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CONBPS

An expert system to improve the efficiency of the construction process

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Abstract

The aim of the research outlined in this paper is to develop a best practice process model for building projects based on the use of an expert system. The CONstruction Best Practice System (CONBPS) focusses on projects which are based on the traditional procurement strategy, using the JCT 80 standard form of contract. The model clearly identifies the sequence of construction activities. It also identifies the roles and responsibilities of the major parties on the building team and the issues within the project cycle, which can prove critical to project success.

The system incorporates many user-friendly functions, including the provision of multi-choice icons and the provision of an on-line help function. Besides, it also provides interim and final reports which are used to advise the participants on the success factors that they have ignored and to which aspects they should pay more attention.

A framework was initially developed focussing on the whole design process with a full knowledge-based system developed for the Inception Stage.

CONBPS can be used as a teaching/learning tool to assist teachers and students to better understand the construction process. Also, it could prove useful to project managers and all the participants in the construction process.

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1 Introduction

Construction projects have been criticised for under-achievement for many decades (Carpenter, 1981; Egan, 1998). This has been reflected in the poor performance on time, cost and quality (Ridout, 1999) and the low satisfaction level of construction clients (CCF, 1998; CIB, 1996, 1997; Egan, 1998; Mackenzie, 1979).

The reasons for this situation are generally two-fold. The first is the temporary multi-organisational structure of projects; the working relationship of the construction team is often temporary. The background of the construction parties is different and they have varying specialist skills. It is critical therefore that the parties understand and appreciate the interdependence and responsibilities of each other. However, the construction participants often find it difficult to rationalise the whole procedure and understand the responsibilities of the other parties (Low, 1998).

The second reason is the inefficient construction process (Low, 1998; Tucker and Ambrose, 1998), especially under the traditional procurement route. In the traditional procurement method the design and construction responsibilities are separated. The contractor is the party responsible for the construction but they do not have responsibility or liability in the design process. This separation of the design and construction process tends to foster a 'them and us' attitude between the designers and contractors. This reduces the team spirit that is vital to the satisfactory conclusion of a building project.

2 Literature review

Construction is a process-based industry. It is therefore important to have a clear understanding of the process. The researchers in the forefront of the industry recognised the importance of modelling and understanding the construction process in order to bring improved methods and technology to the industry (Halpin, 1993; Abeysinghe and Urand, 1999; Finnemore et. al., 2000). Halpin (1993) explicitly mentioned this idea, stating 'we will witness an explosion of new and innovative construction-process technology. Since construction is a process-based industry, we must strive to improve our construction methods and processes. But in order to develop new processes, we must better understand the present processes, which are in place. Moreover, as stated earlier, innovation and process improvement require a framework or notation within which processes can be studied and improved' (p.423).

Apart from academic researchers, both Sir Michael Latham (1994) and Sir John Egan (1998) mentioned that the lack of advanced management of the process is the cause of the poor productivity and quality within the construction industry.

Research into developing a model to reflect the building process has been a popular topic in recent decades. There are several construction process models which have been developed. They can broadly be divided into three categories: data management models (Sanvido and Norton, 1994 and Karhu et. al., 1997), non-data management models (RIBA, 1995; BAA, 1995 ; NHS Executive, 1994) and models which consider the roles of the participants (Kagioglou et. al., 1998, Austin et. al., 1999).

The representative researches for the data management models include Sanviod and Norton (1994) and Karhu et. al. (1997). Sanvido and Norton (1994) developed the Integrated Building Process Model (IBPM) and used the Integration Definition language 0 for Function Modelling (IDEF-0) as the modelling technique. It represented the process as a sequence of activities, described by a verb followed by a noun. Each activity has associated inputs, outputs, controls and mechanisms.

One of the deficiencies in this model was that it was unable to differentiate between value adding and non-value adding activities. It also did not differentiate resources and constraints in inputs. Moreover, it did not incorporate any future learning capability into the model (Kartam et. al., 1997).

To a certain extent, Sanvido and Norton (1994)'s model applied the 'system thinking' concept to a construction projects. However, it ignored two major elements, i.e. the environment and feedback. A system does not stay in an 'isolated' situation, the external environment will influence it and this can make projects difficult to manage (Bennett, 1985). Feedback is another important concept; the aim of feedback is to regulate and improve the performance of the project (ibid.).

Karhu et al. (1997) did research which aimed at modelling the overall construction process systematically creating a generic present-state model covering the design and construction of a building project from the conception of the project in a client's mind to its completion for handover and use. Like Sanvido and Norton (1994)'s research, this model also adopted IDEF-0 as a modelling technique.

There were several common disadvantages among Sanvido and Norton (1994)'s model and Karhu et. al.'s (1997) model. Both models were static models as they intended to model the construction process but they were not able to be updated after inputting information. Besides, there was a lack of interface in these two models and they were unable to provide advice or a recommendation to the user.

The RIBA Plan of Work (RIBA, 1995), the BAA Process Model (BAA, 1995) and the NHS Capital Investment Manual (NHS Executive, 1994) are representatives of research using a non-data management model.

The RIBA Plan of Work (RIBA, 1995) was one of the first expressions of the building process developed by members of the building team (first edition published in 1969) and it is one of the most utilised non-data focused construction process models.

The RIBA Plan of Work is essentially an activity model of the traditional building process classifying the construction process into twelve stages. It was developed from the viewpoint of the architect and identified the construction activities in the whole construction cycle. Additionally, it also provides specimen business letters for use throughout the project cycle.

However, in practice this model may be biased towards the status and role of the architect as it was prepared by the RIBA. Although it mentioned the role of other participants, its description is very shallow and brief. Furthermore, the activities are 'identified' only. It does not mention their sequence and who are the responsible parties.

The BAA Process Model (BAA, 1995) goes beyond the simple sub-division of phases and breaks the process down into the key sub-processes like development management, evaluation and approval, design management, cost management, procurement management, health and safety, implementation and control, commission and handover.

The BAA model shows an improvement compared to the RIBA Plan of Work. However, its main application is at a generic level. The BAA model was developed from BAA's perspective and it focusses on its company condition. Therefore, the model takes little account of the need for improvement of the general construction environment and industry. Besides, the BAA model has designed its own identification of the construction stage. It therefore imposes limitations on those using it as a reference model.

Some government departments, like the National Health Service (NHS) have also published a report which focusses on discussing the issues regarding the roles and responsibilities of construction participants in a construction process (NHS Executive, 1994). This report noted the related issues regarding the appointment of architects, surveyors and engineers for commissions in the National Health Service (NHS). Also, it lists the roles and responsibilities of construction participants throughout the different stages, it also stated the information relating to the conditions of appointment, provision for fees and expenses and specimen certificates etc.

The NHS model faces similar limitations as the BAA model. The model lacks a general application as it focusses on NHS projects and it has developed its own phase classification. Besides, the approach of this model is to identify the related documents and mention the related procedures. It operates in the reverse way to the other process models. The disadvantage of this approach is that it cannot reflect the construction activities in a 'sequential' order.

The process models developed in late 1990's not only focused on process only, but they also addressed the working relationship of the construction team. The representative research includes Kagioglou et. al. (1998) and Austin et. al.'s (1999).

Kagioglou et. al. (1998) did a research project named Process Protocol Level 1, in which they developed a generic design and construction process protocol. They adopted the New Product Development (NPD) process as the development approach.

The system identified the construction activities and the responsible parties on a horizontal X-axis and a vertical Y-axis respectively. The construction activities were divided into four main phases: Pre-Project, Pre-Construction, Construction and Post-Construction. The responsible parties were named as 'Activity Zone' in this model. Apart from describing the activity in a map, it is necessary to use multiple computing skills which include electronic data interchange, artificial intelligence, integrated databases, inter/intranet applications and document management systems, in order to analyse the activities and present the results.

The Process Protocol Level 1 research developed a new construction process model at a macro level and produced a process model which could be applied to any construction procurement route. It had the advantage of general application but at the same time faced the weakness of 'lack of focus'. Within the model, the authors developed a new classification of the construction phases and used activity zones to represent the roles of the responsible parties. This approach is new to construction practitioners and requires a high knowledge of computing skills in order to develop and model the construction activities. It is a positive trend as it makes the model more sophisticated; however, in practice, it may be too complicated for the non-computer literate user.

