurement, warehousing, and purchasing. New courses should be developed to train and educate people to undertake such roles. In addition, enough training should be provided for logistics staff in the company to enhance their knowledge about their jobs and to share best practice among employees.
- It was explained in this study that a separate box for construction logistics should be added to the organisational structure of contractors. The logistics officer is responsible for procuring materials for the projects. He should supervise the purchase coordinator, buyer assistants, and warehouse coordinator.
- Poor logistics scheduling is the second important logistical problem from the survey respondents' view point. Thus, more attention should be paid to scheduling and updating the schedule. Also, a source should be developed that shows numerical data for calculating the lead-times of each material and component in the context of Iran. A useful tool that can be utilised for more accurate logistics planning is a resource booklet. It can be used in conjunction

with the project CPM to enhance the performance of construction logistics. It helps site directors and other decision makers to know what materials are needed, in what quantity, and when and where they are required. In preparing the schedule and the resource booklet, the role of ICT is important, because it provides a basis for sharing accurate information quickly.

- The warehousing management system that is used in most projects is old fashioned. Manual registration of materials and producing daily reports using pen and paper does not work anymore, especially in large projects. The warehousing information should be accessible remotely by decision makers, at each moment. To make this happen, ICT should be implemented for warehouse management. Today, even using a keyboard to enter data is limited owing to its low speed and the high risk of mistakes. The electronic data entry technologies, such as electronic document imaging, scanning, barcodes, and RFID, should be implemented to eliminate the problems of manual data entering. To do so, the contractors and suppliers should set a common standard of ICT usage for material management to remove incompatibilities.
- Standardising logistics processes makes sure that the tasks are done in the best way expected. It reduces the risk of mistakes and inconsistencies and ensures that the required steps are undertaken for carrying out a task. ISO forms and templates are reliable tools that can be used for standardising logistics functions, such as warehousing and purchasing, and minimising operational risks.
- Modern logistics concepts, such as Just-In-Time (JIT), kitting, and consolidation centres (CC), can be applied in building projects. The JIT deliveries enable the firms to reduce warehousing related costs. By utilising kitting techniques, separate materials and components can be incorporated and grouped together in a way that becomes ready for installation onsite. The CC can improve the logistics of projects that are located in busy urban areas, such as Tehran, by combining part-loads to single shipments and reducing the number of heavy vehicles moving around the construction sites.
- The large volume of waste generation in building projects was highlighted in the research. A proper strategy should be set for minimising and managing

waste in building projects. One solution is the application of lean principles in projects which would help the Iranian firms to reduce waste production onsite. Cultural matters play an important role in waste control. Everybody involved in the project should be informed about the causes of waste and should be responsible for reducing waste generation. The culture of reusing and recycling should be promoted and encouraged among all members of the supply chain, including clients, consultants, contractors, managers, engineers and workers. There is also need for the Government to establish a strict code for managing waste by to reduce the negative impacts of building projects on the environment.

- Construction logistics functions cannot be understood in isolation. Practitioners should take the holistic view toward all logistics system components and appreciate that change in one agent of the system affects the performance of the whole system. Internal and external integration of construction logistics allows the practitioners to obtain value by conducting a trade-off analysis between different functions of the system. The model that was created in this research can help the practitioners to carry out internal integration and adopt the holistic approach towards logistics. A software package that integrates all logistical functions and gathers them under one roof can provide advantages for all supply chain members.

12. 6. Further Work

Construction logistics management is a broad topic that can be approached from several different angles. This section presents some areas that are worth being investigated in the future.

- This study identified many factors that affect the logistics practice in building projects. The main strategy of the research was qualitative and, thus, more stress was put on meanings. Future research can be done on the priority and impact level of these factors on the construction logistics system.
- Many hypotheses, such as practitioners' logistics knowledge level, contractors-suppliers mode of relationship, purchasing behaviour, and volume of waste, were developed as the result of the QDA. A quantitative study can be conducted on a larger sample to support or reject the findings of the study.

- The focus of this research was on developing a construction logistics model for the building sector. However, the model may be applied in other sectors. Yet, modification to the model is required to make it compatible with the nature of other sectors of the construction industry.
- The focus of this study was on site logistics and integration of internal logistics functions. Future research may consider external integration and supply chain management subjects.
- Construction logistics can be approached from a sustainability point of view. This research did not consider this factor because interviewees were not familiar with it and did not explain it in their discussion. Further work is required to incorporate this factor into the model.
- Mathematical programming and simulation have the potential to enhance logistics knowledge. Although it is not possible to replicate all aspects of the logistics system in a simulated mode, these methods can provide possibilities for trade-off analysis and optimisation.

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APPENDICES

Appendix 1: Interview guide

بنام خدا

برگه معرفي و انجام مصاحبه

پروژه طراحي مدل مفهومي مديريت لجستيک در ايران

تهران - سال 1388

تاريخ: ساعت:

شماره مصاحبه:

1. معرفي مصاحبه شونده

- نام و نام خانوادگي:
- ميزان تحصيلات:
- رشته تحصيلي:
- ميزان تجربه (سال):
- شغل:
- نام شرکت:
- نوع فعليت شرکت (پيمانکار - مشاور):

2. معرفي محقق

- احسان اثني عشري
- ليسانس مهندسي عمران
- دکتراي مديريت ساخت در دانشگاه ناتينگهام ترنت

3. معرفي تحقيق

- *تعريف لجستيک:*

Logistics = Supply + Material Management + Distribution

- *تعريف مديريت لجستيک:*

عبارت است از انتقال بهينه مواد از محل تدارک به محل توليد و از آنجا به محل مصرف با صرف هزينه حداقل در حاليکه خدمات قابل قبول به مشتري ارائه گردد.

- *تعريف لجستيک پروژه هاي ساخت:*

بسيج کردن منابع مختلف (مصالح، اجزاء، تجهيزات، ماشين آلات، نيروي انساني، تکنولوژي و اطلاعات).

اطمينان از حاضر بودن منابع در زمان صحيح، در مکان صحيح.

- *اهداف تحقيق:*
  1. *شناخت نحوه انجام فعاليتهاي لجستيکي در سايت.*
  2. *شناسايي عوامل موثر در مديريت لجستيک پروژه هاي ساختماني.*
  3. *يافتن مشکلات لجستيکي در پروژه ها.*
- *روش تحقيق:*

استفاده از روش کمي و مصاحبه بي ساختار جهت تاکيد هرچه بيشتر بر تجربيات فعالين بخش ساخت و ساز.

- *محرمانه بودن:*

مصاحبه ها بدون نام با حفظ اطلاعات شخصي و شرکتي

ضبط صداي اختياري

- *انتظارات:*

تجربیات کلي و نه فقط منحصر به یک پروژه

مثالهاي فراوان همراه با رسم نمودار و بیان بصري

- **سوالات تحقیق:**

1. **مدیریت لجستیک در پروژه شما به چه صورت انجام مي گیرد؟**
2. **مشکلات لجستیکي پروژه هاي شما کدامند؟**

4. خلاصه مصاحبه

5. سایر اطلاعات

• عکس • آمار	• بروشور • پیشنهاد براي مصاحبه

Appendix 2: Interviewees' Information

Row	Code	Education	Field of Study	Experience (years)	Job Category	Role	Interview Duration (min)	New Nodes
1	C01	BSc/BEng	Civil Engineering	19	Senior Manager	Contractor	83	18
2	N01	PhD	Structural Engineering	18	Senior Manager	Consultant	76	8
3	C02	MA	Architecture	29	Senior Project Manager	Contractor/Client	142	4
4	C03	MSc	Structural Engineering	17	Senior Manager	Contractor	89	2
5	C04	MSc	Architecture	31	Senior Manager	Contractor	49	0
6	C05	MSc	Civil Engineering	42	Senior Manager	Contractor	62	0
7	N02	MA	Architecture	30	Senior Manager	Consultant	70	1
8	C06	MSc	Mechanical Engineering	30	Senior Manager	Contractor	81	0
9	N03	BSc/BEng	Civil Engineering	19	Site Supervisor	Consultant	56	1
10	C07	MSc (PhD Student)	Civil Engineering	30	Senior Manager	Contractor	100	2
11	C08	MSc	Hydraulic Engineering	32	Senior Project Manager	Contractor	50	1
12	C09	BSc/BEng	Management	30	Site Supervisor	Contractor	68	0
13	C10	MSc	Civil Engineering	39	Site Supervisor	Contractor	99	0
14	C11	MA	Architecture	38	Senior Manager	Contractor	74	0
15	C12	BSc/BEng	Civil Engineering	23	Site Supervisor	Contractor	53	0
16	Cl3	BSc/BEng	Civil Engineering	12	Site Supervisor	Contractor/Client	69	1
17	C14	MSc	Civil Engineering	20	Senior Project Manager	Contractor	51	0
18	C15	BSc/BEng	Civil Engineering	26	Senior Project Manager	Contractor	56	2
19	Cl6	MA	Architecture	12	Site Supervisor	Contractor/Client	52	1
20	N04	BSc/BEng	Civil Engineering	10	Senior Project Manager	Consultant	72	0
21	N05	BSc/BEng	Architecture	25	Senior Manager	Consultant	53	0
22	C17	MSc	Architecture-MBA	30	Senior Manager	Contractor	51	0
23	N06	MSc	Civil Engineering	22	Senior Manager	Consultant	60	0
24	Cl8	MA	Architecture	10	Site Supervisor	Contractor/Client	45	0

Appendix 3: The Questionnaire Covering Letter

The researcher name and

Contact information

The company name and address

Dear Sir/Madam,

Please find attached a questionnaire on *Evaluating the Construction Logistics Management Practice in the Building Sector of the Iranian Construction Industry*. This is a research project in Nottingham Trent University, UK for getting a PhD award. Your contribution to this research enriches the outcomes of the study. Please pass the questionnaire to a colleague who:

1. is familiar with building sector of construction industry in Iran.
2. has working experience in construction sites.
3. has information about support, supply, and procurement.

Please place the completed questionnaire in the provided stamped envelope and post it to the researcher address. All information gathered from the survey will be kept confidentially with the researcher. In case of having any issue or question, please do not hesitate to contact with the researcher via email or phone. Your participation in this research is highly appreciated.

Sincerely Yours,

Ehsan Asnaashari

PhD. Candidate

Construction Management Department

School of Architecture, Design and the Built Environment

Nottingham Trent University, Nottingham, UK

Email: ehsan.asnaashari@ntu.ac.uk

Appendix 4: The Questionnaire in English

Number: L Date:

QUESTIONNAIRE

Evaluating the Construction Logistics Management Practice in the Building Sector of the Iranian Construction Industry

Dear Sir/Madam,

In the recent years, logistics management has attracted attention from both the researchers and the practitioners as an important tool which can increase the efficiency of the construction projects. Logistics management means providing different resources at the right time and at the right location with reasonable price and quality. This study is to evaluate the way managers deal with logistical affairs in construction projects. The result of this study can provide a basis for implementing modern concepts, tools and techniques of logistics management in construction projects in Iran. Certainly, conducting a research project in the field of construction management would not be possible without using your priceless experiences and insight as a practitioner. By answering the questions of this questionnaire, please help us to achieve our aims. This questionnaire has 10 parts consisting 30 questions. Please carefully and honestly answer the questions according to the given guidance. Please skip the questions which are not applicable to you or, for any reason, you do not want to answer them. Since, this study is only focuses on the **building sector**, please answer the question from building construction point of view. It is necessary to express that all data collected from this questionnaire would be kept confidentially and would not be used for commercial purposes. In the case of being interested in receiving the results of this study, you may contact with the researcher by sending emails to ehsan.asnaashari@ntu.ac.uk or check the following website: www.CMSynopsis.com.

Thank you in advance,

Ehsan Asnaashari

PhD. Candidate

Construction Management Department

School of Architecture, Design and the Built Environment

Nottingham Trent University, Nottingham, UK

THE QUESTIONNAIRE IN ENGLISH

Part 1: Demographical Information

1.1 The company name (Optional): ………………………………………………………

1.2 Job (Optional): ……………………………………………………………………...

1.3 Level of education:

□ High School Diploma □ BEng, BSc & BA

□ MSc & MA □ PhD

1.4 Field of study

□ Civil Engineering □ Architecture

□ Management □ Other (please specify): ………....

1.5 Work experience:

□ 1-5 years □ 5-10 years

□ 10-15 years □ 15+ years

1.6 The company grade in building construction:

□ One

□ Two

□ Three

1.7 The company possession mode:

□ Private

□ Semi-private

□ Public

Part 2: Construction Logistics Knowledge

Definition: *logistics is the science of planning to gain and use different resources needed for a production system to work without disruption. Logistics management in construction encompasses purchasing, transportation, site layout designing, warehousing, handling, material management, and waste management.*

2.1 Were you familiar with the logistics concept before reading the above definition?

□ I was completely familiar

□ I was familiar to some extent

□ I had few ideas about it

□ I had no idea at all

2.2 Have you been educated in different logistics topics mentioned below in university or other type of educational institution? (Please put × in front of each logistic field according your extent of education you received)

Topic	Enough Education	General Information	Limited Information	No Education
Site Preparation				
Supply Chain				
Supply & Support				
Transportation				
Warehousing				
Handling Onsite				
Scheduling				
Construction Materials Specifications				
Materials Protection				
Construction Economy				
Waste Management				

2.3 Have employees, who carry out logistical affairs, been trained before or during taking their job? (Please select one or more options. Put × in front of each field according to the extent of training the logistics personnel received.)

Jobs	University Education	Participate in Training Courses	Learning from Colleagues	No Training
Supply & Support Manager				
Financial Manager				
Buying Coordinator				
Warehouse Coordinator				

Part 3: Supply Chain

Definition: *supply chain is a collection of organisations, companies, producers, service providers, and individuals that are positioned in a sequence and transform the raw materials into a final product and present it to the consumer. Supply chain management is to deal with upstream suppliers and downstream consumers to transfer a product with a reasonable price and quality to the final costumer while the supply chain bears the minimum cost.*

3.1 Were you familiar with supply chain concept before reading the above definition?

□ I was completely familiar □ I was familiar to some extent

□ I had few ideas about it □ I had no idea at all

3.2 In general, do you establish long term relationship with your project supply chain members or short term relationship?

□ Short term

□ Short term, but changing it to the long term is preferred

□ Long term

□ Long term, but changing it to the short term is preferred

3.3 Which purchasing channel do you usually choose to provide materials and components listed in the following table for your projects? (Please select one or more options.)

Materials/Components	Manufacturer	Iran Mercantile Exchange	Manufacturer's Agents	Retailers
Steel				
Concrete				
Cement				
Gypsum Powder				
Bricks & Blocks				
Aggregates				
Prefabricated Joists				
Stone				
Tiles				
Plaster & Cement Board				
Pipes				
Mechanical Components				
Electrical Components				
Taps and Sanitary Services				
Bitumen				
Doors				
Windows				
Paint				

Part 4: Logistics Planning and Scheduling

4.1 When do you order your needed material? (Please select one or more options.)

□ Order is based on the project schedule and CPM

□ According to the experience and before the material is finished

□ Whenever the material is finished

□ We buy all materials as soon as possible

4.2 Do you consider the lead times when you plan to purchase materials and components?

□ Yes, we do and its value is accurate

□ Yes, we do but its value is not accurate

□ We rarely do so

□ No, we do not

4.3 From what sources do you get the numerical data of the lead times? (Please select one or more options.)

□ It is determined by experience

□ By asking from manufacturers and suppliers

□ Finding from related tables in Farsi books

□ Finding from related tables in books in other languages

□ It is determined roughly and by guess

□ Other (please specify): ………………………………………………………………...

Part 5: Procurement, Contracts and Supply Sources

5.1 What type of contract and procurement method do you use in your projects? (Please select one or more options.)

□ Traditional method (bills of quantities)

□ In-house

□ Square metre priced system

□ Management contracting

□ Turnkey

□ Fee based system

□ Fixed price system

□ Percentage system

□ Design & Built

□ Other: ……………

5.2 Do you have a vendor list for buying material and components?

□ Yes, we only purchase from the supplier in the vendor list

□ Yes, we mostly buy from the supplier in the vendor but we also consider alternatives

□ Yes, but we rarely use the vendor list

□ No, we do not have a vendor list

5.3 Which criteria are of great importance when you want to add a supplier to your vendor list? (Please score each criterion in the table from 1 (the least) to 10 (the most).)

Criteria	1	2	3	4	5	6	7	8	9	10
Long Term Relationship										
Quality										
Commitment										
The distance to the site										
Price										
Payment Privilege										
Other: ……………….										

5.4 Do you inspect and control the quantity and quality of the material and components delivered to the site?

	Accurate Inspection	General Check (not accurate)	No Inspection
Quantity			
Quality			

Part 6: Transportation

6.1 Have you experienced the following transportation issues in your projects?

	Very Often	Often	Rarely	Never
Early delivery of the material to the site				
Late delivery of the material to the site				

Part 7: Warehousing and Material Protection

7.1 How do you manage your warehouse? (Please select one or more options.)

□ Warehousing software

□ Warehousing software plus Barcode or RFID

□ Manual inventory report

□ We have no system

□ Other (please specify): …………...……………………………………………………

7.2 Does your company possess a consolidation centre to deliver materials and components to a portfolio of projects? (A consolidation centre is a temporary storage area where goods are delivered into the centre, multiple part-loads are combined into single shipments, and loads will be sent to the site when they are required in a just-in-time manner.)

□ Yes, it has positive effects on the construction process

□ Yes, but it does not have positive effects on the construction process

□ Yes, but it has negative effects on the construction process

□ No, we do not have it

7.3 Which materials and components specified below worth being stored for a long time (more than 6 months)? (Please select one or more options.)

□ Steel	□ Cement	□ Aggregates
□ Gypsum Powder	□ Bricks & Blocks	□ Stone
□ Mechanical Components	□ Electrical Components	□ Bitumen
□ Tiles	□ Doors	□ Windows
□ Gypsum & Cement Boards	□ Paint	□ None

Part 8: Logistic Organisation

8.1 Do you have a team in your company to be responsible for supply and support?

□ Yes, we have a dedicated team

□ One or two individuals do this job

□ No, there is no specific person to do this job

8.2 Have you established standards for carrying out logistical task such as purchasing, warehousing, documentation, etc?

□ Yes, we got ISO certificate

□ Yes, but we did not get ISO certificate

□ No, but we intend to take action for process standardisation

□ No, it is not necessary

Part 9: Waste Management

9.1 How do you approximately evaluate the volume of waste production in the construction projects in Iran?

□ Very High	□ Higher than standard
□ Standard	□ Lower than standard

9.2 Which factors are more important in waste production in your projects? (please score each factor in the following table from 1 (the least) to 10 (the most))

Factors	1	2	3	4	5	6	7	8	9	10
Poor Packaging										
Wrong Loading & Unloading Methods										
Low Price of the Materials										
Low Quality of the Materials										
Traditional Construction Methods										
Project Managers' Unawareness										
Workers' Unawareness										
Cultural Matters										
Materials Handling & Re-handling										
Other: ……………………….										

Part 10: Logistical Problems

10.1 Ten fundamental logistics problems in the construction projects are listed in the following table. Considering the importance of each problem, choose one of the provided options.

Problems	Very Important	Important	Important to Some Extent	Not Important
Low Level of Logistics Knowledge among Managers and Engineers				
Poor Logistics Scheduling				
Estimation Mistakes				
Financial Problems				
Construction Material Shortage				
Inappropriate Warehousing and Material Protection				
Unpunctuality of the Suppliers				
Lack of Experts in Construction Logistics Management				
Early or Late Delivery of the Materials to the Site				
Weakness of transportation infrastructures				

10.2 Considering the definition given at the beginning of the questionnaire, to what extent can weak logistics management cause the following problems in construction projects?

Problems	Very Much	Much	To Some Extent	Few	Very Few
Project Costs Increase					
Delays					
Low Quality Construction					
Low Level of H&S					
Waste Increase					

Thank you for your cooperation.