Austin et. al.'s (1999) developed a model which showed that an effective interdisciplinary design relies on all of the team members supporting each other and it identified the interaction of each member within the project team. This model is divided into 12 phases and classified into five stages.

3

Aims of the research

Austin's model can also be applied to any procurement route and introduces the classification of construction stages in the project. However, the weakness of this research is similar to the Process Protocol research; it may be too complex for the non-computer expert.

After reviewing the previous research on construction process modelling, it was found that there are insufficiencies in all the different models and approaches.

These insufficiencies are identified as follows:

- Not widely applicable as the models focus on company perspective or particular sector, e.g. BAA and NHS models
- Not updated and contain bias to a certain sector and profession, e.g. RIBA Plan of Work
- Ignore some important construction concepts, e.g. IBPM and Karhu's (1997) research
- Lack of focus and using too much IT skills, e.g. Process Protocol Level I and Austin et. al. (1999)'s model

The extensive critical review of the construction process models has been discussed in Poon (2001).

It has already been mentioned in Section 1 that the reasons for the under-achievement of the construction process are the temporary multi-organisation structure and the inefficient construction process. Therefore, it was considered necessary to develop a construction process model, which clearly identified the roles and responsibilities of the major parties within the building team and the key issues within the project cycle which can prove critical to project success.

The author has developed a computer driven process model as an aid to improving the management of the project process. The system called the CONstruction Best Practice System (CONBPS). CONBPS is a construction process model, which clearly identifies the roles and responsibilities of the major parties on the building team and identifies the issues within the project cycle which can prove critical to project success. It focusses on the traditional procurement strategy as this is probably the most popular procurement strategy but at the same time subject to most criticism (Carpenter, 1981; Tucker and Ambrose, 1998; Walker, 1995). Besides, it focusses on the JCT 80 standard form of contract, this is because the JCT 80 form, and its successors the JCT 98, (in all its variants) still remains the most commonly used form of contract for the procurement of building work in the United Kingdom (RICS, 1994, 1996 and 2000).

The prototype CONBPS has been developed after obtaining practitioners' comments (Poon et. al. 2000) on the theoretical framework of CONBPS (Poon et. al. 1999). The development of the prototype CONBPS has been discussed in Poon et. al. (2001a). The author demonstrated the prototype CONBPS to the targeted users in order to seek their comments on the system. After obtaining their comments, the updated CONBPS was developed. The improvements included: revising the theoretical framework, adding new construction participants and adding new computerised functions. Also, the system structure, knowledge representation structure and system operation have been revised. The development of updated CONBPS has been discussed in Poon et. al. (2002). The updated CONBPS is the basis for the development of the finalised CONBPS.

The aim of this paper is to describe the process used to develop the finalised CONBPS. Owing to financial and time limits, the final version of CONBPS has focused mainly on the Inception Stage.

4

Research methodology

The methodology for developing the finalised CONBPS prototype includes seven stages: literature review, pilot study, prototype development, extensive practitioners' comments, development of updated system, system evaluation and development of final system.

The RIBA Plan of Work (RIBA, 1995) has been chosen as a skeleton framework but the information from other reports and literature have been added. The theoretical framework has been sent to a discrete sector of the construction industry for their comments.

The primary reason for choosing a discrete sector was to avoid bias. The chosen respondents should have substantial experience in property development, be familiar with construction procedures and preferably be neither a private nor a public developer. Both private and public developers will normally have their own preferences for construction procedures and practices.

The chosen targeted respondents were the Housing Associations within the West Midlands area of England. Housing Associations are a dominant provider of new social housing; they are non-profit making societies established for the purpose of providing rented housing accommodation.

The West Midlands is a geographically diverse region. The decline in the manufacturing sector has had a severe impact in the region, which led to a rapid increase in unemployment and below average wages for those in work. The

West Midlands now ranks second after Northern Ireland for long term unemployment rates and has the highest infant mortality rates in the UK. Because of its specific historical background, the Housing Associations in this region have more opportunity to build a wide range of accommodation.

After seeking the comments from the Housing Associations, a prototype system has been developed. The prototype system has been commented on by practitioners and the methodology used to collect the practitioners' opinion was by interview. The targeted respondents were all participants who were identified in the prototype CONBPS. As the aim of CONBPS is to identify the responsibilities of various participants in the construction project, it was decided to include the opinions from all the parties in order to have a comprehensive picture. These respondents included architects, quantity surveyors, planning supervisors and clients (private and public client). In addition, representatives of the Housing Associations who participated in the previous stage of the research were also interviewed. As only the design stage of the construction project cycle has been developed into the prototype system, contractors were not included and were not interviewed. The author demonstrated the system and asked the several questions in order to guide the interviewees to comment on the system. The questions that were been asked included:

1. Are the critical issues describing each activity appropriate?
2. Are the project team members responsible for each activity appropriate?
3. Is the sequence of work in right order?
4. Is the description of each activity clear?
5. Have some activities been omitted?
6. Do you have any additional comments?

After obtaining the practitioners' comments on the prototype CONBPS, the system was further updated. Significant changes were made to both the theoretical framework and the working system in order to incorporate the practitioners' comments. The next step was to evaluate the updated system, this included two stages: validation and verification.

The validation involved testing the system to ensure it was the correct system – that is, it functioned as the required specification and met the experts' expectations. The validation process of CONBPS also had two stages. The method used for the first stage validation was to demonstrate the updated CONBPS to the potential users, construction participants, including project managers, architects, quantity surveyors, clients, planning supervisors, services engineers and structural engineers, and obtain their comments. The aim of this stage of validation was to check the usability and applicability of CONBPS. Domain experts evaluated the second level of the validation process. The method of pursuing validation was by running a test case. The interviewees at the previous stage worked for different companies, so their understanding of construction process may have been different. This method has an advantage as it can obtain a wide range of opinions on the system. On the other hand, it also has insufficiencies as the comments are probably too broad and may loose focus as the experience of the participants varies. It is therefore necessary to include a case study as a complement to the evaluation stage.

The verification focused on ensuring that the system was developed correctly and accurately and gave solutions or results and which did not contain technical errors (Awad, 1996; Geissman and Schultz, 1988; O'Keffe et. al., 1987). There was a two-level process to carry out verification of CONBPS. The method used to carry out the micro-level verification was to run the system by the author so as to check the discrepancy between the expected outcome and the predicted outcome. The author prepared the checklist which stated the predicted outcome and the actual outcome of each possible combination.

5

Theoretical framework of CONBPS

Based on this checklist, the author should be able to detect any discrepancy between the actual and the expected outcome. The method used to carry out the macro-level verification was by submission of the knowledge-based systems of the updated CONBPS to an expert in developing expert system.

After completion of the evaluation stages, the final version of CONBPS was developed which will be discussed in the later sections.

METHODOLOGY FOR DEVELOPING THE FRAMEWORK

The standard cycle of work in a building project identified in the RIBA Architect's Job Book (1995) and known as 'the RIBA Plan of Work' has been chosen as a skeleton framework. The RIBA Plan of Work is well known by all construction professionals – it is a tried and treated model developed based on feedback from practitioners over a number of years. In the event the RIBA Plan of Work became the skeleton framework and made up only one third to one half of the activities in this new process model. The changes within construction industry has been greater in the last five years than the past fifty years, therefore, new construction management issues were also included in the model. The other activities which were abstracted from the information in various documents are listed as below:

- The RIBA Plan of Work identified within the Architect's Job Book (RIBA, 1995)
- Responsibilities of the quantity surveyor identified by the RICS (RICS, 1983)
- Responsibilities of the contractor in the traditional procurement method (CIOB, 1996; NJCC, 1989)
- Procedure for single-stage tendering identified by the NJCC (NJCC, 1989)
- Responsibilities of the client identified by the Construction Clients Forum (CCF, 1998)
- Current government publications concerned with improving performance of the construction industry (CIB, 1996 and 1997; HM Treasury, 1993, 1994, 1996 and 1998)
- Official advice on health and safety within the construction industry (HSC, 1995a and 1995b; HSE, 1994)
- Design management concept for construction (Gray et. al., 1994)

- Environmental management concept for construction (Griffith, 1997)
- Constructability concept (CII, 1986)

The updated model also incorporates risk management, value management, total quality management (TQM), safety management, design management, environmental management, partnering, benchmarking and constructability.

REASONS FOR CHOOSING THE CRITERIA

The key criteria within this model include time, cost, quality and safety. The first three criteria are the traditional determinants of project success. Safety is an additional factor which should also be included as the construction industry is one of the most dangerous industries in the nation as construction accidents can cause both loss of human life and loss of money to the parties (Sawacha et. al., 1999).

Apart from these criteria, certain 'hotspots' were also identified within each stage of the project cycle. The 'hotspots' were the 'critical activities', to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage. The idea of 'hotspot' has been widely used in government and academic literature. Kagioglou et. al. (1998) introduced the concept of 'phase review' into the Process Protocol Level 1 Report. 'The phase review consists of two elements, which are 'soft' and 'hard' gates. 'Soft' gates enable concurrency in the process whereas 'hard' gates require the temporary overhaul of the project until a decision to proceed is made… The intent of each gate is to assure a high quality of work performance by multifunctional teams at each phase of the project' (p.1:15). Her Majesty's (HM) Treasury (1998) published the 'Procurement Guidance No.2: Value for Money in Construction Procurement' which also developed the same concept. It identifies the 'approval gateway' at the critical points in the project cycle. The users should take appropriate action at such gateways. The concept of 'hotspots' in this project follows this direction.

PARTIES RESPONSIBLE FOR CONSTRUCTION ACTIVITIES

The participants, at the inception stage, include the architect, quantity surveyor, client and the planning supervisor. The architect, quantity surveyor and client are identified as they are the identified participants in the Standard Condition of JCT Contract. The planning supervisor is also an important party in the building process. In the traditional procurement strategy, contractors will not participate in the project until the estimating stage.

The planning supervisor is a relatively new role in the construction process that was introduced following the implementation of the Construction (Design Management) CDM Regulation in 1994. They have overall responsibility for co-ordinating the health and safety aspects of the design and planning phase for the early stages of the health and safety plan and the health and safety file (HSE, 1994).

After seeking the comments from the practitioners, several additional roles have been added, including: project manager, structural engineer and service engineer.

FRAMEWORK OF THE PROCESS MODEL FOR BUILDING PROJECTS

Figures 5.1 and 5.2 illustrate the theoretical framework for the final version of CONBPS.

The theoretical framework has two pages. The first page lists the activities and the second page lists the responsible parties.

Description of first page

Figure 5.1 is divided into three columns. The first column states the *criteria*.

Time, cost and quality are the well-known traditional determinants of project success. Safety is an important issue and should also be included in the model.

Figure 5.1 • **Activities in construction stage A – 'Inception'**

Stage A: Inception

Criteria		Activities		Note
H		1	Appoint a project manager	
H		2	Prepare statement of need	
H		3	Assisting the client in order to identify the objectives	
TCQ		4	Prepare project execution plan (explain)	CA
T		5	Prepare process execution plan (explain)	CA
H		6	Identify stakeholders' list	
CQ		6a	Negotiate and appoint relevant stakeholders	Sub
CQ		6b	Select the appropriate principal consultants	Sub
CQ		6c	Discuss with consultants about their terms of appointment	Sub
CQ	No → Go back to activity 6a	6d	Appoint relevant consultants	Sub
C		7	Meet client to discuss their budget and requirements	
Q		8	Inform client about his job responsibilities	
H		9	Obtain the Client's approval of the project execution plan and direct all the project team for implementation	
H		10	Prepare project brief	
TCQ		11	Establish the project scope	
T		12	Communicate to the consultants about the requirements of Client's Brief	
H		13	Assist in site selection	
Q		13a	Undertake site appraisal	Sub
Q		14	Set up targets and monitoring procedure for the project	
Q		14a	Set up monitoring procedure for the progress of design work	Sub
T		14b	Set up monitoring procedure for regulating programme and progress	Sub
Q		14c	Set up monitoring procedure for co-ordination of the consultants	Sub
C		14d	Set up monitoring procedure for cost and financial reward of project	Sub
T		14e	Set up appropriate channels of communication between project team	Sub
Q		14f	Set up monitoring procedures for performance parameters	Sub
T		14g	Set up consultants' reporting and recording procedures	Sub
T		14h	Set up meeting structure	Sub
Q		15	Co-ordinate the activities on all legal agent issues	
CQ		15a	Advise the client on appropriate procedures for dealing with insurance claims	Sub
Q		16	Advise the client on obtaining appropriate specialist input	CA
C		17	Undertake cost studies	
C		18	Investigate and evaluate financial options	CA
Q		19	Discuss with consultants about feasibility of achieving the objectives	
S		20	Determine whether the project falls within the CDM Regulations	
S		20a	Identify appropriate Planning Supervisor	Sub
H	No → Go back to activity 20a	20b	Appoint Planning Supervisor	Sub
S		20c	Inform the client of their duties under CDM Regulations	Sub
S		20d	Contribute to Health and Safety File and Plan	Sub
Q		21	Update feasibility plan	
TCQ		22	Undertake site investigations	
T		23	Consult with local authority and other statutory authorities	CA
C		24	Provide cost advice relating to local authority and others etc.	
Q		25	Evaluate structural implications of options	
Q		26	Evaluate services implications of options	
Q		27	Evaluate the feasibility plans	
H		28	Feasibility studies for options and make recommendations	

Figure 5.2 • **Roles of participants in construction stage A – 'Inception'**

Stage A: Inception

Project Manager	Architect	Quantity Surveyor	Structural Engineer	Service Engineer	Planning Supervisor	Client
1A						1M
2A						2M
3M						3A
4M						4A
5M						5A
6M						6A
6aM						6aA
6bA	6bA	6bA	6bA	6bA		6bM
6cA	6cA	6cA	6cA	6cA		6cM
6dA	6dA	6dA	6dA	6dA		6dM
7M		7A				7A
8M						8A
9M	9A					
10M	10A					10A
11M	11A					11A
12M	12A	12A	12A	12A		
13M	13A					13A
13aM	13aA		13aA			
14M	14A	14A	14A	14A		
14aM	14aA					
14bM						14bA
14cM	14cA	14cA	14cA	14cA		
14dM		14dA				
14eM	14eA	14eA	14eA	14eA		
14fM	14fA	14fA	14fA	14fA		
14gM	14gA	14gA	14gA	14gA		
14hM	14hA	14hA	14hA	14hA		
15M						15A
15aM						15aA
16M						16A
		17M				
18M	18A	18A	18A	18A		
19M	19A	19A	19A	19A		
20M						
20aM						20aA
20bA					20bA	20bM
20cA					20cM	20cA
	20dA	20dA	20dA	20dA	20dM	
21M	21A					
22M	22A		22A			
23M	23A	24M	23A	23A		
			25M			
				26M		
27M	27A 28M	28A	27A	27A		

Key 1-28 Activities M - Main party, A - Associated party

The 'hotspot' identifies the 'critical activities' within each stage of the project cycle to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage. The method used to identify the 'hotspot' activities is based on three steps. The first step deals with the identification by the author after finishing the literature review and the second step is incorporating comments made by the practitioners who participated in the pilot study.

The second column shows the *activities* of the construction process, the numbers indicate the sequence of work and the text is the description. The activities that are listed encompass the typical issues in the traditional procurement strategy, but also reflect the modern construction management issues.

The third column is the *note*. 'CA' means continuous activity. These activities needed to be updated throughout the whole construction stage as they should be undertaken throughout the project. 'Sub' means sub-heading activities. Certain activities are classified into a hierarchy, which consists of main activities and sub activities as not all activities have the same level of importance.

Description of second page

Figure 5.2 identifies the *participants* in the construction process. The participants include the architect, quantity surveyor, client, planning supervisor, project manager, structural engineer and building services engineer.

Architect
Traditionally, the architect has to perform two roles, firstly that of designing a building and secondly that of administering the project. He/ she does this by co-ordinating the contribution of consultants and then administering the building contract. Besides, he/ she is also the first point of contact with the client and the person who interprets the client's brief.

There has been a dramatic change in the architects' role in recent years and there is now no dual role for the architect (RIBA, 1992). The architect acts as design manager who is responsible for co-ordinating design tasks (Gray et. al. 1994; RIBA, 1992). The loss of the leadership role means that the architect is no longer in a position to influence the rest of the construction process (RIBA, 1992). This is mainly because of the increasing competitiveness and the influence of the other professions. According to a study prepared by Smith and Morris (1992), out of a total of forty-four services listed in the Standard Form of Agreement (SFA/92) for the Appointment of an Architect, thirty-nine were undertaken by competing professions.