Appendix 5: Questions and Variables Description

Categories	QDA Topics	Questions No.	Variables	Question Type	Variable Type	Measure Type
Demographical Information	-	q1.1	Company Name	Open	-	-
	-	q1.2	Job	Open	-	-
	-	q1.3	Education	Category	Attribute	Nominal
	-	q1.4	Field of Study	Category	Attribute	Nominal
	-	q1.5	Experience (years)	Category	Attribute	Scale
	-	q1.6	The Company Grade	Category	Attribute	Ordinal
	-	q1.7	The Company Possession Mode	Category	Attribute	Nominal
Construction Logistics Knowledge	Logistics Knowledge	q2.1	Logistics Knowledge	Rating Likert	Behaviour	Ordinal
	Logistics Education	q2.2.1	Site Preparation	Rating Likert	Behaviour	Ordinal
		q2.2.2	Supply Chain			
		q2.2.3	Supply & Support			
		q2.2.4	Transportation			
		q2.2.5	Warehousing			
		q2.2.6	Handling Onsite			
		q2.2.7	Scheduling			
		q2.2.8	Construction Materials Specifications			
		q2.2.9	Materials Protection			
		q2.2.10	Construction Economy			
		q2.2.11	Waste Management			
	Logistics Training	q2.3.1	Supply & Support Manager	List	Behaviour	Nominal
		q2.3.2	Financial Manager			
		q2.3.3	Buying Coordinator			
		q2.3.4	Warehouse Coordinator			

Categories	QDA Topics	Questions No.	Variables	Question Type	Variable Type	Measure Type
Supply Chain	Supply Chain Knowledge	q3.1	Supply Chain Knowledge	Rating Likert	Behaviour	Ordinal
	Relationship with Suppliers	q3.2	Relationships Length	Category	Behaviour	Nominal
	Material Delivery Channels	q3.3.1	Steel	List	Behaviour	Nominal
		q3.3.2	Concrete			
		q3.3.3	Cement			
		q3.3.4	Gypsum Powder			
		q3.3.5	Bricks & Blocks			
		q3.3.6	Aggregates			
		q3.3.7	Prefabricated Joists			
		q3.3.8	Stone			
		q3.3.9	Tile & Carpet			
		q3.3.10	Plaster & Cement Board			
		q3.3.11	Pipes			
		q3.3.12	Mechanical Components			
		q3.3.13	Electrical Components			
		q3.3.14	Taps and Sanitary Services			
		q3.3.15	Bitumen			
		q3.3.16	Doors			
		q3.3.17	Windows			
		q3.3.18	Paint			
Logistics Planning and Scheduling	Material Scheduling	q4.1	Order Time	List	Behaviour	Nominal
	Lead Time	q4.2	Lead Time	Category	Behaviour	Nominal
		q4.3	Lead Time Numerical Data	List	Behaviour	Nominal
Procurement, Contracts and Supply Sources	Procurement & Contracts	q5.1	Procurement, Contracts & Supply Sources	List	Behaviour	Nominal
	Supply Sources	q5.2	Vendor List	Category	Behaviour	Nominal

Categories	QDA Topics	Questions No.	Variables	Question Type	Variable Type	Measure Type
		q5.3.1	Long Term Relationship	Rating Scale	Behaviour	Scale
		q5.3.2	Quality			
		q5.3.3	Commitment			
		q5.3.4	The distance to the site			
		q5.3.5	Price			
		q5.3.6	Methods of payment			
		q5.3.7	Other			
	Material Inspection	q5.4.1	Quantity	Rating Likert	Behaviour	Ordinal
		q5.4.2	Quality			
Transportation	Material Delivery	q6.1.1	Early delivery of the material to the site	Rating Likert	Behaviour	Ordinal
		q6.1.2	Late delivery of the material to the site			
Warehousing and Material Protection	Warehousing	q7.1	Warehouse System	List	Behaviour	Nominal
	Consolidation Centre	q7.2	Consolidation Centre	Category	Behaviour	Nominal
	Long-term Material Storage	q7.3	Critical Materials	List	Opinion	Nominal
Logistic Organisation	Logistics Organisation	q8.1	Logistics Team	Category	Behaviour	Nominal
	Standardised Logistics Process	q8.2	Process Standardisation	Category	Behaviour	Nominal
Waste Management	Waste Production Volume	q9.1	Waste Volume	Rating Likert	Opinion	Ordinal
	Causes of Waste	q9.2.1	Poor Packaging	Rating Scale	Opinion	Scale
		q9.2.2	Wrong Loading & Unloading Methods			
		q9.2.3	Low Price of the Materials			
		q9.2.4	Low Quality of the Materials			
		q9.2.5	Traditional Construction Methods			
		q9.2.6	Project Managers' Unawareness			
		q9.2.7	Workers' Unawareness			

Categories	QDA Topics	Questions No.	Variables	Question Type	Variable Type	Measure Type
		q9.2.8	Cultural Matters			
		q9.2.9	Materials Handling & Re-handling			
		q9.2.10	Other			
Logistical Problems	Logistics Risks	q10.1.1	Low Level of Logistics Knowledge among Managers and Engineers	Rating Likert	Opinion	Ordinal
		q10.1.2	Poor Logistics Scheduling			
		q10.1.3	Estimation Mistakes			
		q10.1.4	Financial Problems			
		q10.1.5	Construction Material Shortage			
		q10.1.6	Inappropriate Warehousing and Material Protection			
		q10.1.7	Unpunctuality of the Suppliers			
		q10.1.8	Lack of Experts in Construction Logistics Management			
		q10.1.9	Early or Late Delivery of the Materials to the Site			
		q10.1.10	Weakness of transportation infrastructures			
	Poor Logistics Management Consequences	q10.2.1	Project Costs Increase	Rating Likert	Opinion	Ordinal
		q10.2.2	Delays			
		q10.2.3	Low Quality Construction			
		q10.2.4	Low Level of H&S			
		q10.2.5	Waste Increase			

Appendix 6: The Questionnaire in Farsi

تاریخ: بنام خدا شماره: L

پرسشنامه

بررسی میزان آشنایی فعالان بخش ساخت و ساز با مفهوم مدیریت لجستیک و کاربرد آن در پروژه های ساختمانی

دوست و همکار گرامی،

امروزه مدیریت لجستیک به عنوان یک ابزار مهم در جهت افزایش میزان بهره وری در پروژه های ساختمانی مورد توجه محققان و فعالان بخش عمران در سراسر جهان قرار گرفته است. مدیریت لجستیک عبارت است از فراهم کردن منابع مختلف در زمان مطلوب، مکان مطلوب، با قیمت و کیفیت مناسب. این پژوهش قصد دارد نحوه برخورد مدیران و مجریان پروژه های ساختمانی با مسائل لجستیکی را ارزیابی نماید. نتایج این تحقیق راه را برای بکاربستن ابزارها و تکنیک های مدرن مدیریت لجستیک در پروژه های ساختمانی هموارتر خواهد نمود. بطور یقین انجام پروژه های تحقیقاتی در رشته مدیریت ساخت بدون استفاده از گنجینه تجربیات ارزنده شما ممکن نخواهد بود. لذا خواهشمند است با پاسخ دادن به 30 سوال این پرسشنامه که در 10 بخش طبقه بندی شده به غنای اطلاعات موجود افزوده و ما را در جهت نیل به اهداف این پژوهش یاری فرمایید. خواهشمند است طبق راهنمایی های ارائه شده به پرسشها پاسخ داده و سوالاتی که به شرکت و یا شغل شما ارتباط ندارند و یا به هر دلیل مایل به جواب دادن به آنها نیستید را بدون پاسخ باقی بگذارید. با توجه به اینکه این تحقیق تنها روی پروژه های ساختمانی تمرکز دارد، خواهشمند است با پیش فرض قرار دادن شرایط **صنعت ساختمان سازی** به سوالات پاسخ فرمائید. لازم به ذکر است که اطلاعات بدست آمده از این پرسشنامه بصورت محرمانه محافظت شده و در جهت اهداف تجاری مورد استفاده قرار نخواهد گرفت. در صورت علاقمندی به دریافت نتایج این تحقیق، می توانید با آدرس پست الکترونیک ehsan.asnaashari@ntu.ac.uk تماس حاصل نموده و یا از سایت اینترنتی www.CMSynopsis.com بازدید فرمایید.

با سپاس فراوان،
مهندس احسان اثنی عشری
دانشجوی دکتری مدیریت ساخت - دانشگاه ناتینگهام ترنت انگلستان

قسمت اول: اطلاعات اولیه

1.1 نام شرکت (اختیاری): ....

1.2 سِمت (اختیاری): ....

1.3 میزان تحصیلات:

☐ دیپلم ☐ کاردانی ☐ کارشناسی ☐ کارشناسی ارشد ☐ دکترا

1.4 رشته تحصیلی:

☐ مهندسی عمران (گرایش: ....) ☐ مهندسی معماری (گرایش: ....)
☐ مدیریت (گرایش: ....) ☐ سایر (لطفاً ذکر فرمائید): ....

1.5 تجربه کاری:

☐ 1 تا 5 سال ☐ 5 تا 10 سال ☐ 10 تا 15 سال ☐ 15 سال به بالا

1.6 رتبه شرکت (گرید) در ساختمان سازی:
☐ یک ☐ دو ☐ سه

1.7 نوع مالکیت شرکت:
☐ خصوصی ☐ نیمه خصوصی ☐ دولتی

قسمت دوم: میزان آشنایی با مفهوم لجستیک

تعریف: *لجستیک علم برنامه ریزی برای در اختیار گرفتن و استفاده از منابع مختلفی است که برای عملکرد پیوسته یک سیستم تولیدی مورد نیاز هستند. در ساختمان سازی مدیریت لجستیک شامل برنامه ریزی برای خرید، حمل و نقل، جانمایی، انبار، جابجایی و استفاده از نیروی انسانی، تجهیزات و مصالح می باشد.*

2.1 قبل از ارائه تعریف فوق به چه میزان با مفهوم لجستیک آشنایی داشتید؟
☐ کاملا آشنایی داشتم ☐ تا حدودی آشنایی داشتم ☐ آشنایی خیلی کمی داشتم ☐ هیچ آشنایی نداشتم

2.2 آیا در دوران تحصیل در دانشگاه و یا موسسات آموزشی غیر دانشگاهی، آموزش در زمینه های مختلف لجستیک که در زیر آمده دریافت نموده اید؟ (در مقابل هر گزینه میزان آموزشی که دریافت کرده اید را با علامت X مشخص فرمائید.)

زمینه لجستیک	آموزش کافی دیده ام	اطلاعات کلی دریافت کردم	بصورت خیلی محدود اشاره شد	هیچ آموزشی داده نشد
تجهیز کارگاه				
زنجیره عرضه				
تدارکات				
حمل ونقل				
انبارداری				
جابجایی مصالح داخل کارگاه				
برنامه زمانبندی				
مشخصات مصالح				
نگهداری مصالح				
اقتصاد ساختمان				
کنترل ضایعات				

2.3 آیا افراد شاغل در زمینه لجستیک که در زیر نام برده شده اند قبل یا حین انجام کار آموزش لازم را دریافت می کنند؟ (در مقابل هر یک از شغلها میزان آموزشی که دریافت می شود را با علامت X مشخص فرمائید.)

شغلها	تحصیلات دانشگاهی در رشته مرتبط با شغل دارند	دوره آموزشی مدون میگذرانند	از طریق همکاران با تجربه آموزش میبینند	هیچ آموزشی نمی بینند
مدیر تدارکات				
مدیر مالی				
کارپرداز				
انباردار				

2

قسمت سوم: زنجیره تأمین

تعریف: *زنجیره تأمین، مجموعه ای از سازمانها، شرکتها، افراد، تولید کنندگان و ارائه کنندگان خدمات می باشد که منابع طبیعی و مواد خام را با توالی مشخص به یک محصول نهایی تبدیل کرده و به مصرف کننده عرضه می کنند. مدیریت زنجیره تدارکات عبارت است از مدیریت روابط با تامین کنندگان بالادست و مصرف کنندگان پایین دست برای انتقال سرویس با بهترین قیمت به مشتری نهایی در حالیکه کمترین هزینه به زنجیره تأمین تحمیل گردد.*

3.1 آیا قبل از ارائه تعریف فوق برای زنجیره عرضه با این مفهوم آشنایی داشتید؟

□ کاملا آشنایی داشتم □ تا حدودی آشنایی داشتم □ آشنایی خیلی کمی داشتم □ هیچ آشنایی نداشتم

3.2 بطور کلی با اعضای زنجیره عرضه در پروژه ها (مانند تأمین کنندگان مصالح و ماشین آلات) رابطه کاری بلند مدت (بیش از یک پروژه) دارید یا کوتاه مدت (فقط یک پروژه)؟

□ رابطه کوتاه مدت

□ رابطه کوتاه مدت ولی ترجیح می دهیم به رابطه بلند مدت تبدیل کنیم

□ رابطه بلند مدت

□ رابطه بلند مدت ولی ترجیح می دهیم به رابطه کوتاه مدت تبدیل کنیم

3.3 معمولا برای خرید مصالح و تجهیزات زیر از چه کانالهایی اقدام می کنید؟ (لطفاً یک یا چند گزینه را انتخاب فرمائید.)

مصالح	تولید کننده	بورس کالا	عوامل رسمی فروش	فروشندگان جزء
فولاد				
بتن				
سیمان				
گچ				
آجر و بلوک				
شن و ماسه				
تیرچه				
سنگ				
کاشی و سرامیک				
پنل های گچی یا سیمانی				
لوله های آب و فاضلاب				
تاسیسات حرارتی و برودتی				
تاسیسات برقی				
شیرآلات و سرویسهای بهداشتی				
قیر				
دریها				
پنجره ها				
رنگ				

3

قسمت چهارم: برنامه ریزی و زمانبندی لجستیک

4.1 چه زمانی مصالح موردنیاز خود را سفارش می دهید؟ (لطفاً یک یا چند گزینه را انتخاب فرمائید.)

□ طبق برنامه زمانبندی و CPM　□ بصورت تجربی قبل از اتمام موجودی انبار
□ هر وقت مصالح موجود تمام شد　□ حتی المقدور همه مصالح مورد نیاز خریداری و انبار می شود

4.2 آیا هنگام خرید مصالح و تجهیزات بحث "طول مدت سفارش" یا "lead time" را در نظر می گیرید؟ (به عنوان مثال از زمان سفارش تاسیسات آسانسور تا زمان تحویل حدود 4 ماه طول میکشد که به این زمان "مدت سفارش" میگویند.)

□ بله، بصورت دقیق درنظر گرفته میشود　□ بله، ولی دقیق نیست
□ تنها برای اقلام خاص بصورت حدودی تخمین زده می شود　□خیر، درنظر گرفته نمی شود

4.3 اطلاعات عددی مربوط به "طول مدت سفارش" مصالح و تجهیزات بیشتر از چه منابعی تهیه می گردد؟ (به عنوان مثال عدد 4 ماه برای آسانسور از چه مأخذی بدست آمده است؟) (لطفاً یک یا چند گزینه را انتخاب فرمائید.)

□ بصورت تجربی تعیین می گردد　□ پرسش از تولیدکنندگان یا فروشندگان
□ جداول مربوطه در کتابهای داخلی　□ جداول مربوطه در کتابهای خارجی
□ بصورت حدسی تعیین می گردد　□ سایر(ذکر شود): ....

قسمت پنجم: تدارکات

5.1 از چه روش تدارکاتی در پروژه های خود استفاده می کنید؟ (لطفاً یک یا چند گزینه را انتخاب فرمائید.)

□ **متعارف:** مدیریت اجرای کار با پیمانکار، طراحی با مشاور، تأمین مالی با کارفرما و نظارت با مشاور می باشد.
□ **دستمزدی:** مانند روش متعارف می باشد ولی در اینجا تأمین مصالح با کارفرماست.
□ **امانی:** در این روش دستگاه اجرایی راساً انجام کلیه فعالیتهای مربوط به اجرای عملیات را بر عهده می گیرد.
□ **قیمت مقطوع:** کار با یک قیمت مقطوع به عامل اجرا واگذار می شود.
□ **روش متر مربع:** کار براساس قیمت متعارف و متر مربع زیربنا (و نه بر اساس فهرست بها) به پیمانکار واگذار می شود.
□ **روش درصدی:** همان روش سنتی است لیکن پرداختها براساس درصدی از هزینه ها به پیمانکار داده میشود.
□ **روش مدیریت اجرا:** نوعی از سیستم متعارف است که کارفرما سازمان خارجی دیگری رابه منظور مدیریت و کنترل پروژه به خدمت می گیرد.
□ **طرح وساخت:** کارفرما تهیه طرح پایه و نظارت براجرای پروژه را به مهندس مشاور واگذار نموده و از طریق قراردادی دیگر خدمات طراحی و ساخت پروژه را به یک واحد طرح وساخت واگذار می نماید.
□ **کلید در دست:** مسوولیت طراحی واجرا بطور کامل با پیمانکار است به گونه ای که بعد از تکمیل پروژه کارفرما فقط با چرخاندن یک کلید بهره برداری از کار را آغاز مینماید.
□ **سایر:** ....

5.2 آیا برای خرید مصالح و تجهیزات لیستی از فروشندگان معتبر (Vendor List) تهیه کرده اید؟

□ بله و فقط از فروشندگان موجود در لیست استفاده می کنیم
□ بله اکثراً از فروشندگان موجود در لیست استفاده می کنیم ولی گزینه های دیگر را هم در نظر می گیریم
□ بله ولی به ندرت از لیست استفاده می کنیم
□ خیر لیستی تهیه نکرده ایم

4

5.3 برای قرار دادن یک تأمین کننده مصالح و تجهیزات در Vendor List کدام فاکتور از اهمیت بیشتری برخوردار است؟ (از شماره 1 تا 10 امتیاز دهی فرمائید. 1 کمترین و 10 بیشترین امتیاز می باشد.)

فاکتور	1	2	3	4	5	6	7	8	9	10
ارتباطات طولانی مدت										
کیفیت										
خوش قولی										
مسافت تا کارگاه										
قیمت										
نحوه پرداخت (بصورت اقساط یا چک مدت دار)										
سایر										

5.4 هنگام وارد شدن مصالح و تجهیزات به سایت آیا نسبت به کمیت و کیفیت آنها بازرسی صورت می گیرد؟

	کنترل کامل و دقیق صورت می گیرد	بازرسی کلی صورت می گیرد ولی چندان دقیق نیست	کنترلی صورت نمی گیرد
کمیت			
کیفیت			

قسمت ششم: حمل و نقل

6.1 آیا موارد زیر در پروژه های شما رخ می دهد؟ (لطفاً یک گزینه را انتخاب فرمائید.)

	خیلی زیاد	زیاد	به ندرت	به هیچ وجه
زود رسیدن مصالح به کارگاه				
دیر رسیدن مصالح به کارگاه				

قسمت هفتم: انبارداری و نگهداری مصالح

7.1 از چه سیستم انبارداری در پروژه ها استفاده می کنید؟

☐ نرم افزار کامپیوتری انبار داری
☐ نرم افزار به اضافه بار کد یا RFID
☐ کارتکس و گزارش روزانه بصورت دستی
☐ سیستم مدون خاصی نداریم
☐ روش دیگر (ذکر فرمایید) ....

7.2 آیا شرکت شما دارای انبار مرکزی برای خدمت رسانی به پروژه های مختلف می باشد؟ (انبار مرکزی بدین معنا که اگر شرکت شما همزمان اجرای چند پروژه را در اختیار داشته باشد، مصالح و تجهیزات در یک انبار واحد نگهداری گردیده و تنها 1 یا 2 روز قبل از استفاده به کارگاه ها منتقل شوند.)

☐ بله. این انبار تأثیر مثبتی بر روند انجام کار داشته
☐ بله. ولی این انبار تأثیر مثبت چندانی نداشته است
☐ بله. ولی این انبار تأثیر منفی بر روند انجام کار داشته
☐ خیر. انبار مرکزی نداریم

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7.3 کدامیک از مصالح و تجهیزات زیر ارزش انبار بیش از شش ماه در کارگاه را دارند؟ (یک یا چند گزینه را انتخاب فرمائید.)

□ فولاد □ سیمان □ شن و ماسه □ گچ □ آجر و بلوک

□ سنگ □ تاسیسات مکانیکی □ تاسیسات برقی □ قیر □ کاشی و سرامیک

□ درها □ پنجره ها □ پنلهای جدا کننده □ رنگ □ هیچکدام

قسمت هشتم: سازماندهی لجستیک

8.1 آیا در شرکت شما ،گروه یا تیم مسئول تدارک مصالح و تجهیزات وجود دارد؟

□ بله. یک تیم مسئول انجام این وظایف است

□ یک یا دو نفر این وظایف را انجام می دهند

□ خیر. مسئولی وجود ندارد.