Quantity surveyor
The traditional role of quantity surveyor is a professional who provides advice on cost and financial management for the construction process. The traditional services provided are considered to be of a technical basis, such as preparing the cost plan and the bills of quantities etc. (Burnside and Westcott, 1999).

The changing role of the quantity surveyor in recent years has been significant (Ashworth, 1981; Donohoe, 2000). This is because of the changes of emphasis within the construction industry, from *cost* to *value* and the recognition of the importance of procurement and management skills (Ashworth, 1994). According to the results of research by Keel et. al. (1994), over eighty percent of clients interviewed see the role of the quantity surveyor changing. Sixty seven percent of respondents see an increasing role in the areas of project management, lead consultancy, cost and value management, mechanical and electrical services and advising on overseas methods and costs.

Client
Traditionally, the client is defined as the sponsor of the construction product or service (Ahmed and Kangari, 1995; Potter, 1995). There have been numerous research recommendations in recent years advising that clients should

participate in the construction process (e.g. CIB, 1996; Latham, 1994; NEDO, 1975) and stating that their involvement is critical to the success of the project (Davenport and Smith, 1995; Kometa et. al., 1996; Thompson, 1991 etc.). Latham (1994) stated that 'implementation begins with clients' (p.3). The client's involvement during project development and implementation is critical to project success (Thompson, 1991).

Generally, the higher the level of client involvement, the higher the level of satisfaction. Gunning and Courtney (1994) did an investigation on the private sector client contribution to the construction process in Northern Ireland. They drew the conclusion that 'if private sector clients take fuller control of their projects either directly or indirectly, they will be assured of improved satisfaction at the completion stage with their priorities constantly concentrating the minds of all other associates' (p.18).

Planning supervisor
The planning supervisor is a relatively new role in the construction process that was introduced following the implementation of the Construction (Design Management) CDM Regulation in 1994. They have the overall responsibility for co-ordinating the health and safety aspects of the design and planning phase and for the early stages of the health and safety plan and the health and safety file (HSE, 1994).

Project manager
The project manager is responsible for the management and administration of the project duties which were traditionally within the architect's role.

Structural engineer
The structural engineer is responsible for issues concerned with design of the structural efficiency and stability.

Building services engineer
The building services engineers are obliged to design the internal control systems, i.e. heating, ventilating, air conditioning and lighting installations, and utilities such as electrical supplies, lifts and compressed air.

Each box in figure 5.2 identifies the number of activities and the role of the responsible parties. The number identifies the sequence of the activities and the capital letter identifies the 'status' of the responsible parties. For example, if 1A appears in the column of the project manager and 1M in the column of the client, this means that the major party responsible for activity one is the client with the project manager acting in an associated role. The major role is the leading participant for that activity, the associate participant is the supporting party for that activity.

Sometimes, the construction activities run in parallel, like activities 23, 24 and activities 27, 28. These two-pair activities are running coincidentally as the responsible parties for these two-pair activities are different.

In order to enable the participants to view their responsibilities, a matrix is provided which shows the responsibilities of construction participants (see table 5.1).

Table 5.1 • **Roles of participants in construction stage A – 'Inception'**

		Project manager	Architect	Quantity surveyor	Structural	Services engineer	Planning	Client
1	Appoint project manager	●						■
2	Statement of need	●						■
3	Project execution plan	●						■
4	Process execution plan	●						■
5	Appointment of stakeholders	●						■
5a	Negiate and appoint relevant stakeholders	●	■	■	■	■		
5b	Select the appropriate principal consultants	●	■	■	■	■		
5c	Discuss with consultants about their terms of appointment	●	■	■	■	■		
5d	Appoint relevant consultants	●	■	■	■	■		
6	Discussion of client's requirements	●		■				■
7	Inform client to discuss their job and responsibilities	●						■
8	Project brief	●						■
9	Project scope	▲						
10	Site appraisal		▲					
11	Provide guidelines on cost about achieving objectives			▲				
12	Site appraisal cost studies			▲				
13	Evaluation of finance options	●	■	■	■	■		
14	Discussion of feasibility of achieving objectives	●	■	■	■	■		
15	Determining whether the project fall into CDM Regulations	▲						
	Appoint planning supervisor						■	●
	Inform the client their duites under CDM Regulations						●	■
	Contribute to Health and Safety File and Plan		■	■	■	■	●	
16	Updating feasibility plan	▲						
17	Site investigation		▲					
18	Co-ordinate consultations with local and statutory authorities	▲						
19	Consult with local authority and other statutory authorities		▲		▲	▲		
20	Provide cost advice			▲				
21	Evaluate structural implications of options and contribute to cost assessment				▲			
22	Prepare strategies and cost implications against options					▲		
23	Evaluate the feasibility plans	●	■		■	■		
24	Cost feasibility for options			▲				
	● Major role							
	■ Associated role							
	▲ Single responsibilities							

6

Development of CONBPS

DEVELOPMENT TOOL OF CONBPS

The aim of this project was to develop an automated process model which listed all the construction activities and their responsible parties. The intention of the model was to provide information to the users on the activities that:

- need to be performed
- the aspects that require special attention
- provide relevant additional information prior to the start of a particular activity

The knowledge stored in the system was derived from relevant literature including regulations together with comments received from experienced practitioners.

The system tries to provide the above information via interim reports. Additionally at the end of the project the system should provide a report explaining which tasks have been skipped and the possible consequences.

Expert systems have been employed in numerous advisory tasks where a high degree of decision logic is required in order to offer suitable advice. Such systems are built using tools known as 'expert system shells'. These shells comprise a predefined inference engine that can manipulate the knowledge contained within to solve problems in the area of expertise to which the knowledge appertains. This means that the focus of development is switched from 'how' the knowledge can be used to 'what' knowledge it should contain.

There are numerous expert system shells commercially available. The choice of the most appropriate shell depends upon the requirement of the application. For the CONBPS application the following characteristics were considered desirable:

- The ability to run on a PC computer under the Windows operating system
- Explanation and justification capabilities
- User friendly interface
- The capability to link with other software
- Within the financial resources available for the research project

Several kinds of software such as traditional programming languages, e.g. Visual Basic and C++ and traditional expert system languages, such as LISP, Prolog and Crystal, were considered.

The use of a traditional programming language has its advantages as it can perform varieties of functions that may not be able to be done using a commercial package. On the other hand, it takes a long time to build up and it is much more complicated and therefore, difficult to debug. Also, it is difficult to acquire knowledge at the knowledge acquisition stage and often it is not economic in terms of time and cost. Besides, if the knowledge is tied up with an algorithm, this imposes a further restriction.

The use of Prolog, Lisp and Crystal also face similar problems as a traditional programming language. It is difficult to find full information in order to write the programme and the programme can be complex and difficult to debug. Although there are the Window-base versions, they are not available in house and are beyond the financial constraint of this research project.

The chosen development tool for this model was the ‘expert system shell’. An expert system shell is a package designed to support the development of a knowledge-based system. These shells comprise a predefined inference engine that knows how to use the knowledge base to reach conclusions.

The knowledge representation technique and utilities have already been built into these tools. An expert system can be built without having to create the reasoning and data structure components. Thus, expert system shells are easy to use, especially for developing prototype systems.

The most suitable expert system shell satisfying these requirements was ‘XpertRule’ (© Attar Software).

The development environment within XpertRule is a highly graphical environment with an intelligent user interface and extensive on-line help. An XpertRule application is constructed graphically as a hierarchy of chained tasks (displayed on the Map View). A task can consist of a decision tree representing a flow chart controlling procedures, graphical dialogs, procedures, reports or other tasks. Complex knowledge can be structured into a hierarchy of chained tasks (Attar, 1999). The knowledge representation will be further discussed in section 6.3.

STRUCTURE OF CONBPS

The CONBPS breaks down the construction stages into different files. Each construction stage consists of three files. Because of limitation of time, only the RIBA Plan of Work Stage A ‘Inception’ has been used for demonstration and testing purposes. It has three knowledge-based systems, which are ‘CONBPS_A’, ‘A_All’ and ‘A_Main’. As each construction stage has three separated knowledge-based systems, there is an independent ‘introduction’ file which gives the brief description of these knowledge-based systems.

CONBPS_A

‘CONBPS_A’ comprises all the construction activities in construction stage A. It is suitable for the project manager or other participants who are interested in the overall construction process. The operation of this file is similar to the old versions. It lists the construction activities in sequence. The users answer whether they have finished the previous activity. If the answer is ‘yes’, or ‘processing’, then they proceed to the next activity. The user should answer ‘yes’ if they have completed that activity. If they have started that activity but it has not yet been completed, they should answer ‘processing’. If the user answers ‘no’, the system will ask them whether they would like to continue or not. If the user does not want to continue, the system will list the report of this stage and then it will end.

A_All

‘A_All’ comprises the construction activities with reference to the responsible parties in construction stage A. This file is suitable for users who intend to check the responsibilities of a particular party. The user can choose a specific role about which they would like to know more. For example, if you choose ‘project manager’, then it will only show the activities which should be done by the project manager. This file will show all the activities which are the responsibility of the project manager, either they are acting as a ‘major role’ or as an ‘associated party’.

A_Main

'A_Main' classifies the construction activities with reference to the major responsible parties in the construction stage A. These files only show the activities which relate to the parties which act as the major party.

KNOWLEDGE REPRESENTATION OF CONBPS

The 'decision trees' are the main knowledge representation method in 'XpertRule' and they were chosen as the knowledge representation method in this project. CONBPS is an expert system which models the construction process and the activities are listed as a sequence. If it is presented in a tree, it is easier to identify the errors. Besides, it is also more convenient for the practitioners to comment as they can see the flow of logic in a diagram.

Description of the decision tree

A decision tree is a hierarchically arranged according to a semantic network and is closely related to a decision table. It is composed of nodes and branches that represent decisions or outcomes. Nodes represent connectors between the tree and branch. The node at the top of the tree that has no parent is called the root node. Nodes with no children are called leaves. The leaf nodes of a decision tree represent all the possible solutions that can be derived from the tree. The nodes are referred to as answer nodes, and all other nodes in the tree are referred to as decision nodes. Each decision node represents a question or decision that when answered or decided, determines the appropriate branch of the decision tree to follow (Awad, 1996; Giarrantano and Riley, 1994).

Advantages of decision tree

Representation method
The representation of a decision tree is both compact and efficient, far better than other forms used by conventional rule based systems. The traditional programming technique, which may consist of many 'IF'… 'AND'... 'OR'... 'THEN'... 'ELSE' program statements, is difficult to debug and test all possible decision paths, let alone to optimise the flow to maximise performance. Such programs, over time, become impossible to maintain.

On the other hand, a 'decision tree' shows decision-making logic in an easy to understand graphical form for capturing, structuring, representing and maintaining knowledge. The graphical nature makes them more understandable and the inference form trees can be orders of magnitude faster than an inference form rule because of the elimination of the need to search rule bases. A tree can represent many 'rules' and when the logic is executed by following a path down it, the user is effectively bypassing rules that are not relevant to the case in hand. The user does not have to look at every rule to see if it 'fires'.

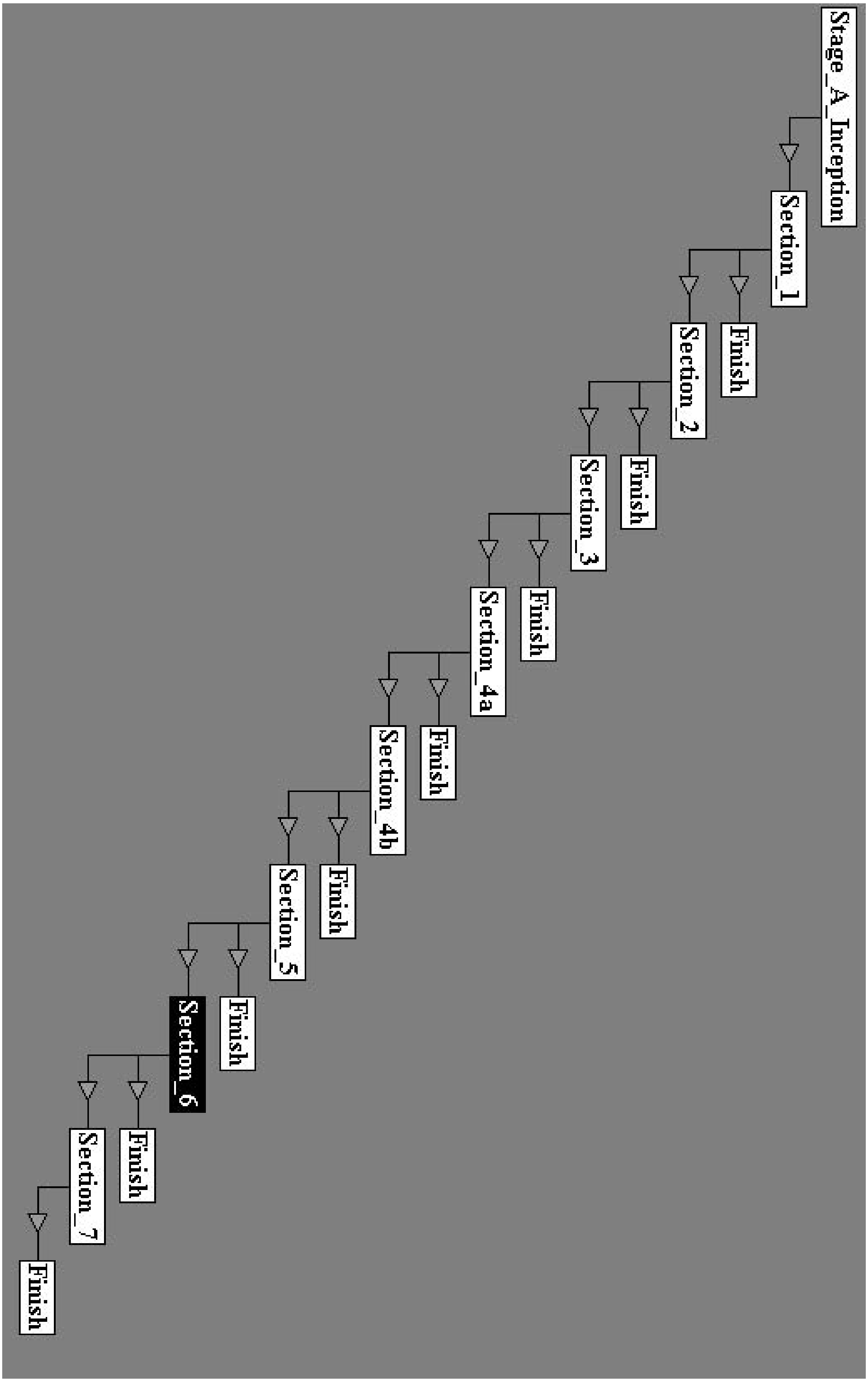
Knowledge acquisition
Using a 'decision tree' as a method of knowledge representation also has an advantage on knowledge acquisition, which is acknowledged as the bottleneck of expert system development.

XpertRule is a specialised system for capturing knowledge and developing intelligent applications. It provides:

- A graphical development environment that makes it easy to prototype, build, maintain and test knowledge based systems
- Solutions which can be delivered on Microsoft Windows PC's and networks and on the Internet / Intranets using the XpertRun run time

Knowledge structuring
Furthermore, a decision tree also provides an advance in knowledge structuring. Lack of a modelling methodology for decomposing a large application into a hierarchical structure of rule sets represents a major difficulty in building traditional knowledge based systems. Without the structuring of rule sets, developing a rule base for a large application becomes difficult. This problem is compounded by the lack of formal ways of structuring within the rule base 'inference engine'. Several ad hoc methods of

Figure 6.1 **• Map of CONBPS_A**



structuring rule sets have been put forward, such as spider diagrams and concept maps. These methodologies aim to model the application by establishing a hierarchy of concepts, each concept with a corresponding rule set or a rule base. The developer must then add control rules, agendas or demons to force the flow of the inference engine, to correspond to the structuring of concepts.

XpertRule enables highly complex KBS applications to structure into more manageable units of knowledge – each unit being called a 'Task' – and to be able to build and visualise the overall structure with a tasks 'Map'.

System testing

Unlike a process chart, decision trees can be tested immediately. The XpertRun Inference Engine can be used to 'run' the application at any time. Automatic default user dialogs are generated, enabling the testing of prototypes with no developer effort. Nesting of trees can be used to relate sub-tasks to a main task. Therefore, any errors can be found and corrected immediately.