8.2 آیا نسبت به استاندارد کردن پروسه مدیریت لجستیک (شامل مکاتبات، مناقصات، استعلامها، فرم های مربوطه، نظارت و غیره) اقدام کرده اید؟

□ بله و استاندرد ISO دریافت نموده ایم

□ بله ولی استاندارد ISO دریافت نکردیم

□ خیر ولی قصد داریم نسبت به استاندارد سازی اقدام کنیم

□ خیر، لزومی ندارد

قسمت نهم : مدیریت ضایعات

9.1 به طور تقریبی میزان تولید ضایعات (پرت) در پروژه های ساختمانی ایران را چطور ارزیابی می کنید؟

□ خیلی زیاد است □ زیاد است □ کمی بالاتر از استاندارد است □ در حد استاندارد است

9.2 کدام عوامل اهمیت بیشتری در تولید ضایعات در پروژه های شما دارند؟ (از شماره 1 تا 10 امتیاز دهی فرمائید. 1 کمترین و 10 بیشترین امتیاز می باشد.)

عامل	1	2	3	4	5	6	7	8	9	10
بسته بندی ضعیف مصالح										
نحوه بارگیری و تخلیه										
قیمت پایین مصالح										
کیفیت پایین مصالح										
روش های قدیمی ساخت										
نا آگاهی مدیران پروژه										
نا آگاهی کارگران										
مسائل فرهنگی و عدم مسئولیت پذیری										
جابجایی چند باره مصالح و انبار ضعیف										
سایر:										

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قسمت دهم: مشکلات لجستیکی

10.1 در زیر 10 مشکل اصلی سیستم مدیریت لجستیک پروژه های ساختمانی گردآوری شده اند. خواهشمند است با توجه به اهمیت هرمشکل یکی از گزینه های روبروی آنرا انتخاب فرمایید.

مشکلات	خیلی مهم	مهم	تا حدودی مهم	مهم نیست
سطح پائین دانش مدیران و مهندسین در زمینه مدیریت لجستیک				
عدم وجود برنامه مدون ومنطبق با CPM برای لجستیک				
بروز اشتباهات در مرحله متره و برآورد (تخمین)				
مسائل مالی (مانند کمبود نقدینگی)				
کمبود مصالح ساختمانی				
نداشتن انبار مناسب (از لحاظ فضا وسیستم انبارداری)				
بدقولی عرضه کنندگان مصالح				
فقدان نیروی کار متخصص در زمینه مدیریت لجستیک				
دیر یا زود فرستادن مصالح به کارگاه				
ضعف زیرساختهای بخش حمل ونقل				

10.2 با توجه به تعاریفی که در ابتدای پرسشنامه گفته شد، ضعف مدیریت در بخش لجستیک تا چه اندازه می تواند در بروز مشکلات زیر نقش داشته باشد؟

مشکلات	خیلی زیاد	زیاد	تاحدودی	کم	خیلی کم
افزایش هزینه های پروژه					
بروز تأخیرات پی در پی					
کیفیت پائین ساخت					
کم شدن ضریب ایمنی در کارگاه					
افزایش میزان ضایعات					

با تشکر فراوان از همکاری صمیمانه شما
مهندس احسان اثنی عشری

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Appendix 7: The Construction Logistics Model

Appendix 8: The Relationships Description Table

Row	Relationship Code	Node 1	Node 2	Description
1	CC1	Purchasing Channels	Material Costs	Buying from manufacturers is often beneficial because they usually offer lower prices in comparison to the retailers and agents.
2	CF1	Purchasing Channels	Finance	Payment instalment and purchasing by credit is not possible when you deal with manufacturers. But the retailers usually offer payment privileges to keep long-term relationships with contractors.
3	CP1	Culture	Personnel	The behaviour of the personnel and the way they react to different situations depends on their culture.
4	CP2	Culture	Project Size & Location	The geographical position of the project affects the culture of the people.
5	CS1	Culture	Suppliers	The relationship with suppliers can be made stronger by forming friendships or partnerships. The positive points in the Iranian culture that can help in an effective relationship with suppliers are collectivism and the ability to produce joy and excitement. The negative points that may prevent parties establishing close relationships are team-working inability and jealousy.
6	CS2	Purchasing Channels	Supplier Selection	Selecting purchasing channels highly depends on the amount and volume of materials required. For small volumes, usually retailers and suppliers are selected, while for large volumes and bulk ordering, manufacturers are the better choice.
7	CW1	Culture	Waste	A culture should be developed to minimise waste onsite and then it should be promoted among all people involved in the project. In many cases, subcontractors and workers do not have the sense of responsibility to avoid material wastage.
8	CW2	Material Costs	Warehousing	A high rate of inflation amplifies the idea of purchasing and storing materials as soon as possible. This is beneficial because material prices go up day by day. However, it may be risky and the material price dropping suddenly causes capital waste.
9	DP1	Delivery	Peak Working Seasons	In peak seasons or agricultural harvesting time, there is a shortage of heavy vehicles. Hence, delivery time may increase.

Row	Relationship Code	Node 1	Node 2	Description
10	DS1	Delivery	Scheduling	Delivery should be based on material schedules. Deliveries should be carried out in the proper sequence. Late delivery may cause delay in the schedule.
11	DS2	Delivery	Suppliers	Local suppliers can deliver the materials faster.
12	DW1	Delivery	Warehousing	There should be coordination between the deliveries and the warehouse to provide enough storage space for loads. Early delivery may cause problems because there is not enough space onsite to receive materials. Materials, components, tools and plants can be stored in central warehouses of the company and transported to the sites when they are required on JIT basis. In fact, the central warehouse can have a function similar to a consolidation centre.
13	EC1	Estimation	Material Costs	If the inflation rate is very high, the required materials cannot be purchased at the estimated prices. This may put the project in financial difficulties.
14	EC2	Economy	Material Costs	In a recession period, the materials price decreases because there will be a reduction in materials demand.
15	ER1	Demolition & Excavation	Recycling	After demolition, materials, such as bricks, steel sections, door and window frames, can be reused or sold.
16	ET1	Demolition & Excavation	Transportation	Demolition debris and excavated soil should be sent to the landfill and this incurs transportation costs.
17	EW1	Estimation	Waste	The material wastage rate should be considered in the estimation.
18	FE1	Finance	Estimation	Estimation is the only way to understand whether there are enough funds to undertake the project. Poor estimation leads to wrong budget allocation which causes the creation of a gap between the budget and real costs.
19	FI1	Finance	ICT	ICT in financial management is important because it makes the process of report writing faster, easier and more visual. The available software produces cash flow and resource consumption graphs. Yet, use of ICT may incur costs.
20	HC1	Handling	Construction Methods	The handling strategy and types of equipment required vary for different structures and buildings. For steel structures, cranes are used but for concrete structures, because the structure is raised gradually, it is not necessary to use cranes.
21	HD1	Handling	Delivery	The site authorities should be informed about the delivery time to provide enough labour for unloading and handling materials. This is more crucial when

Row	Relationship Code	Node 1	Node 2	Description
				materials are delivered at night.
22	HF1	Handling	Finance	Wrong distribution of materials onsite leads to cost increases because extra money should be paid to labour to re-handle materials to the suitable places.
23	HP1	Handling	Personnel	Specialised workers can be employed for unloading materials. This increases the unloading speed and decreases the number of materials damaged during unloading and handling.
24	HP2	Handling	Project Size & Location	The choice of machine depends on the size and height of the project. For high rise buildings, tower cranes can be used and, for other projects, lifts and winches can be utilised instead of cranes.
25	HW1	Handling	Warehousing	The distance between the place materials are stored and where they should be incorporated into the building should be optimised. If materials are stored very close to the building, they may cause obstacles and disrupt the circulation of staff and materials. If materials are stored very far from the building, it will take a long time to handle them to the point of use. Long handling distance may increase amount of re-handling.
26	IE1	Information	Economy	Having enough information about the market and economic conditions helps the firms to anticipate peak construction periods.
27	IM1	Information	Material Costs	Information about specifications and prices of materials and components should be provided to conduct purchasing. The more accurate the data, the better purchasing can be done.
28	IP1	Material Inspection	Material Packaging	If the load comes in packages, it will be counted and, if the load is loose, it should be weighed.
29	IQ1	Material Inspection	Material Quality	The quality of delivered materials should be checked by sending samples to a lab or by observation by a professional.
30	IS1	Information	Scheduling	Scheduling information includes the order point, order time, time when the items are needed, transportation time, and lead time.

Row	Relationship Code	Node 1	Node 2	Description
31	IW1	Information	Warehousing	The warehouse information makes sure that materials and components are ready and available when different parties want them. When materials are received by the warehouse coordinator, a receipt should be issued that includes information, such as the item description, quantity, date of purchase, date of delivery, the supplier name and a traceable label. Handling details (the time and location the materials are needed) and health and safety information may be also included in the receipt or inventory report. All items that enter the site should be registered in the warehouse inventory. The inventory report should include information about the item description, available stock, the amount purchased, and the amount consumed. The site supervisor needs this information because he must ensure that resources are ready for starting activities that are planned in the schedule. In retrieval time, a receipt should be generated by the warehouse coordinator that includes information about the item description, the item label (code), quantity, recipient name, and date of retrieval.
32	IW2	Material Inspection	Warehousing	All materials should be inspected before storage.
33	LF1	Clients	Finance	The client is liable to pay the project's costs.
34	LH1	Site Layout	Handling	Decisions to use cranes, hoists, scaffolds and lifting equipments influence the design of the site layout
35	LK1	Site Layout	Knowledge	Designing the site layout needs extensive knowledge about warehousing, handling methods, required facilities, and required machines.
36	LM1	Clients	Construction Methods	Clients may be get involved in the process of choosing construction methods and sequence of tasks.
37	LP1	Site Layout	Project Size & Location	In urban projects, the space is often tight and this makes designing the site layout more difficult. Also, larger projects need more facilities and office spaces. Facilities required onsite may change according to the size and financial weight of the projects.
38	LQ1	Clients	Material Quality	Some clients are very sensitive to the quality of materials used and have their own standards.
39	LS1	Site Layout	Scheduling	The sequence of material deliveries affects the site layout.
40	LS2	Clients	Material Selection	Clients may ask the contractor to procure specific materials.

Row	Relationship Code	Node 1	Node 2	Description
41	LT1	Site Layout	Transportation	The factors that should be considered for designing routes are having close access to resources, reducing handling distance, allowing convenient circulation of pedestrians and vehicles.
42	LW1	Site Layout	Warehousing	An important part of designing the site layout is to decide on the type and volume of storage space required.
43	LW2	Site Layout	Waste	Anticipating proper storage in site layout can reduce material waste and designing access routes carefully can reduce time waste.
44	MD1	Construction Methods	Delivery	Ready mix concrete should be delivered to the site on a JIT basis. Building steel sections onsite increases the number of deliveries. JIT can be used for delivery of steel sections.
45	ME1	Material Selection	Economy	The housing market condition affects the material selection. In the recession period, people cannot sell houses at previous prices and, thus, they look for cheaper materials while keeping the functionality and quality. In a boom period, people look for luxury materials to achieve competitive advantages.
46	MI1	Material Selection	Information	Information about specification and properties of materials can be found in books, manuals or manufacturers' catalogues.
47	MI2	Material Selection	ICT	Information about specification of materials may be accessible in electronic form.
48	MI3	Material Quality	Information	To ensure that quality materials will be ordered, enough information about specification, properties, expected quality and brand of materials should be provided by the technical office.
49	MM1	Material Selection	Construction Methods	The choice of construction method affects the choice of material required.
50	MN1	Material Selection	New Materials	Establishment of new regulations and codes to reduce the buildings' weight necessitates the use of new light materials.
51	MP1	Construction Methods	Project Size & Location	The location and size of the project affects the choice of construction method. To fabricate steel sections, concrete sections or other components onsite, there should be enough space to have a small steel workshop.
52	MS1	Construction Methods	Site Layout	The choice of concrete or steel structure affects the way site layout is designed.
53	MT1	Material Selection	Technology	Technological advancement provides alternatives for the older materials.
54	MW1	Construction Methods	Waste	Traditional construction methods increase the amount of waste production.

Row	Relationship Code	Node 1	Node 2	Description
55	MW2	Construction Methods	Warehousing	For concrete structures, proper storage should be provided for formworks and steel rods. Erection of concrete structures takes longer and this means it takes longer to have a proper warehouse.
56	NF1	Consultants	Finance	Consultants can carry out material standardisation in the design stage. Standardised materials can be order in bulk to get discounts and reduce the project's costs.
57	NH1	New Materials	Handling	New materials are lighter and, thus, easier to be loaded, unloaded and handled without any special equipment.
58	NM1	New Materials	Material Costs	New materials are more expensive.
59	NM2	Consultants	Construction Methods	Consultants may be responsible for making decisions about construction methods.
60	NP1	New Materials	Material Packaging	New materials often have higher costs and come in proper packages.
61	NS1	Consultants	Material Selection	Consultants may be responsible for selecting materials for the project.
62	NT1	New Materials	Transportation	New materials are lighter and large numbers of them can be loaded in a vehicle which means fewer deliveries to the site.
63	NW1	New Materials	Waste	New materials are more flexible and are not broken during transportation, unloading and handling and this reduces the volume of waste generation onsite.
64	NW2	Consultants	Warehousing	Material standardisation reduces the variety of materials delivered to the site which leads to improvement in storage practice and the material identification process on site.
65	NW3	New Materials	Warehousing	Using new materials with proper packaging leads to having an organised warehouse with materials that can be labelled and identified easily. New materials are more expensive and may need special care during the storage period.
66	OC1	Material Shortage	Material Costs	Shortage of materials may increase the materials' price.
67	OE1	Material Shortage	Economy	The Government, by giving mortgage or other incentives, may increase materials demand which leads to material shortages. Material shortages is also likely in a boom period after a long recession. Exporting materials is also an issue that may cause material shortages.
68	OH1	Offsite and Prefabrication	Handling	Special equipment may be required for handling prefabricated components.
69	OP1	Organisational Structure	Personnel	The organisational structure shows the personnel that are required for different

Row	Relationship Code	Node 1	Node 2	Description
				jobs.
70	OS1	Material Shortage	Scheduling	Material shortages endanger the schedule and cause delay. If material shortages are expected, materials may be ordered as soon as possible.
71	OT1	Offsite and Prefabrication	Transportation	Prefabricated components may require special transportation facilities.
72	OW1	Offsite and Prefabrication	Waste	Offsite construction and using prefabricated materials decreases the volume of waste onsite.
73	OW2	Material Shortage	Warehousing	To avoid material shortages, contractors have to buy and store materials ahead. This increases the size of the inventory onsite and incurs more warehousing costs.
74	PC1	Peak Working Seasons	Material Costs	In peak seasons, demand increases lead to price increases.
75	PC2	Material Packaging	Material Costs	Packaging increases the cost between 10 to 20 per cent. High value materials and luxury items should come in proper packaging.
76	PE1	Project Size & Location	Demolition & Excavation	In urban projects, excavation and transporting the removed soil should be carried out in more than one stage.
77	PF1	Project Size & Location	Finance	Larger projects need larger capital.
78	PF2	Personnel	Finance	The logistics manager is in collaboration with the financial manager to reimburse payment dues.
79	PF3	Purchasing	Finance	The volume of the material that will be bought depends on availability of cash.
80	PF4	Material Packaging	Finance	Acquiring special equipment for handling packed materials may incur extra costs.
81	PH1	Material Packaging	Handling	Packaging makes handling easier and faster. Yet, special equipment, such as a lift truck or crane, may be required to unload packed items and pallets.
82	PK1	Personnel	Knowledge	Soft factors, such as knowledge and culture, have a direct impact on logistics management via personnel. Strategies should be established to enhance the logistics knowledge level among the staff. Also, cultural values, such as waste minimisation and recycling, should be set and promoted onsite.
83	PL1	Project Size & Location	Material Shortage	In undeveloped regions, where the site is far from the cities, there are labour, materials and construction machine shortages.
84	PO1	Peak Working Seasons	Material Shortage	Shortage of materials may occur in material consumption peak times.

Row	Relationship Code	Node 1	Node 2	Description
85	PP1	Project Size & Location	Material Packaging	In urban projects, the importance of packaging is higher because there is limited space available onsite and the warehouse should be more efficient. By going further from the cities, large space is usually available to store loose materials.
86	PP2	Personnel	Purchasing	Purchasing should be confirmed in the trade committee and conducted by the buying coordinator. The logistics manager should oversee the process of material selection, supplier identification, getting quotations, and inspection.
87	PP3	Purchasing	Project Size & Location	In small projects, usually the site supervisor, based on his previous experience, estimates the volume of required materials and buys them. In medium and large projects, purchasing is carried out based on accurate estimation and the schedule that is mostly developed by Critical Path Method (CPM).
88	PS2	Peak Working Seasons	Scheduling	Peak periods should be considered in the schedule. It may affect the time of order, transportation or change the sequence of deliveries.
89	PS4	Personnel	Site Layout	The site logistics manager should be able to design and modify site layouts during the course of the project.
90	PS5	Personnel	Scheduling	The site logistics manager should be linked with the project control unit to be aware of the materials requirements, project's schedule and delivery dates.
91	PS6	Personnel	Suppliers	The logistics manager should establish an effective relationship with the suppliers and evaluate their performance in the project.
92	PS7	Purchasing	Scheduling	The purchasing should be carried out based on the project's schedule.
93	PS8	Material Packaging	Site Layout	Packaging materials helps to have a more organised site.
94	PT1	Peak Working Seasons	Transportation	Shortage of transportation facilities may occur in peak periods.
95	PT2	Project Size & Location	Transportation	Narrow, steep and busy streets may cause problems for transporting resources to the site. When the project is located in undeveloped regions or far from urban areas, transportation costs increases because materials cannot be procured locally. Different transportation modes may be required according to the site location.
96	PT3	Personnel	Transportation	A coordinator should be appointed to manage transportation tasks. His responsibilities are: managing deliveries, developing delivery schedules, supervising the loading and unloading process, and dealing with drivers' issues.

Row	Relationship Code	Node 1	Node 2	Description
97	PT4	Purchasing	ICT	Sending material requisitions and gathering quotes can be done online.
98	PT5	Material Packaging	Transportation	Packaging makes transportation easier and faster.
99	PW1	Project Size & Location	Warehousing	In urban projects, there is less space for warehousing than projects outside of the cities. Warehousing in urban projects depends on site location, the street width, the land dimensions, entrance condition, and land position (north or south side of the street). To occupy a proportion of the street for temporary storage of materials in urban projects, there are regulations enforced by the municipalities that may be variable in different regions and cities (for example, one third of the street width). In undeveloped regions, there may be lack of proper storage facilities, such as silos.
100	PW2	Peak Working Seasons	Weather Conditions	The geographical position of the project affects construction peak times. In hot regions, the peak time is in winter and, in cold regions, the peak time is in summer.
101	PW3	Personnel	Warehousing	A coordinator should be appointed to manage warehousing tasks. His responsibilities are: receiving incoming loads, storing items in identifiable locations, collating requisitions with the available stock, releasing items to working parties, and issuing an inventory report for higher authorities on a regular basis. The coordinator is responsible to keep the stock level over the certain amount indicated by the site supervisor (stock level indicator).
102	PW4	Personnel	Waste	A coordinator should be appointed to manage waste onsite. His responsibilities are: collection and disposal of waste, minimising waste, providing advice for other parties on waste reduction and environmental conservation matters.
103	PW5	Purchasing	Warehousing	The volume of the material that will be bought depends on the availability of storage space onsite. In small projects, when the onsite stored materials go below a certain level, the construction manager will be informed by the foreman to buy more. The site supervisor will be informed when the purchase is conducted to prepare a suitable storage space for coming materials.
104	PW6	Material Packaging	Warehousing	Packing materials helps to have an organised warehouse. It also enhances the level of security and affectivity of the retrieval process.
105	RC1	Recycling	Culture	A cultural basis should be built that promotes recycling in projects.
106	RP1	Resource Conservation	Material Packaging	Proper packaging protects the natural resources. However, some packaging materials are dangerous for the environment and are not naturally recyclable.

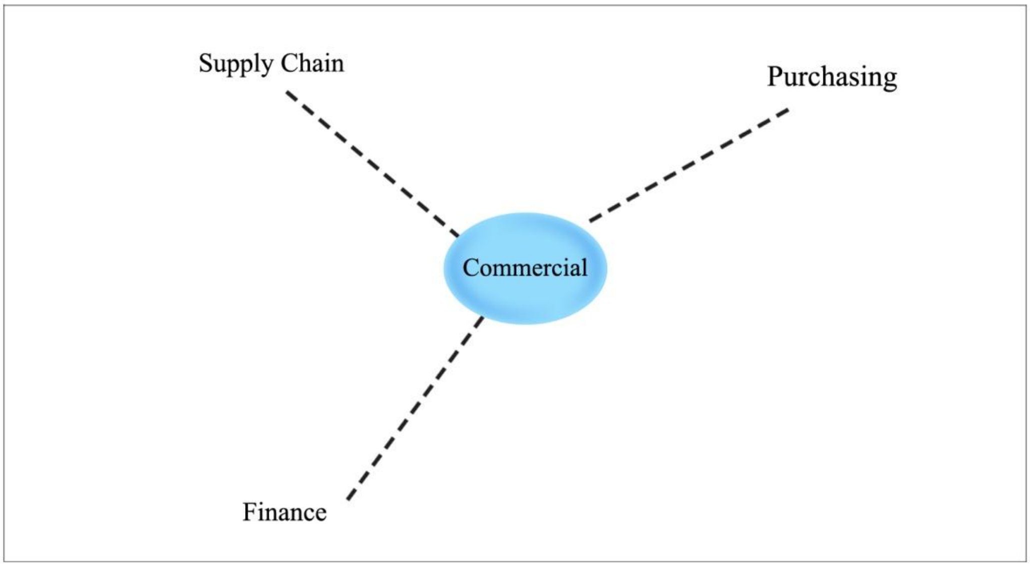
Row	Relationship Code	Node 1	Node 2	Description
107	RW1	Resource Conservation	Waste	Attention to resource conservation reduces the amount of waste.
108	SC1	Supplier Selection	Material Costs	The supplier who offers the lowest price will be selected to procure materials without sacrificing quality.
109	SC2	Scheduling	Material Costs	If the inflation rate is high, it may be worth buying some materials, such as steel, as soon as possible. However, the risk of price decrease should also be considered. The heavy financial load of some items may affect logistics schedule. Preparing money to buy these items may take time and cause delay in the schedule.
110	SE1	Suppliers	Economy	When the economy is down, suppliers do everything to sell their products. If the economy is booming the suppliers may increase prices. The material prices decrease in a recession because demand reduces.
111	SF1	Suppliers	Finance	Through a long-term relationship, contractors can get discounts and payment privileges from suppliers.
112	SF2	Scheduling	Finance	Financial problems of the clients endanger the schedule. Early order of materials freezes the capital.
113	SL1	Supplier Selection	Project Size & Location	The distance of the supplier to the project location is a criterion for selecting suppliers.
114	SN1	Scheduling	Consultants	Changes and alteration in drawings during the course of the project cause problems for the schedule.
115	SQ1	Supplier Selection	Material Quality	Material quality is an important criterion when a supplier is to be selected.
116	SS1	Supplier Selection	Suppliers	Selecting suppliers may be based on previous collaborations and keeping long-term relationships.
117	SS2	Scheduling	Suppliers	The suppliers' indifferences and low commitment are factors that endanger the schedule.
118	TC1	ICT	Culture	Resistance to change is a problem in ICT utilisation. Some staff may feel that ICT will take their jobs or some people do not trust the results produced by software.
119	TD1	Traffic Rules	Delivery	Traffic regulations specifically in urban areas affects delivery times.
120	TE1	ICT	Estimation	ICT is helpful in estimating and increases the speed of preparation and accuracy of estimation. The basic function of all estimation software is to produce organised tables that shows the description, units, amount, cost per unit, and total cost of different tasks

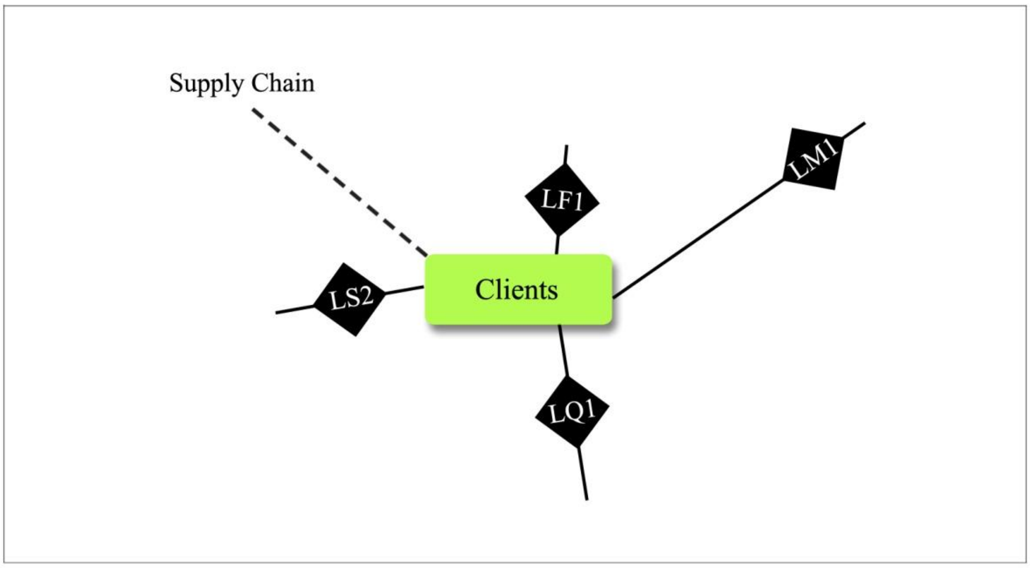
Row	Relationship Code	Node 1	Node 2	Description
121	TF1	Technology	Finance	Using new technology may increase the total cost of the project.
122	TF2	Transportation	Finance	In addition to the fuel price and distance, factors such as type, height, volume, size, and weight of the load affect the transportation cost. The transportation cost may be calculated based on the price index, weight/distance or a general quote given by the driver.
123	TK1	ICT	Knowledge	In undeveloped areas, staff are not competent enough to work with complex software packages. In these regions, employing a competent IT user incurs high costs.
124	TP2	ICT	Project Size & Location	The level of ICT utilisation in the construction organisations in Iran is variable depending on the size of the firms. The large companies have ICT departments.
125	TQ1	Transportation	Material Quality	The desired material quality is not always achievable because of long distances and high transportation costs.
126	TS1	Transportation	Material Selection	The distance of the supplier to the construction site and transportation cost is important in the time of material selection and purchasing.
127	TS2	ICT	Supply Chain	By utilising ICT, different parties involved in the project can communicate with each other more easily and this increases the speed of decision making. The level of ICT utilisation depends on the size of the firms.
128	TW1	ICT	Warehousing	ICT enables different people to have enough information about the stock level and inventory in each project. Software can be used for registering, tracking and retrieval of materials in a warehouse. Also, software is utilised to issue materials enter and exit receipts, and to produce inventory and stock reports.
129	WF1	Warehousing	Finance	The longer the storage period, the more warehousing cost should be paid which includes staff, space allocation and maintenance. Moreover, extra money should be paid for insurance, and installing features such as security systems, enter/exit control, identification system, fire alarm, and fire extinguishers. Long-time storage may cause cash flow problems, because the client's capital is frozen by purchasing materials ahead and storing them in warehouses.
130	WH1	Waste	Handling	Poor loading, unloading and handling increase the amount of waste onsite. Poly-handling increases the likelihood of material damage while it wastes the working time of skilled labours.
131	WM1	Waste	Material Costs	Because materials are cheap, enough attention is not paid to minimising waste.

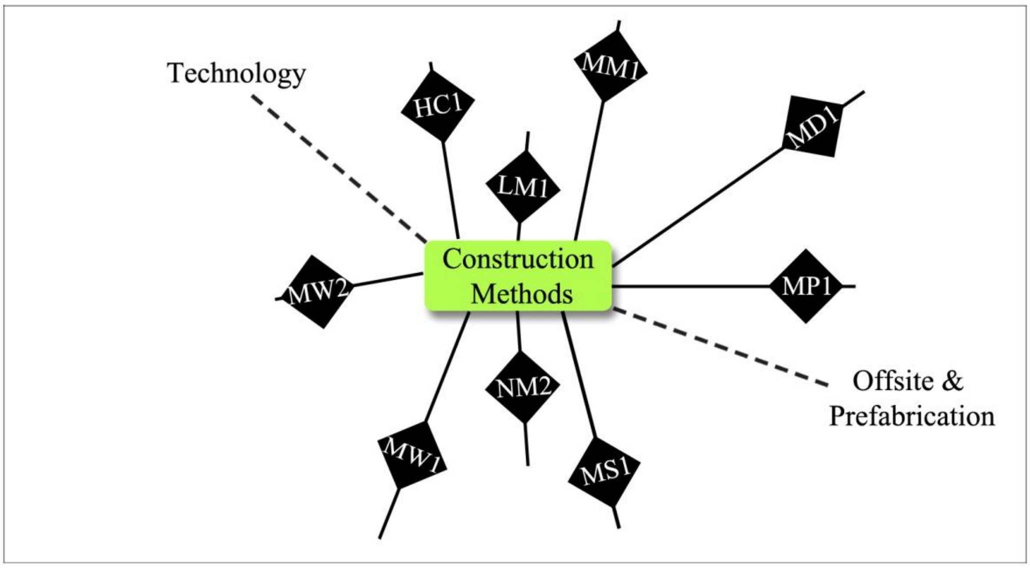
Row	Relationship Code	Node 1	Node 2	Description
132	WP1	Waste	Material Packaging	Poor packaging causes waste because materials may get damaged. A large proportion of loose materials is wasted. Delivering materials in loose form increases the rate of waste generation because a large proportion of materials gets damaged during transportation, unloading, handling and the warehousing process.
133	WQ1	Waste	Material Quality	Poor quality materials will be broken and damaged during transportation, handling and storage.
134	WS1	Weather Conditions	Scheduling	Variable weather conditions and geographical location of the project affect the logistic schedule and may change materials ordering time and the delivery sequence.
135	WS2	Warehousing	Scheduling	There is a continual demand for some materials in different stages of construction and, therefore, they should be stored onsite. Some materials have a long lead-time and should be ordered early. These materials may be stored onsite for a period of time to avoid delays in projects. If materials are ordered early, more warehousing space is required. Hence, order time also depends on the space availability onsite.
136	WS3	Warehousing	Suppliers	To minimise the impact of suppliers' indifferences, logical quantities of materials should be stored onsite.
137	WW1	Waste	Warehousing	Poor material protection in warehouses leads to material wastage because they may get damaged. To minimise waste, a suitable space should be provided for materials according to their nature, specifications, and safety requirements. Also, attention should be paid to regulations and codes that recommend the correct way of warehousing and materials storage. Some materials and components may be depraved owing to long time storage. All items in the warehouse should be inspected and checked regularly in predetermined intervals. If materials are damaged or depraved, they should be delivered offsite.

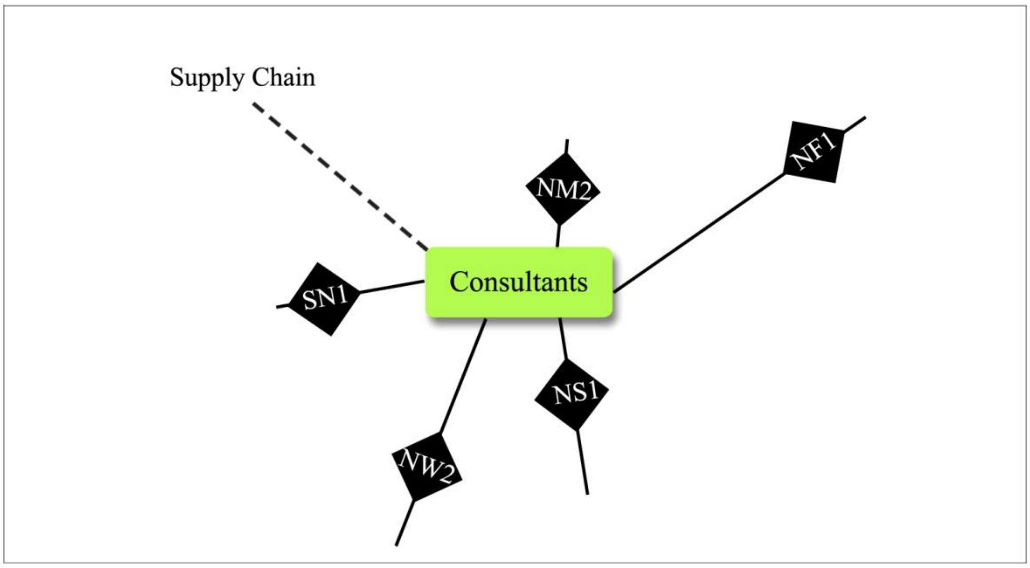
Appendix 9: Subsystems and Agents Close Up

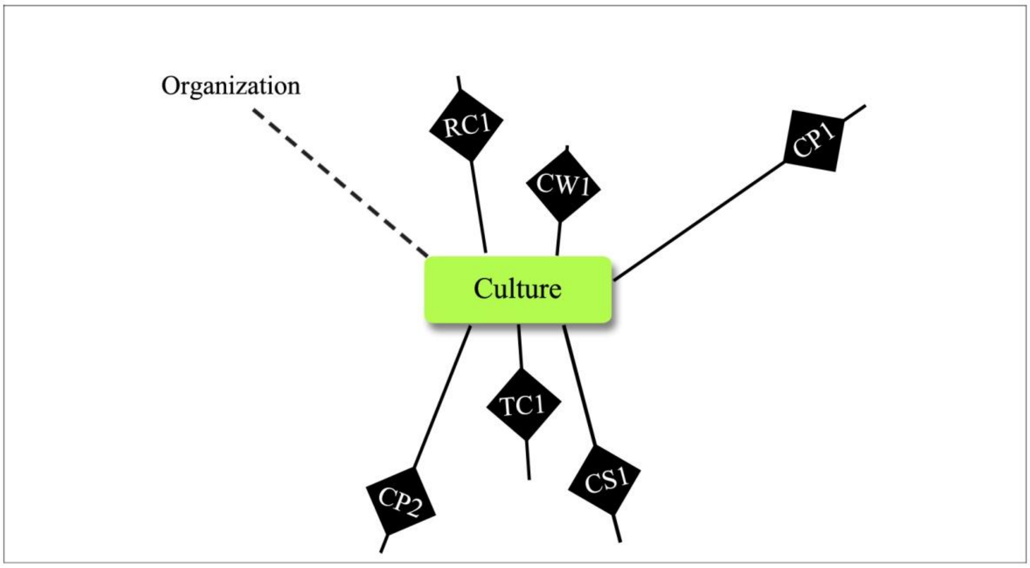
This section includes diagrams that show the branches and relationships of each subsystem and agent of the construction logistics model. It aims to reduce the level of confusion caused by following lengthy relationship lines in the model. All subsystems and agents are sorted alphabetically. By focusing on each agent, its branches and relationships can be considered without using the final model.

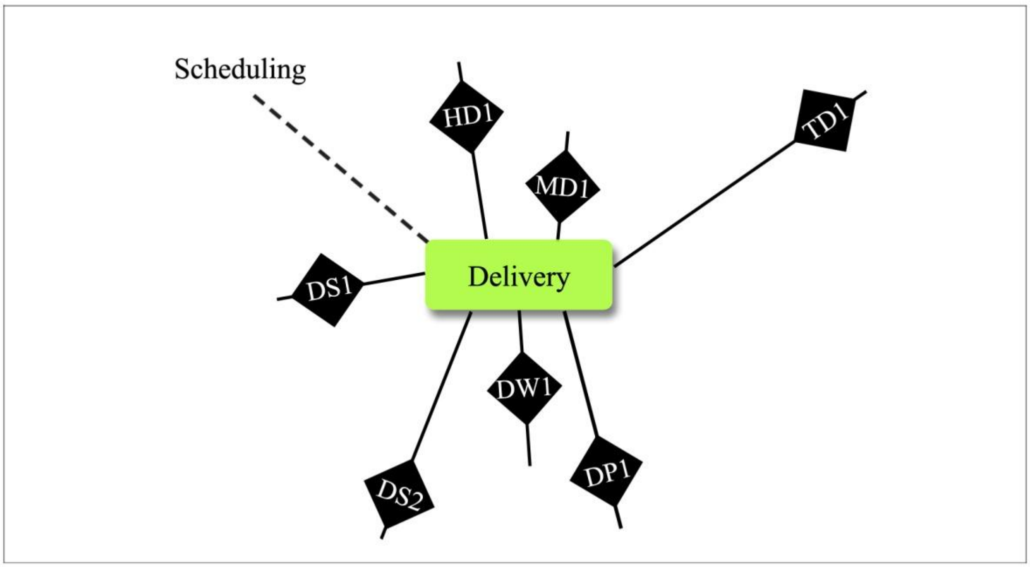


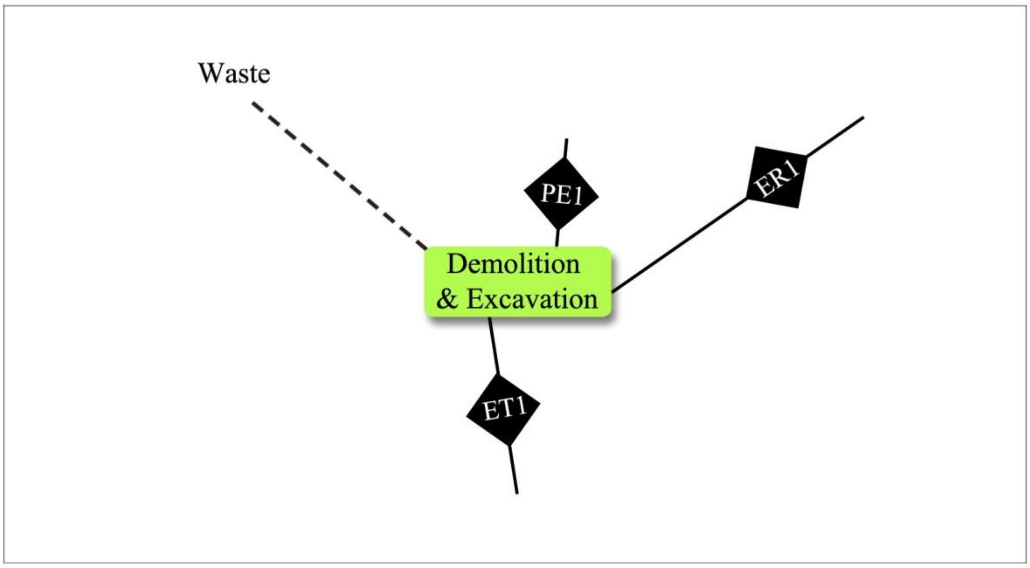


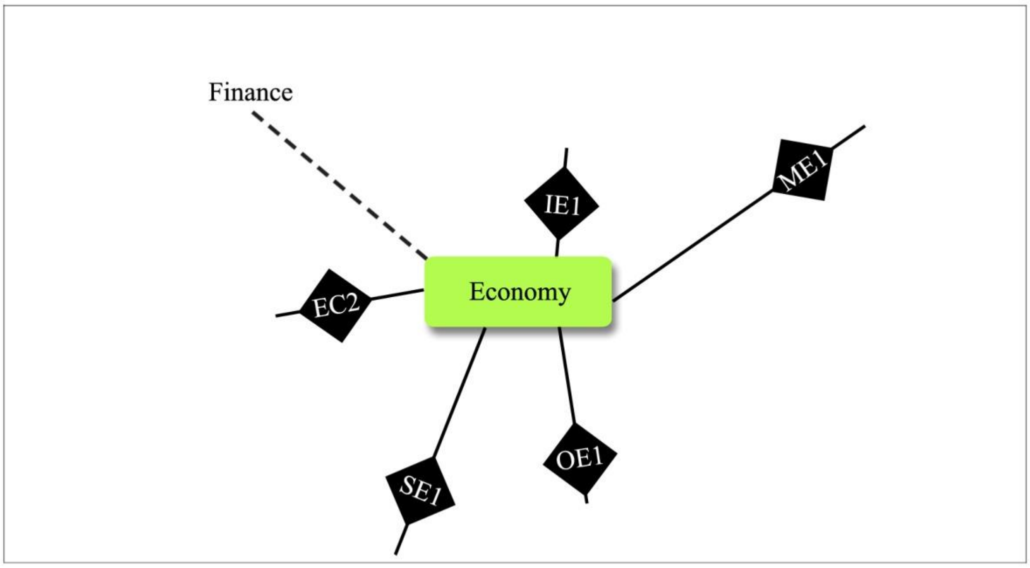

Technology
HC1
MM1
MD1
LM1
Construction Methods
MW2
MP1
NM2
Offsite & Prefabrication
MW1
MS1