Knowledge representation of CONBPS

Figure 6.1 is the map of updated CONBPS_A. As there are many activities, it is more convenient to build-up and debug if it is divided into several sections. Each section is linked to finish individually as it aims to allow the system to stop at any point.

Figure 6.2 shows the decision tree of 'Finish'. The aim of this decision tree is to link the 'Report'. No matter where the project stops at, it will still link to the report section.

CONBPS_A provides a function of asking whether the project has a project number. The aim is to save the record of the answers of the project. If the user answers 'Yes', then it will open the record of the previous answer. On the other hand, if the user answers 'No', the system will ask the user to give the project number for this operation. After finishing the current operation, it will update the current record.

Figure 6.3 shows a part of the decision tree of section 1 of CONBPS_A. Accordingly, the activities are listed in a sequence. Each activity is represented in one box; the text of each activity is described in an attached 'dialogue box'. If the answer to an activity is 'yes' or 'processing', it will proceed to the next activity. If the answer to an activity is 'no', it will proceed to an 'Activity uncompleted' statement. Also, it will allow the user to have the option to end the project or not. The operation of the system will be discussed in section 6.4 in greater detail.

In order to achieve some looping or setting of the activities, some 'procedures' need to be set. In order to differentiate, there is a 'P' attached to the activity box. Under certain circumstances, a label is needed to be attached in order to perform certain functions. The label is the grey colour box in the decision tree.

Figure 6.4 shows the section 6 of CONBPS_A. Activities 23 and 24 are operating at the same time, and that means the system should ask the user whether they are doing activity 23 or 24 at a certain time. This section has set up the procedure for performing this function, that is the split of the decision tree after activity 22.

Figure 6.5 shows the map of A_All. The aim of this file is to allow individual participants to see what activities that they are involved in.

Figure 6.6 is the decision trees for A_All participants. It shows all the activities which are the responsibility of each participant. Besides, each participant is linked to his or her relevant report and their list of activities.

Figure 6.7 shows the detailed description of the map for the project manager. As there are many activities, it is better to divide the activities into small sections. Also, each section is linked to the 'finish' so as to let the users go to the end of the operation at any time.