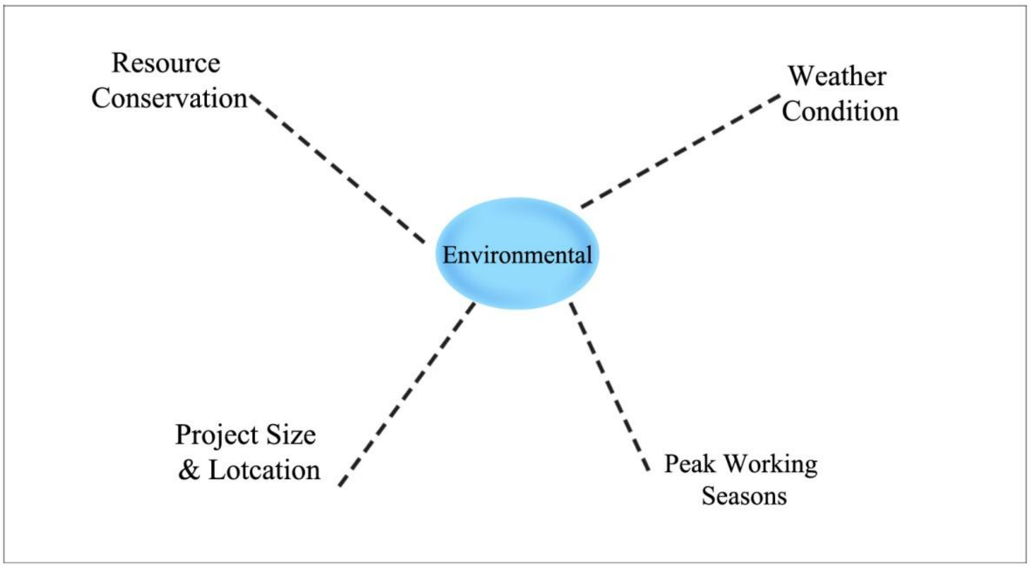

Supply Chain
NM2
NF1
Consultants
SN1
NS1
NW2

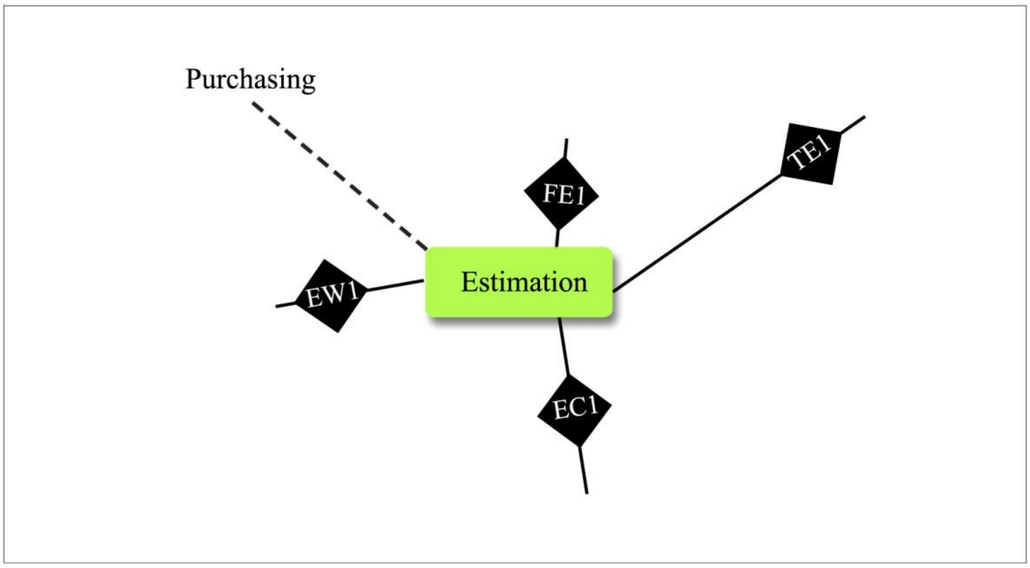

Organization
RC1
CW1
CP1
Culture
TC1
CP2
CS1

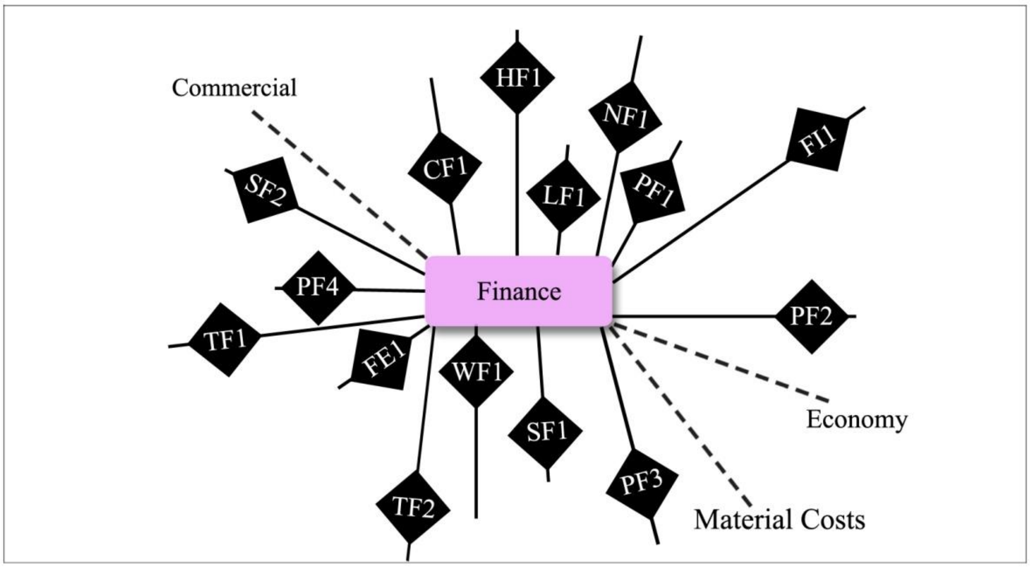

Scheduling
HD1
TD1
MD1
DS1
Delivery
DW1
DS2
DP1

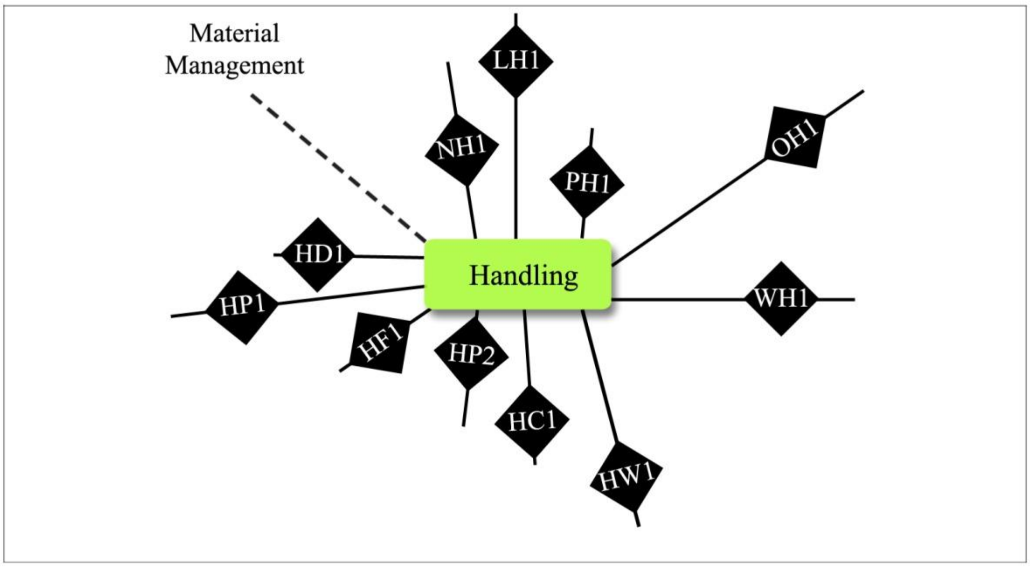

Waste
PE1
ER1
Demolition
& Excavation
ET1

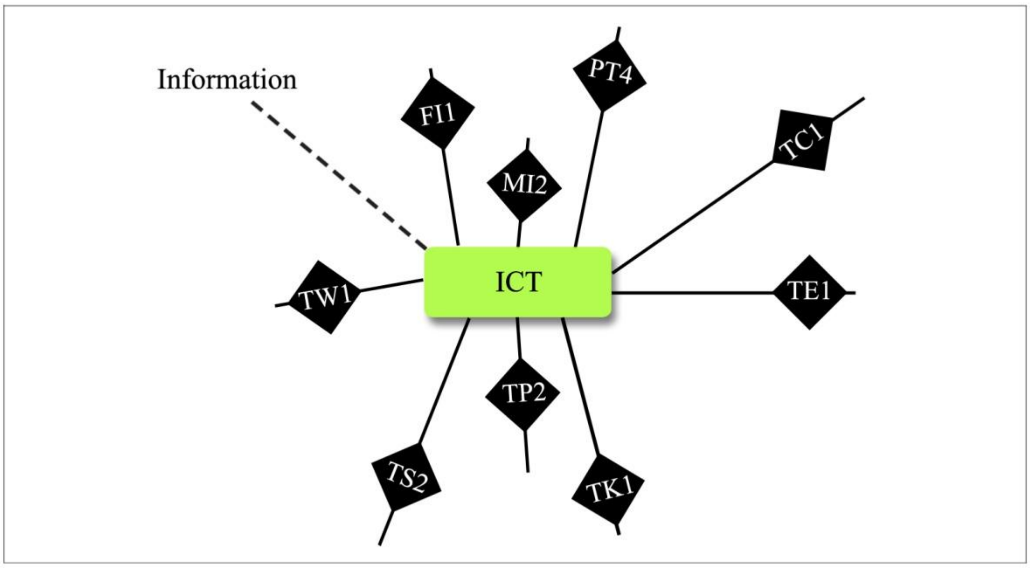

Finance
IE1
ME1
EC2
Economy
SE1
OE1

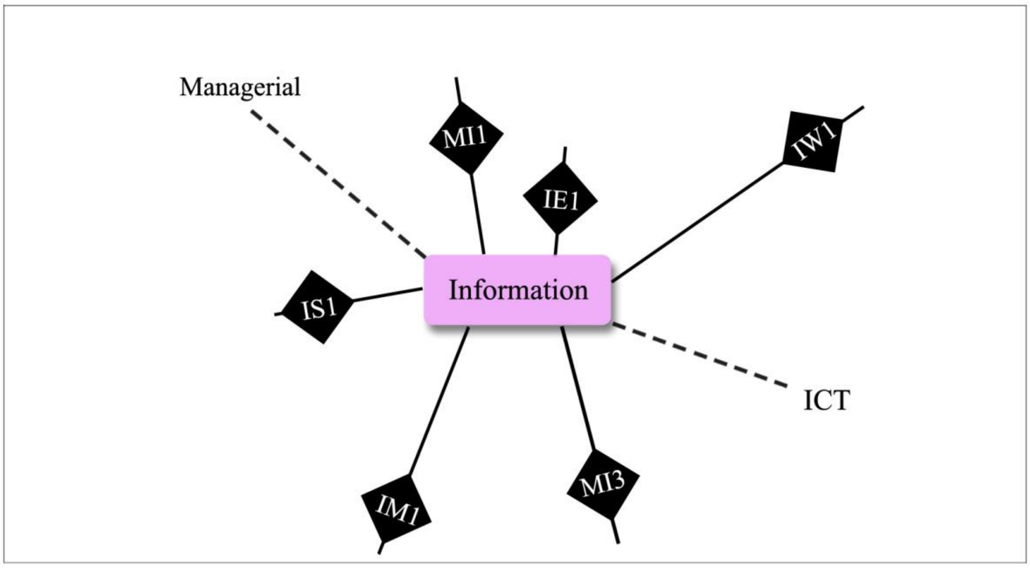

Resource Conservation
Weather Condition
Environmental
Project Size & Lotcation
Peak Working Seasons

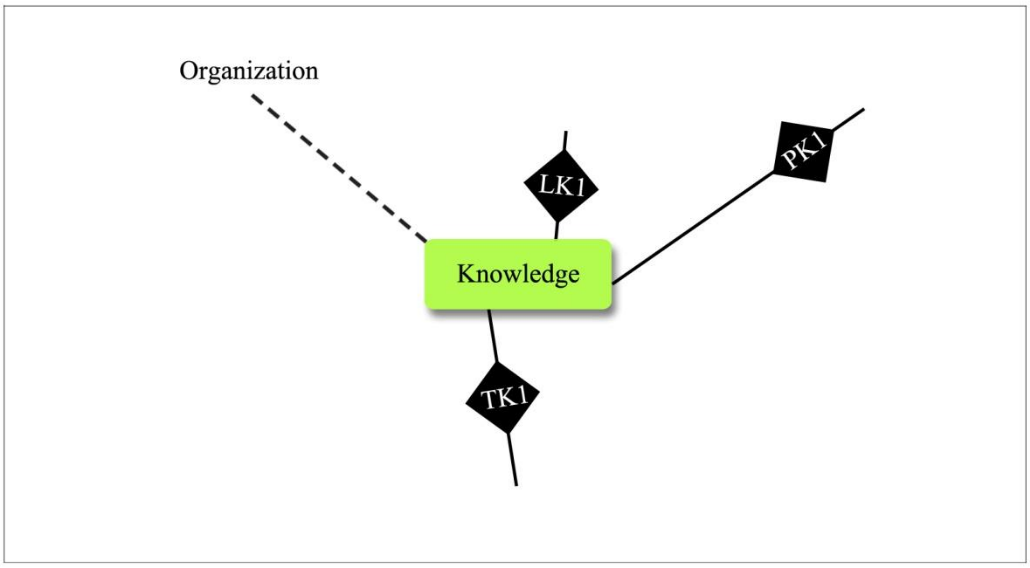

Purchasing
FE1
TE1
EW1
Estimation
EC1

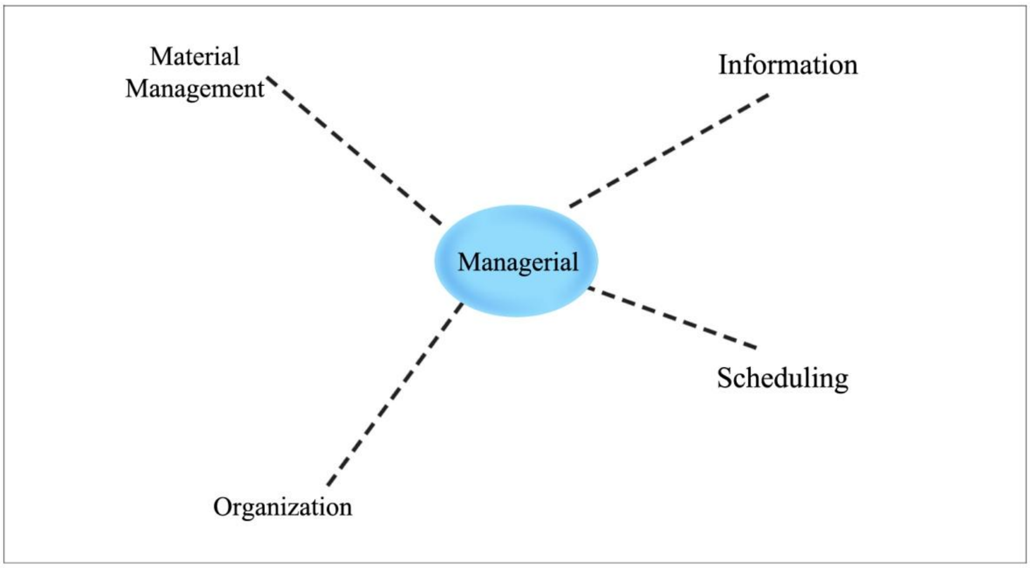

Commercial
HF1
NF1
FI1
CF1
LF1
PF1
SF2
PF4
Finance
PF2
TF1
FE1
WF1
SF1
Economy
PF3
TF2
Material Costs