Figure 6.2 • **Decision tree of CONBPS_A – Finish**

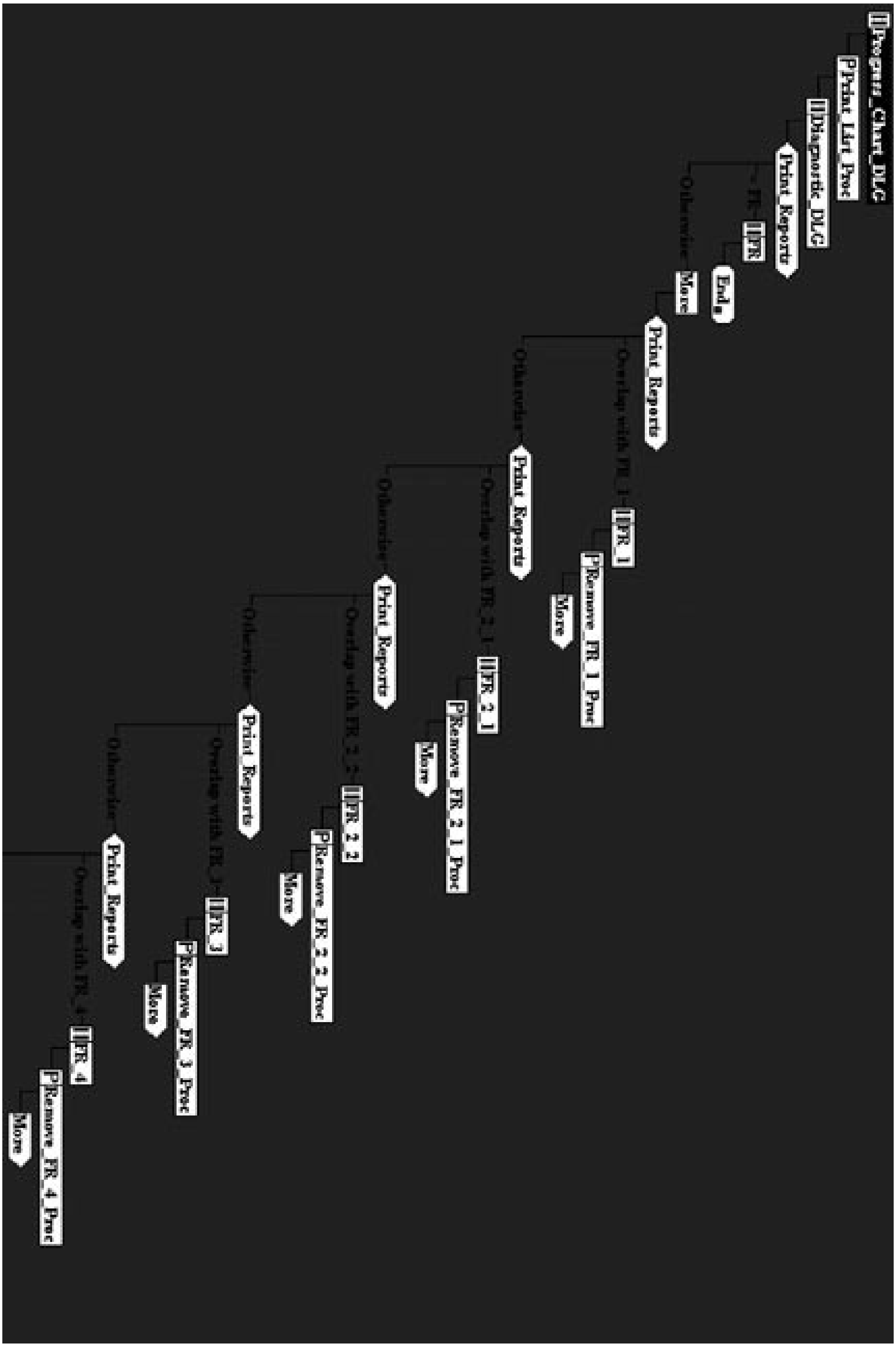


Figure 6.3 • **Decision tree of CONBPS_A – Section 1**

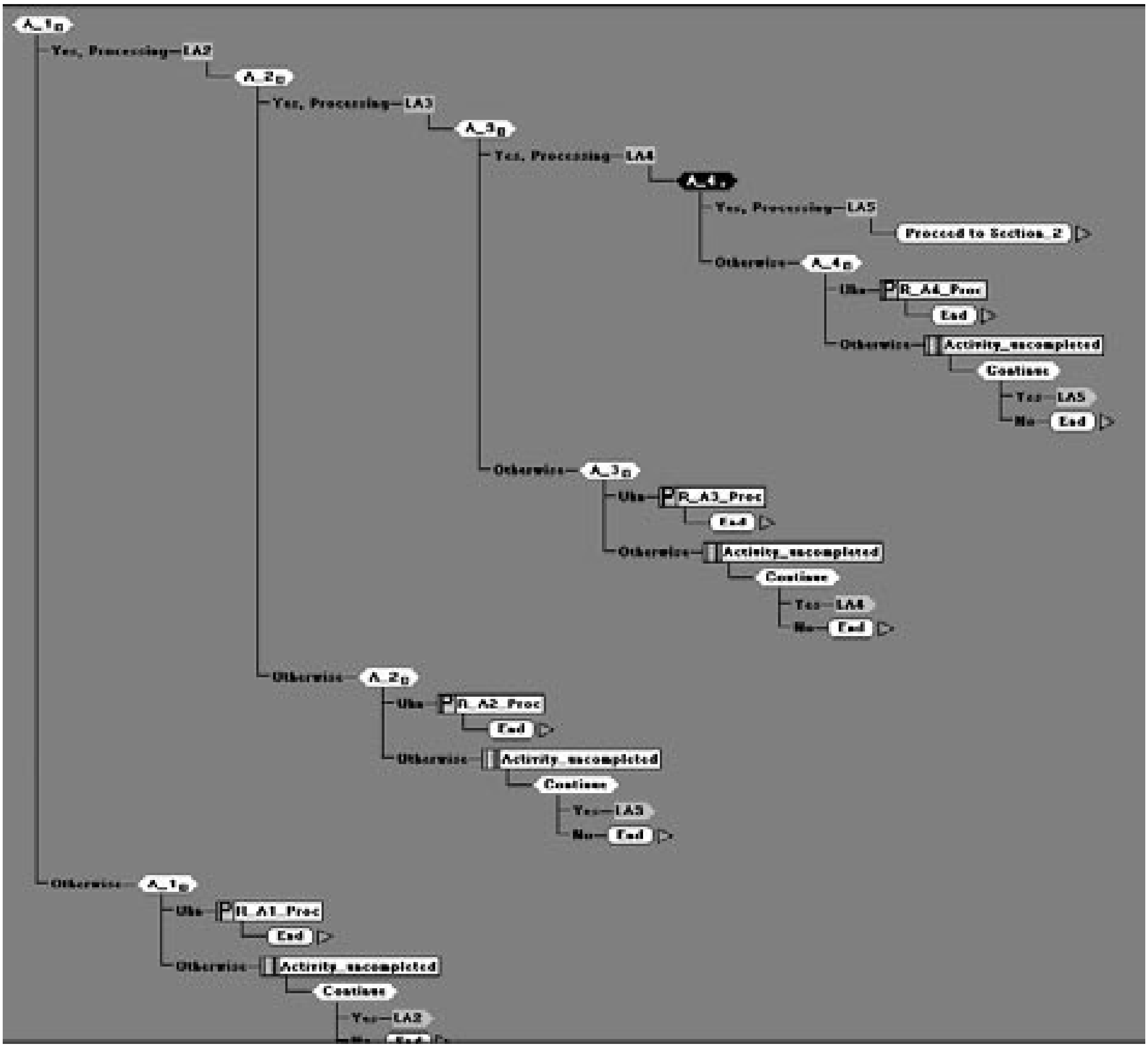


Figure 6.4 • **Decision tree of CONBPS_A – Section 6**

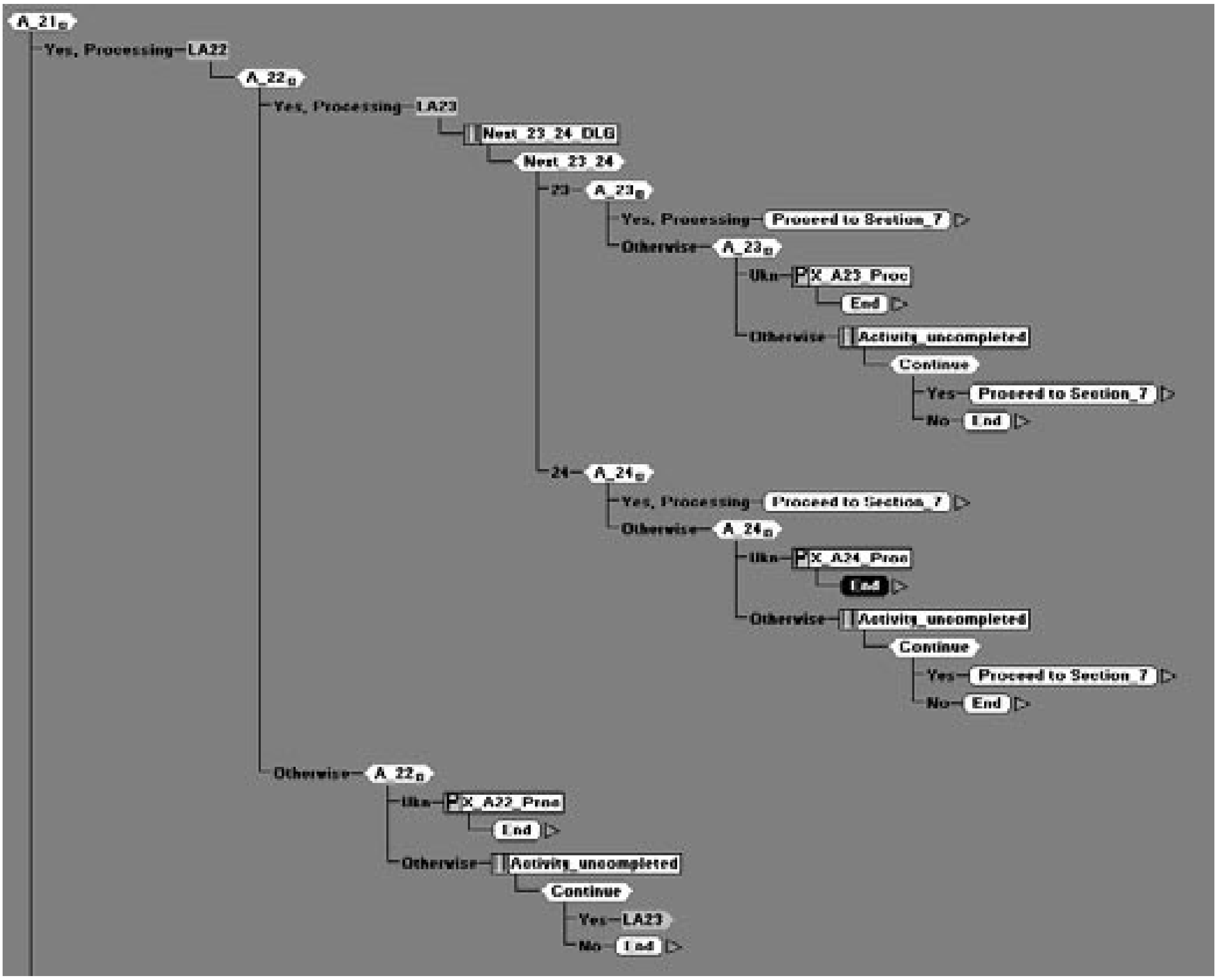


Figure 6.5 • **Map of A_All**

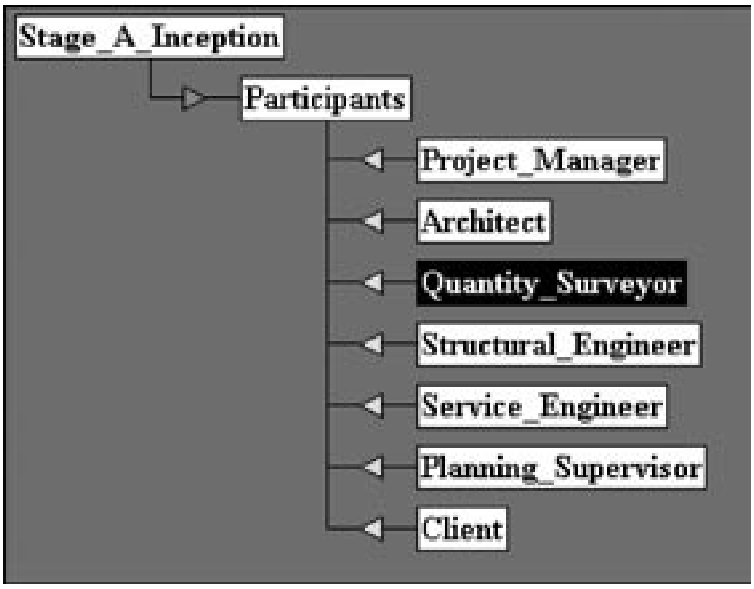