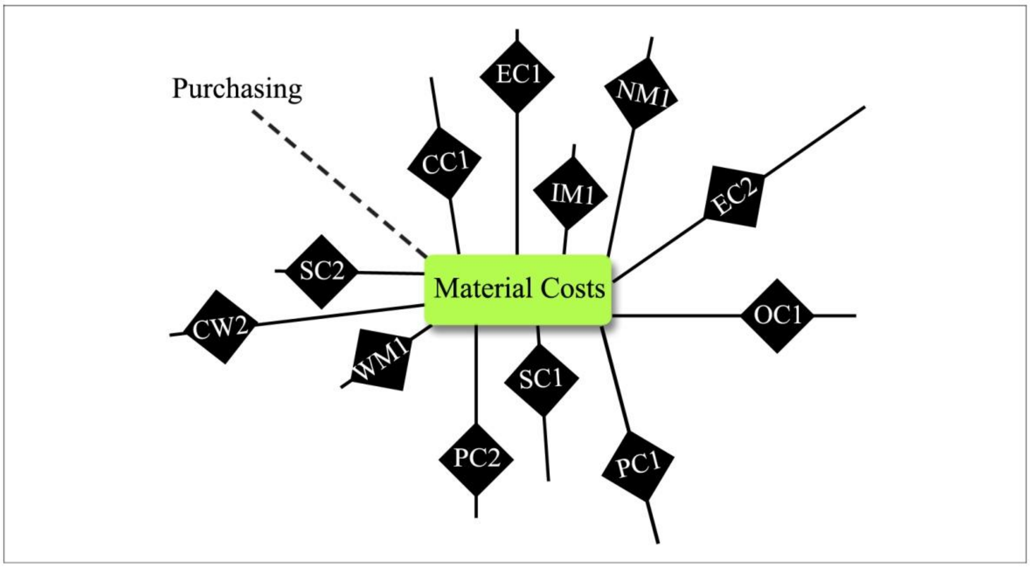

Material
Management
LH1
NH1
PH1
OH1
HD1
Handling
HP1
WH1
HF1
HP2
HC1
HW1

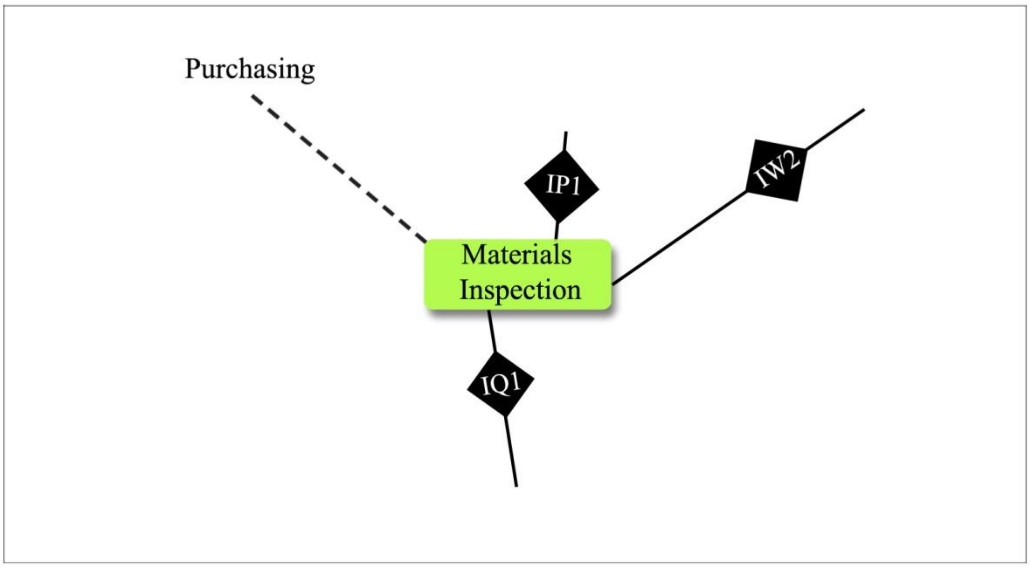

Information
PT4
FI1
TC1
MI2
ICT
TW1
TE1
TP2
TS2
TK1

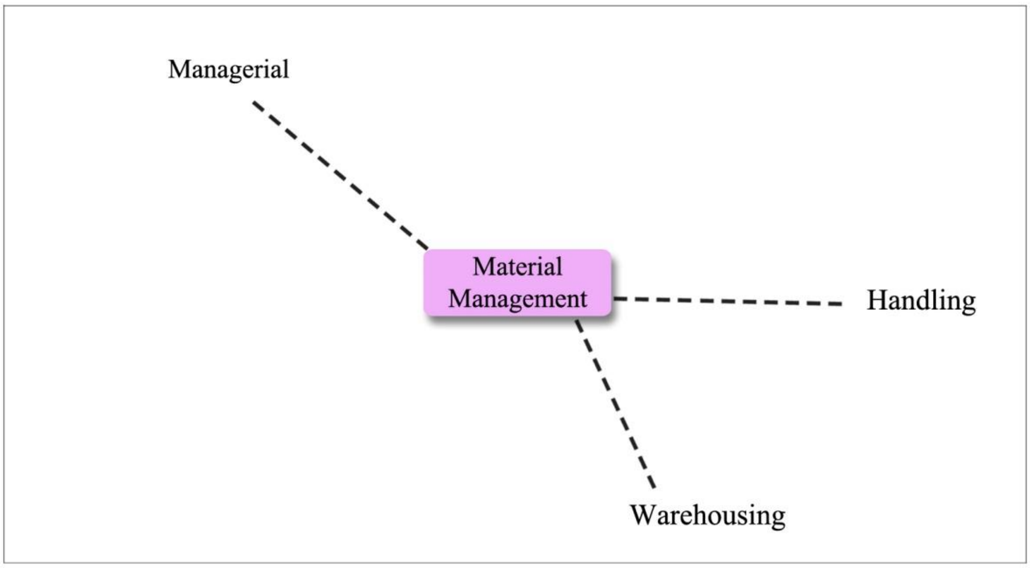

Managerial
MI1
IW1
IE1
Information
IS1
ICT
IM1
MI3

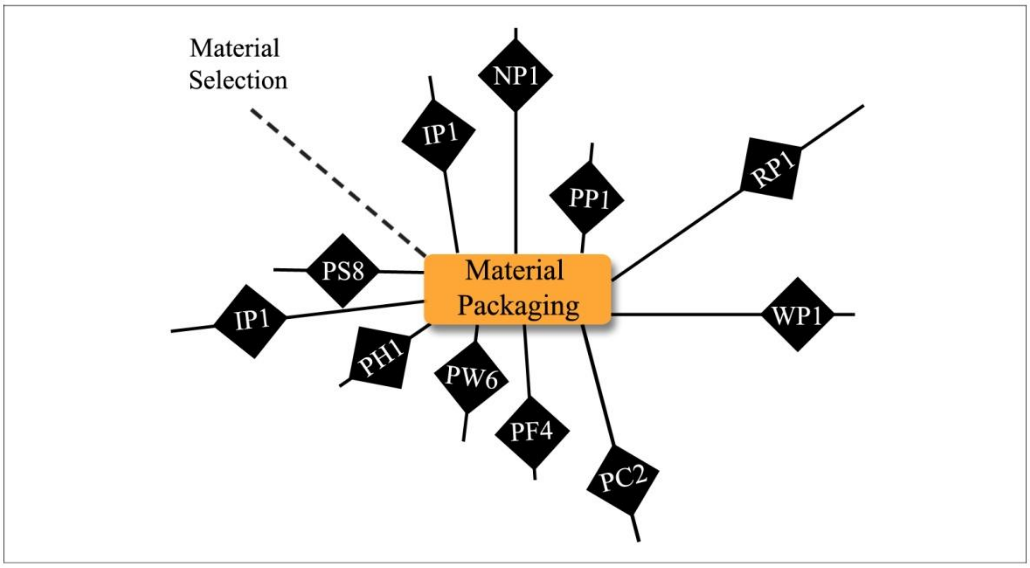

Organization
LK1
PK1
Knowledge
TK1

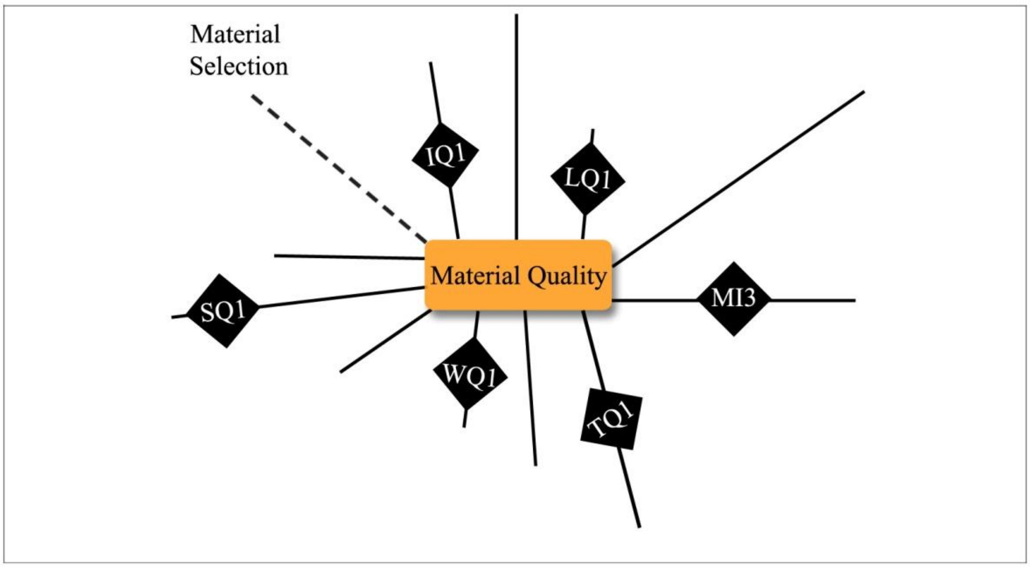

Material
Management
Information
Managerial
Scheduling
Organization

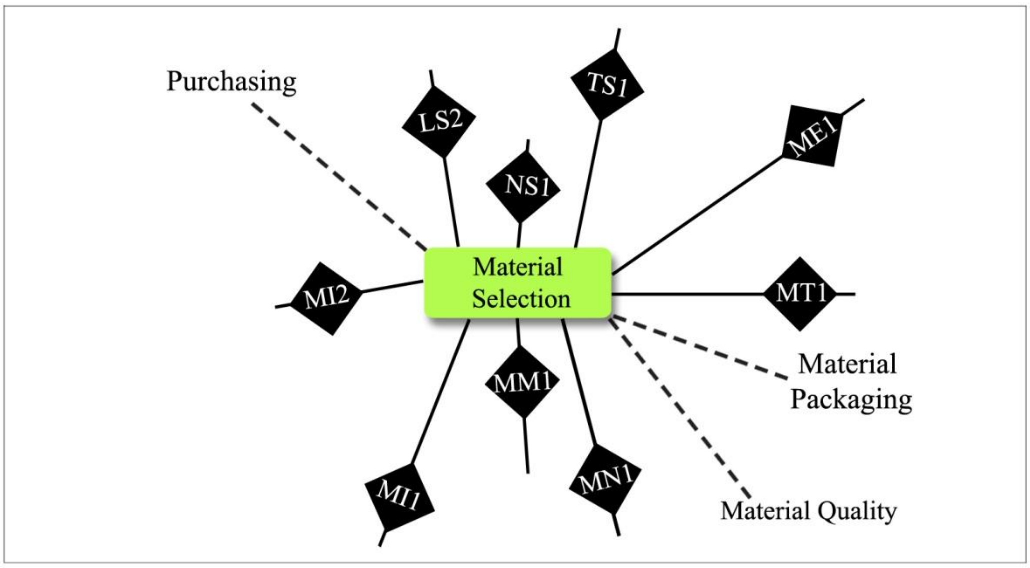

Purchasing
EC1
NM1
CC1
IM1
EC2
SC2
Material Costs
CW2
OC1
WM1
SC1
PC2
PC1

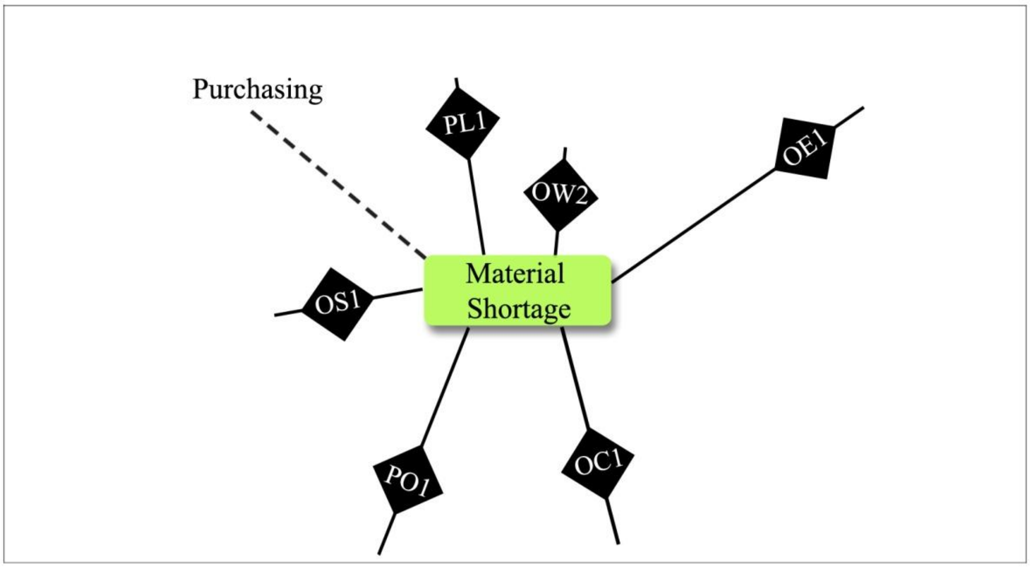

Purchasing
IP1
IW2
Materials Inspection
IQ1

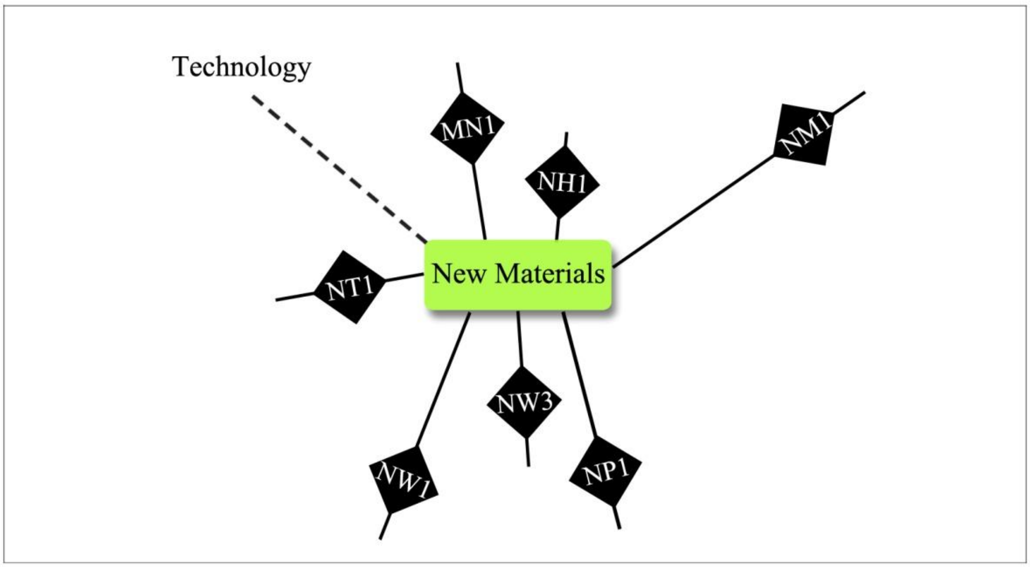

Managerial
Material Management
Handling
Warehousing

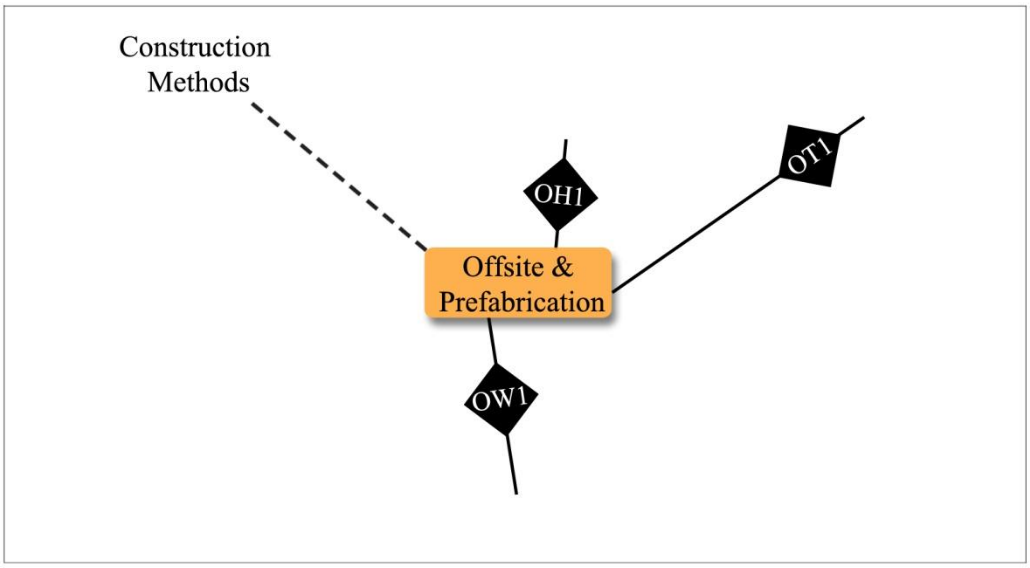

Material Selection
NP1
IP1
PP1
RP1
PS8
Material Packaging
IP1
WP1
PH1
PW6
PF4
PC2

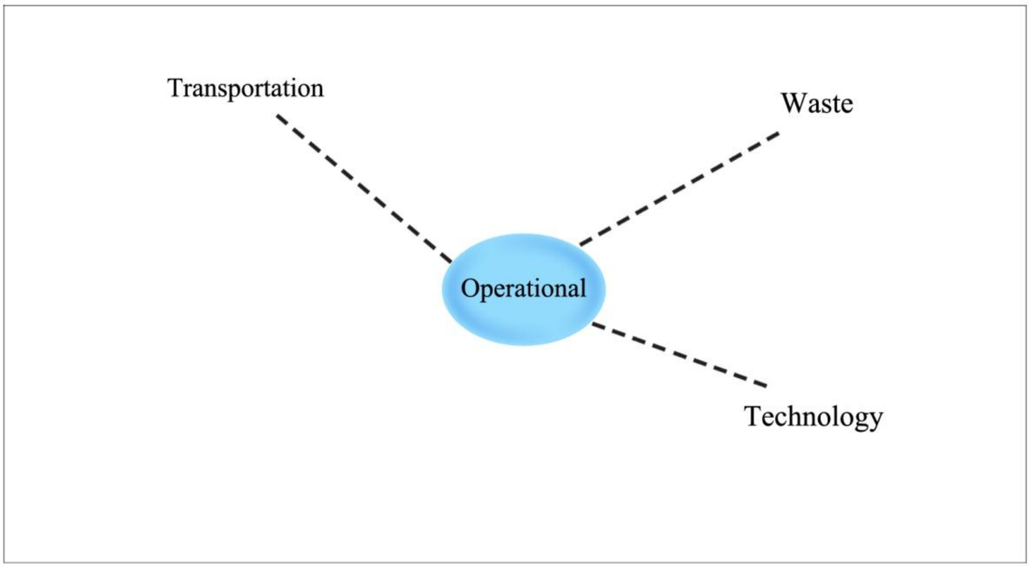

Material Selection
IQ1
LQ1
Material Quality
SQ1
MI3
WQ1
TQ1

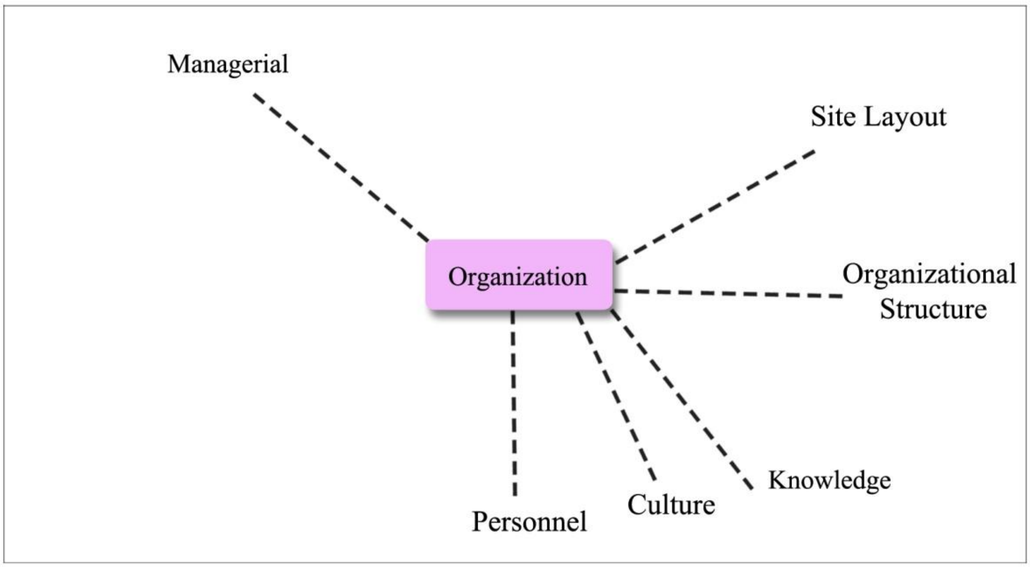

Purchasing
TS1
LS2
ME1
NS1
Material Selection
MI2
MT1
MM1
Material Packaging
MI1
MN1
Material Quality

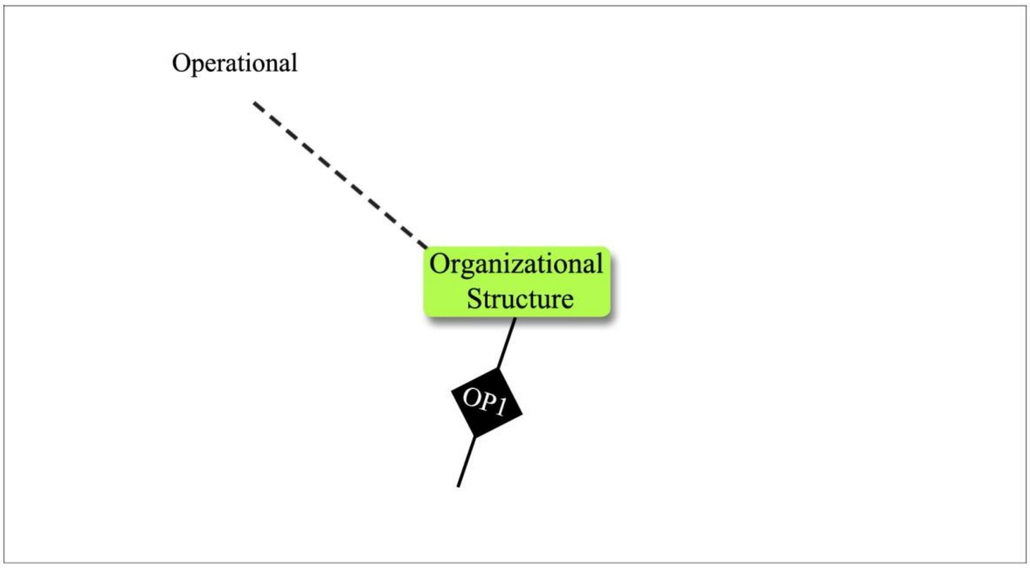

Purchasing
PL1
OE1
OW2
Material Shortage
OS1
PO1
OC1

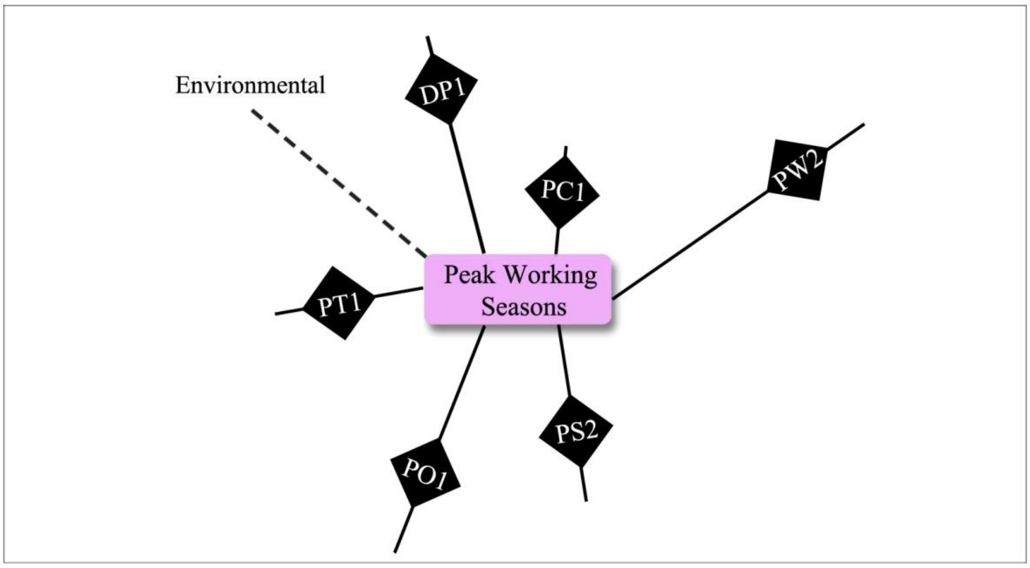

Technology
MN1
NH1
NM1
NT1
New Materials
NW3
NW1
NP1

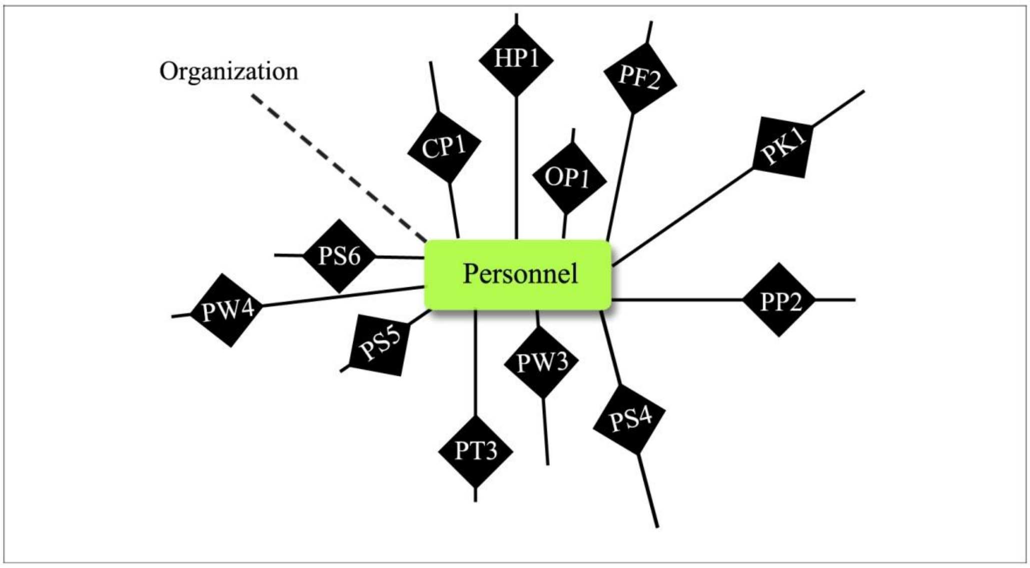

Construction Methods
OH1
OT1
Offsite & Prefabrication
OW1

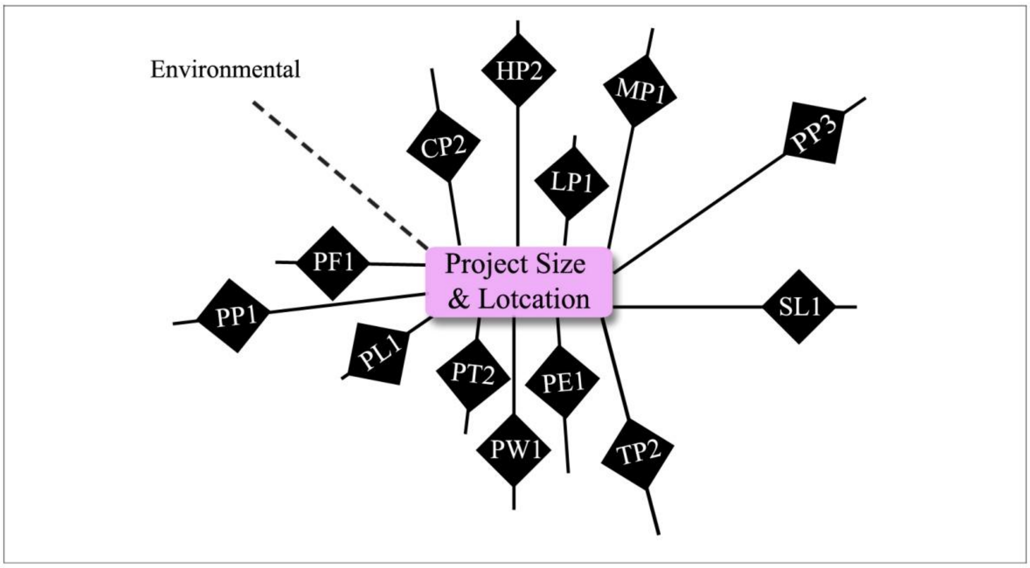

Transportation
Waste
Operational
Technology

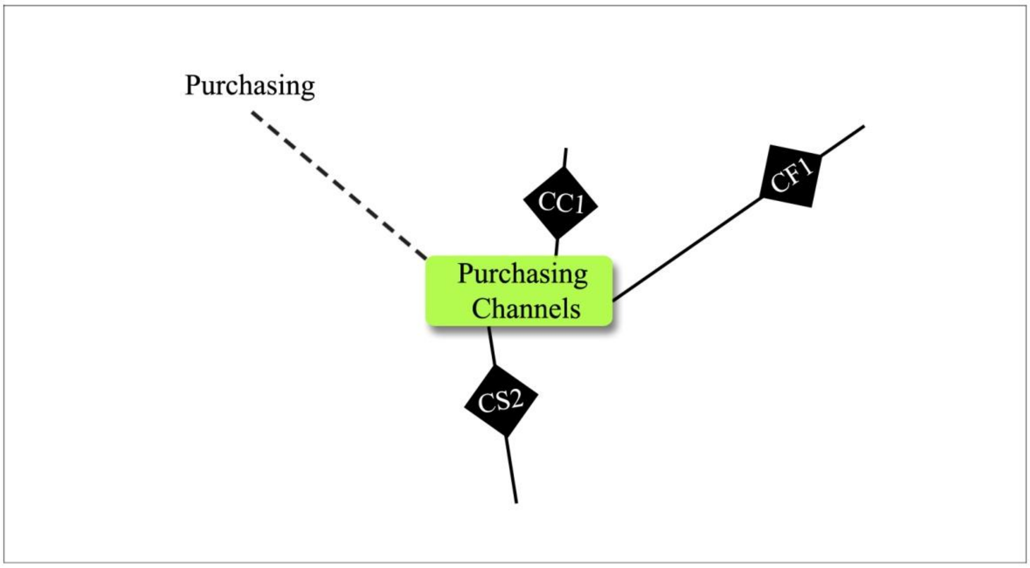

Managerial
Site Layout
Organization
Organizational Structure
Personnel
Culture
Knowledge

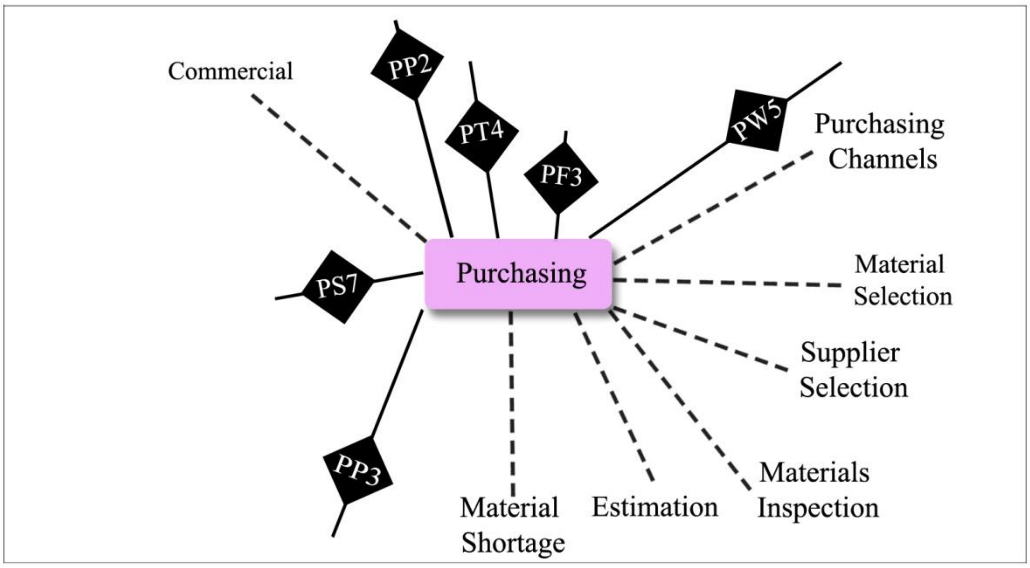

Operational
Organizational Structure
OP1

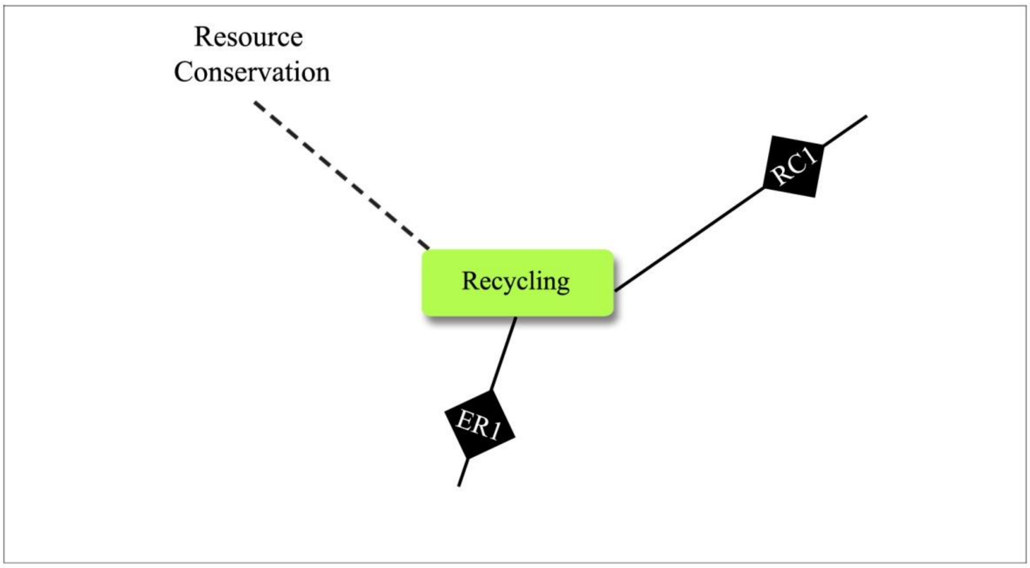

Environmental
DP1
PC1
PW2
PT1
Peak Working Seasons
PO1
PS2

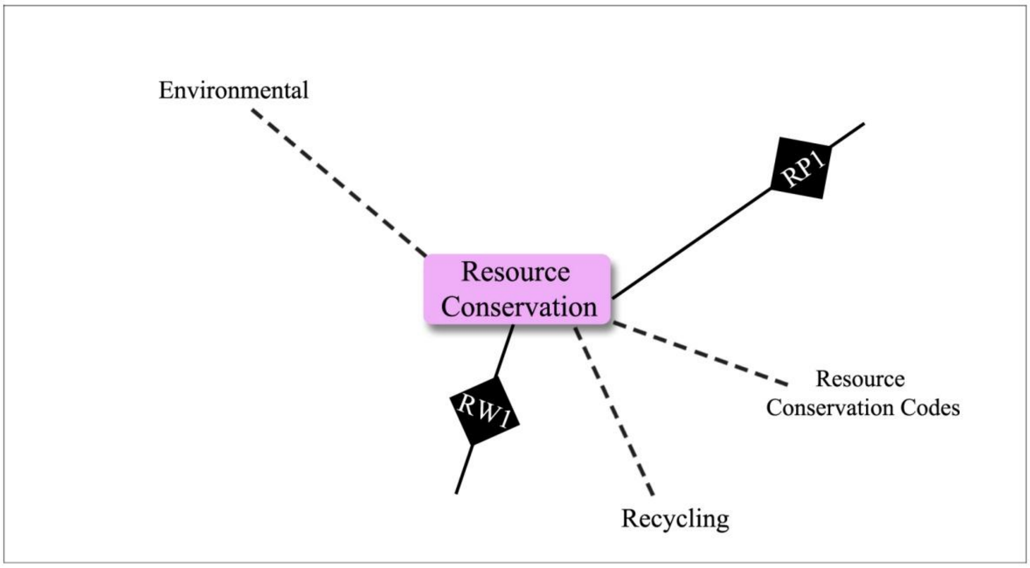

Organization
HP1
PF2
CP1
OP1
PK1
PS6
Personnel
PW4
PP2
PS5
PW3
PS4
PT3

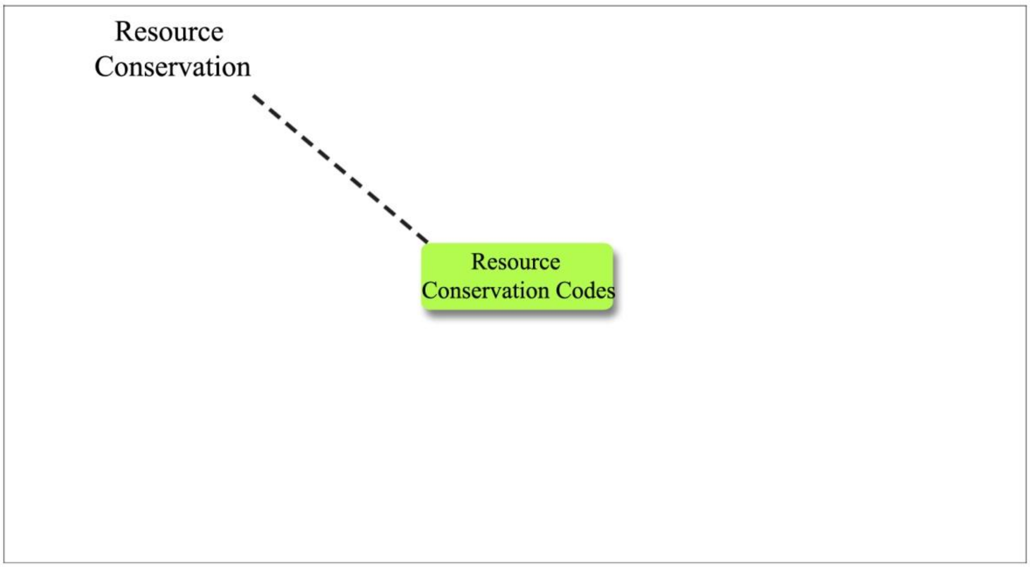

Environmental
HP2
MP1
CP2
LP1
PP3
PF1
Project Size
& Lotcation
PP1
SL1
PL1
PT2
PE1
PW1
TP2

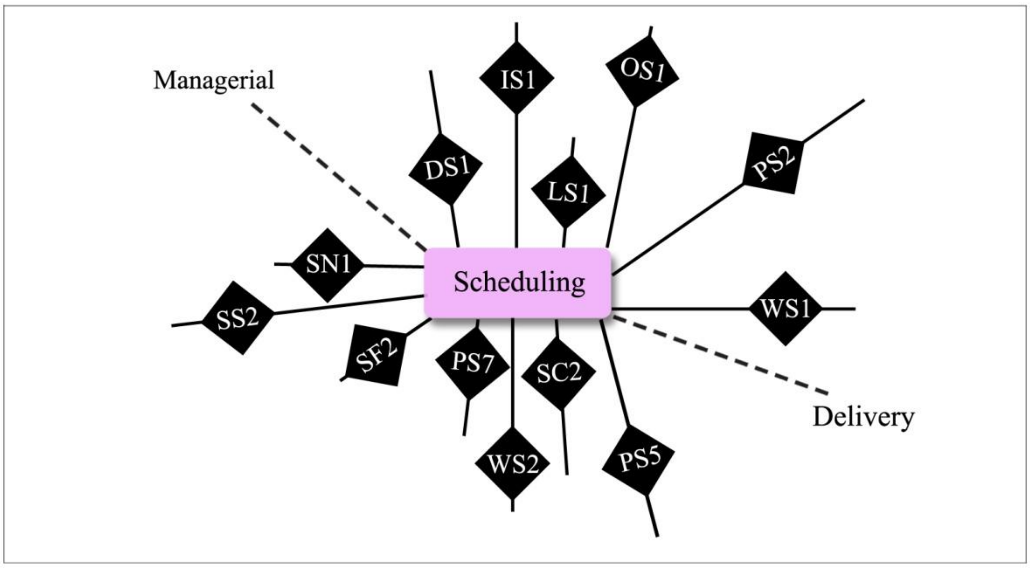

Purchasing
CC1
CF1
Purchasing
Channels
CS2

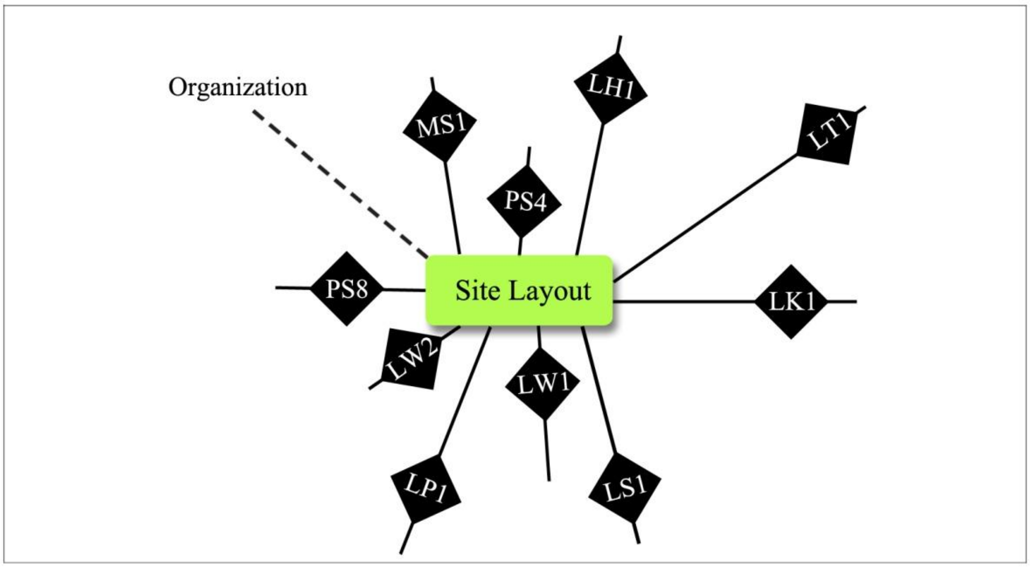

Commercial
PP2
PT4
PF3
PW5
Purchasing Channels
PS7
Purchasing
Material Selection
Supplier Selection
PP3
Material Shortage
Estimation
Materials Inspection

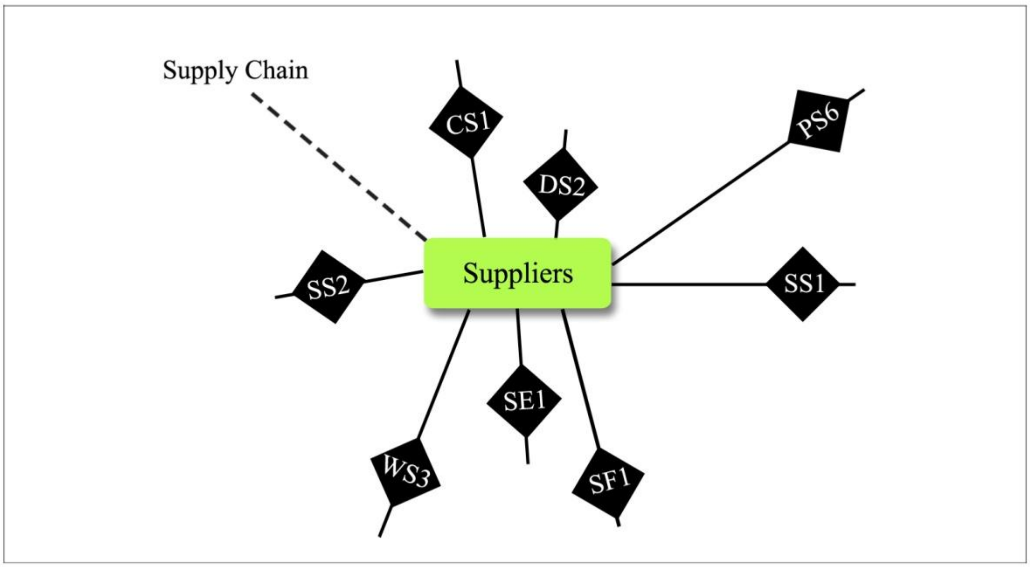

Resource Conservation
RC1
Recycling
ER1

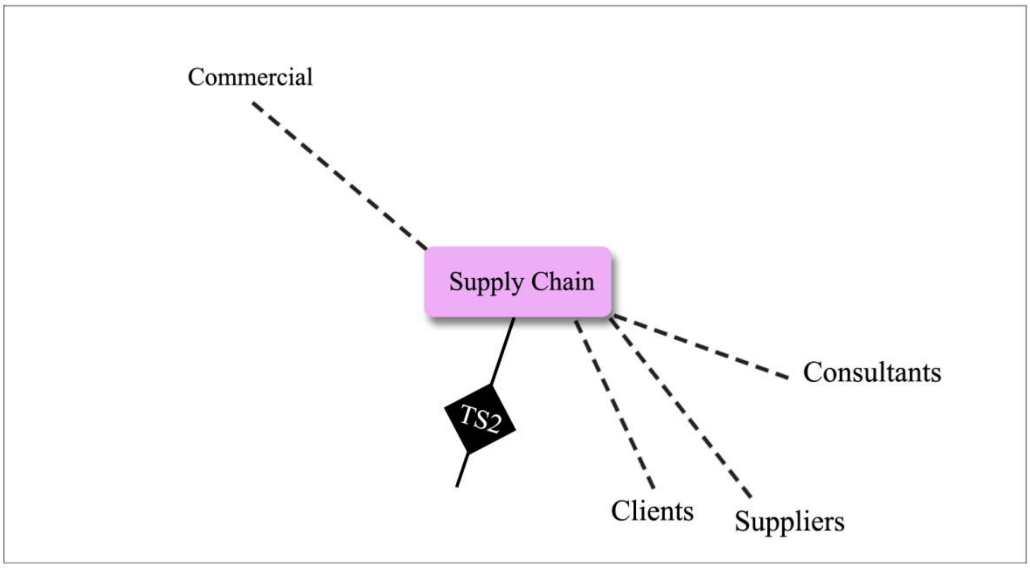

Environmental
RP1
Resource Conservation
RW1
Resource Conservation Codes
Recycling

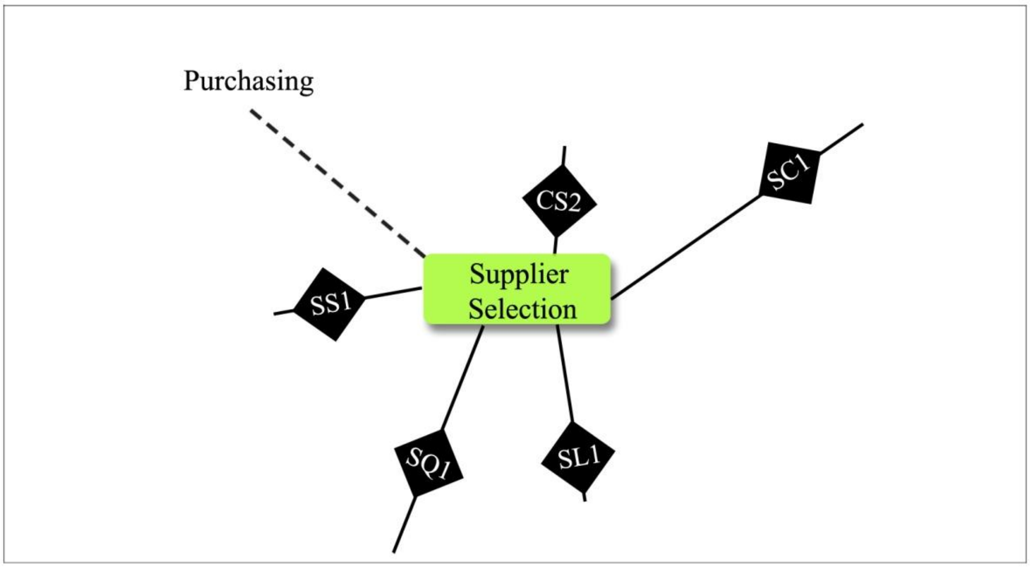

Resource
Conservation
Resource
Conservation Codes

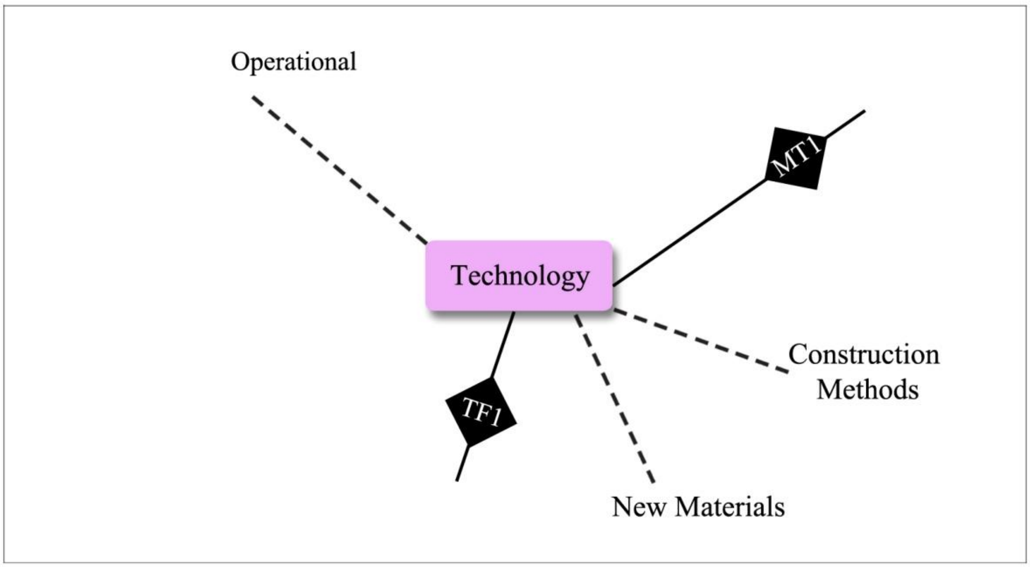

Managerial
IS1
OS1
DS1
LS1
PS2
SN1
Scheduling
SS2
WS1
SF2
PS7
SC2
Delivery
WS2
PS5

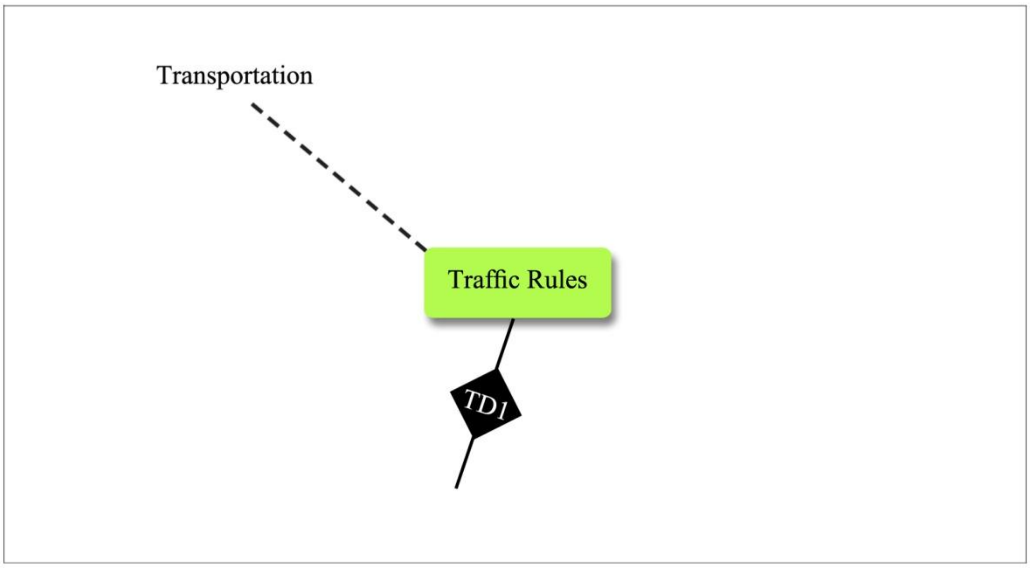

Organization
LH1
MS1
LT1
PS4
PS8
Site Layout
LK1
LW2
LW1
LP1
LS1

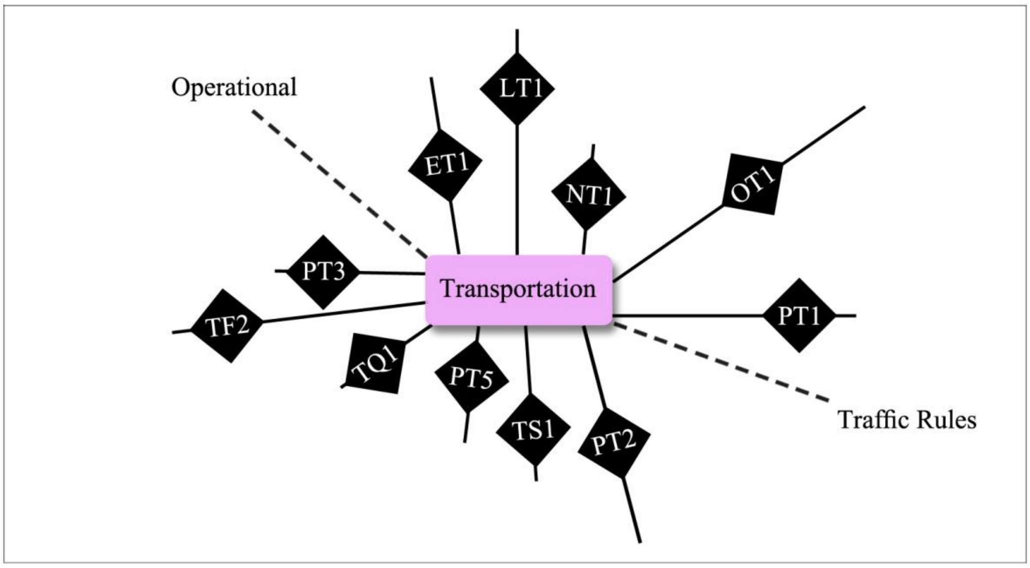

Supply Chain
CS1
DS2
PS6
SS2
Suppliers
SS1
SE1
WS3
SF1

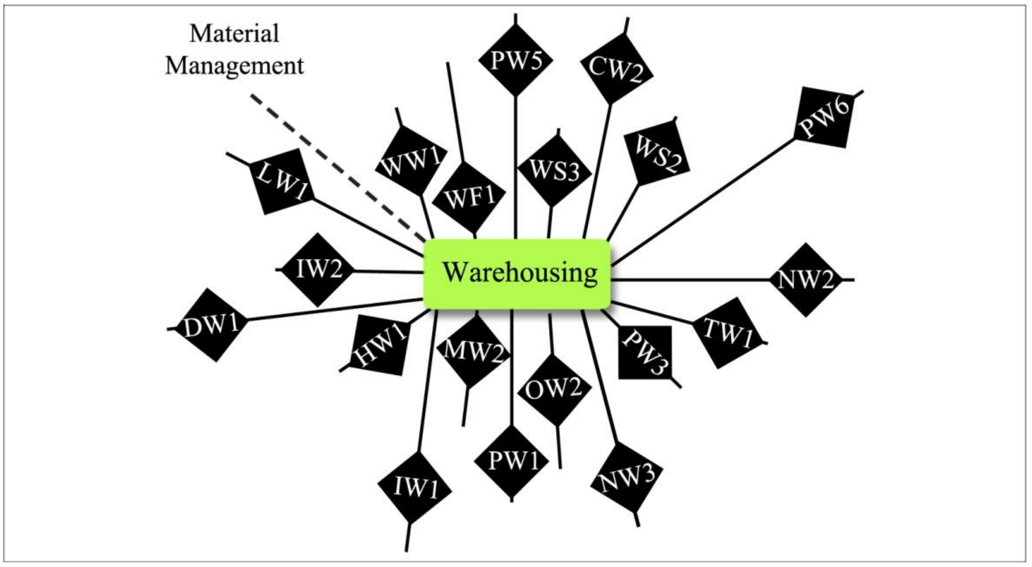

Commercial
Supply Chain
TS2
Consultants
Clients
Suppliers


Purchasing
CS2
SC1
Supplier Selection
SS1
SQ1
SL1


Operational
MT1
Technology
Construction
Methods
TF1
New Materials


Transportation
Traffic Rules
TD1


Operational
LT1
ET1
NT1
OT1
PT3
Transportation
TF2
PT1
TQ1
PT5
TS1
PT2
Traffic Rules


Material
Management
PW5
CW2
PW6
WW1
LW1
WF1
WS3
WS2
IW2
Warehousing
NW2
DW1
HW1
MW2
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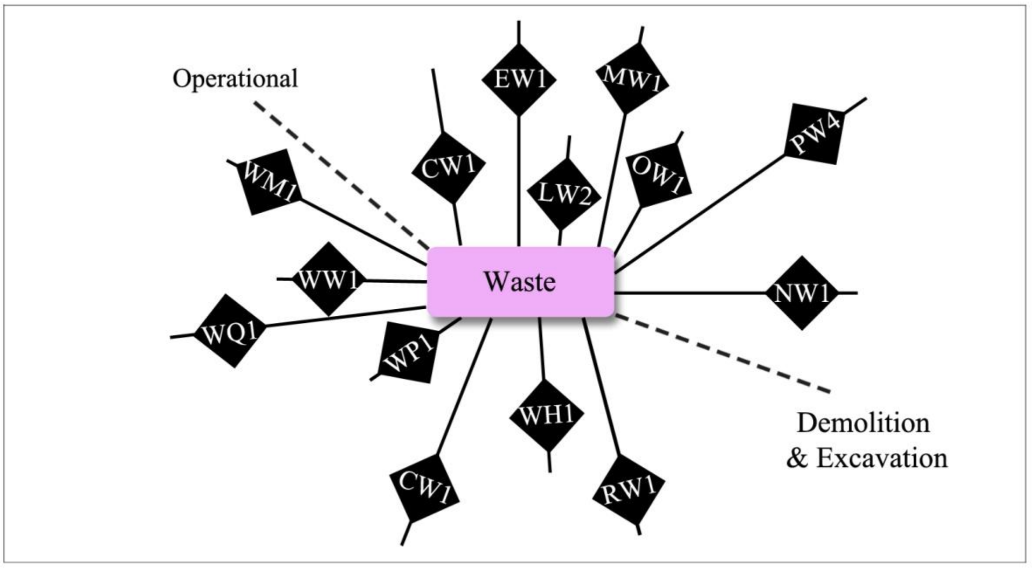
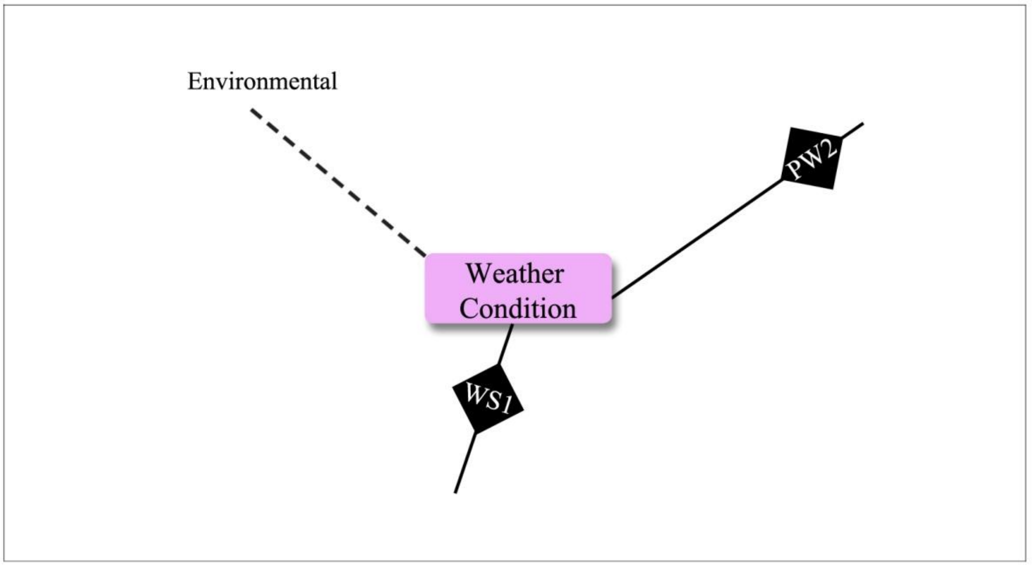
OW2
PW1
NW3
IW1


Operational
EW1
MW1
PW4
WM1
CW1
LW2
OW1
WW1
Waste
NW1
WQ1
WP1
Demolition
& Excavation
WH1
CW1
RW1


Environmental
PW2
Weather
Condition
WS1

Appendix 10: Publications

- Asnaashari, E., Karam-Barangi, B., Karam-Barangi, S., (2011). Construction Logistics Management in Building Projects in Iran: the Warehousing Process, the 6th International Conference on Construction in the 21st Century (CITC-VI), Kuala Lumpur, Malaysia.
- Alaghbandrad, A., Nobakht, M., Asnaashari, E., (2011). ICT Adaptation in the Iranian Construction Industry: Barriers and Opportunities, the 28th International Symposium on Automation and Robotics in Construction (ISARC2011), Seoul, Korea.
- Asnaashari, E., Karam-Barangi, B., Knight, A., Hurst, A., Alaghband-Rad, A., Karam-Barangi, S., (2010). Construction Materials Logistics Management in Building Projects in Iran: The Purchasing Process, COBRA (RICS) 2010 Conference (The Royal Institution of Chartered Surveyors), Dauphine University, Paris, France.
- Alaghband-Rad, A., Asnaashari, E., Knight, A., Hurst, A., (2010). ICT Utilization in Administrative Tasks in the Iranian Construction Organisations, The 26th Annual Conference and Annual General Meeting, Association of Research in Construction Management (ARCOM), Leeds, UK.
- Asnaashari, E., Knight, A., Hurst, A., (2009). Delays in the Iranian Construction Projects: Stakeholders and Economy, The 5th International Structural Engineering and Construction Conference, University of Nevada Las Vegas, USA.
- Asnaashari, E., Knight, A., Hurst, A., Shahrabi, S. F. (2009). Causes of Construction Delays in Iran: Project Management, Logistics, Technology and Environment. The 25th Annual Conference and Annual General Meeting, Association of Research in Construction Management (ARCOM), Nottingham, UK.
- Asnaashari, E., Knight, A., Hurst, A. (2009). Organisations and Complexity: Challenging Newtonian Style of Thinking. Challenging Your Field Conference, Nottingham Trent University, Nottingham, UK.

- Asnaashari, E., Shahrabi, S. F., Knight, A., Hurst, A., (2009). Causes of Delays in Iran Construction Industry. The 5th International Conference on Construction in the 21 Century, Istanbul, Turkey.
- Asnaashari, E. (2009) Construction Material Management and RFID Application. The 3rd Conference on Projects' Procurement Systems, Sharif Technical University, Tehran, Iran.
- Asnaashari, E., Hurst, A.G., Knight, A. (2008). Logistics Management in Construction Projects in Iran. BuHu (Research Institute for the Built and Human Environment) the 8th International Postgraduate Research Conference, Czech Technical University in Prague, Czech Republic, Czech Technical University in Prague.