Figure 6.6 • **Decision tree of A_All - Participants**

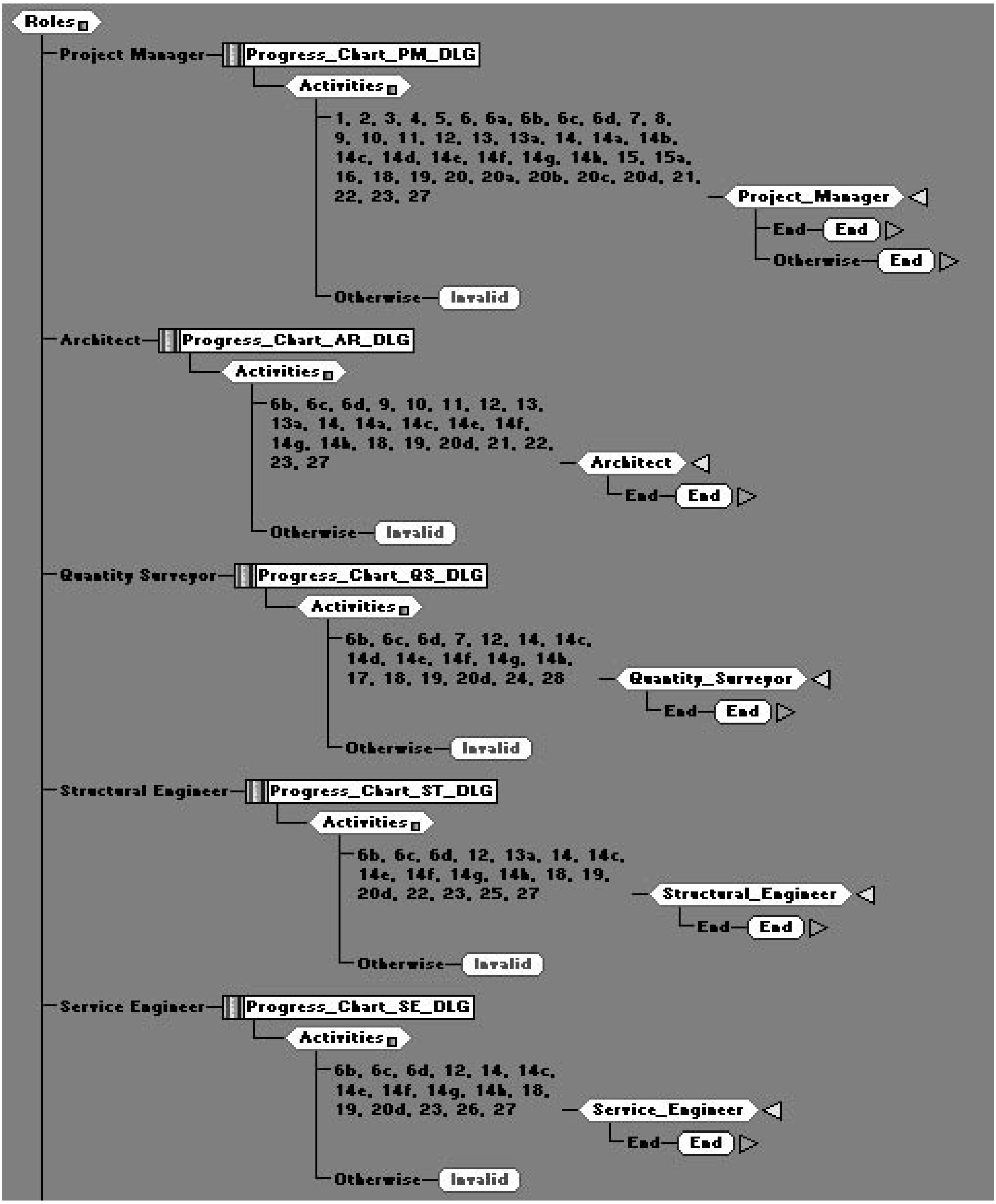


Figure 6.7 • **Map of Participant 'Project Manager'**

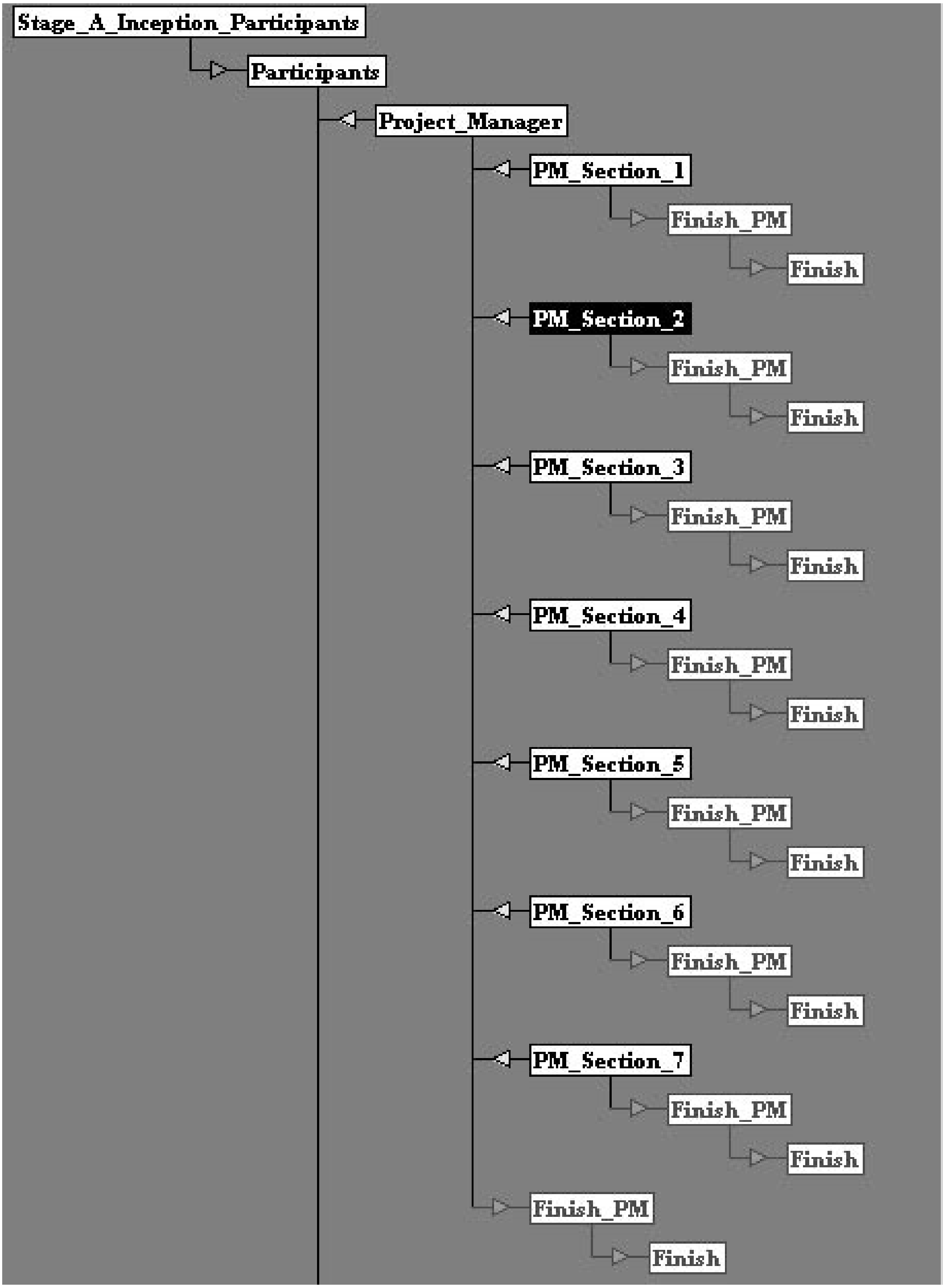


Figure 6.8 • **Decision tree of A_All - Project Manager (Section)**

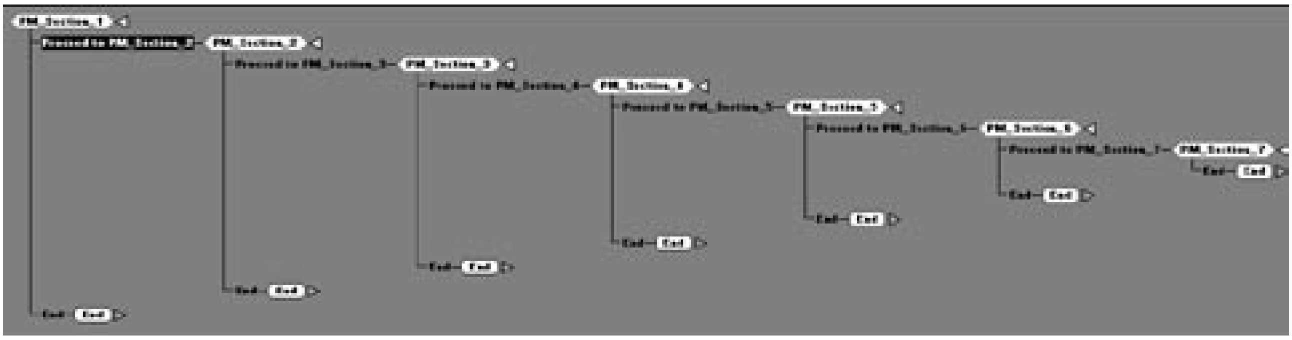


Figure 6.9 • **Decision tree of activities for Project Manager - Section 1**

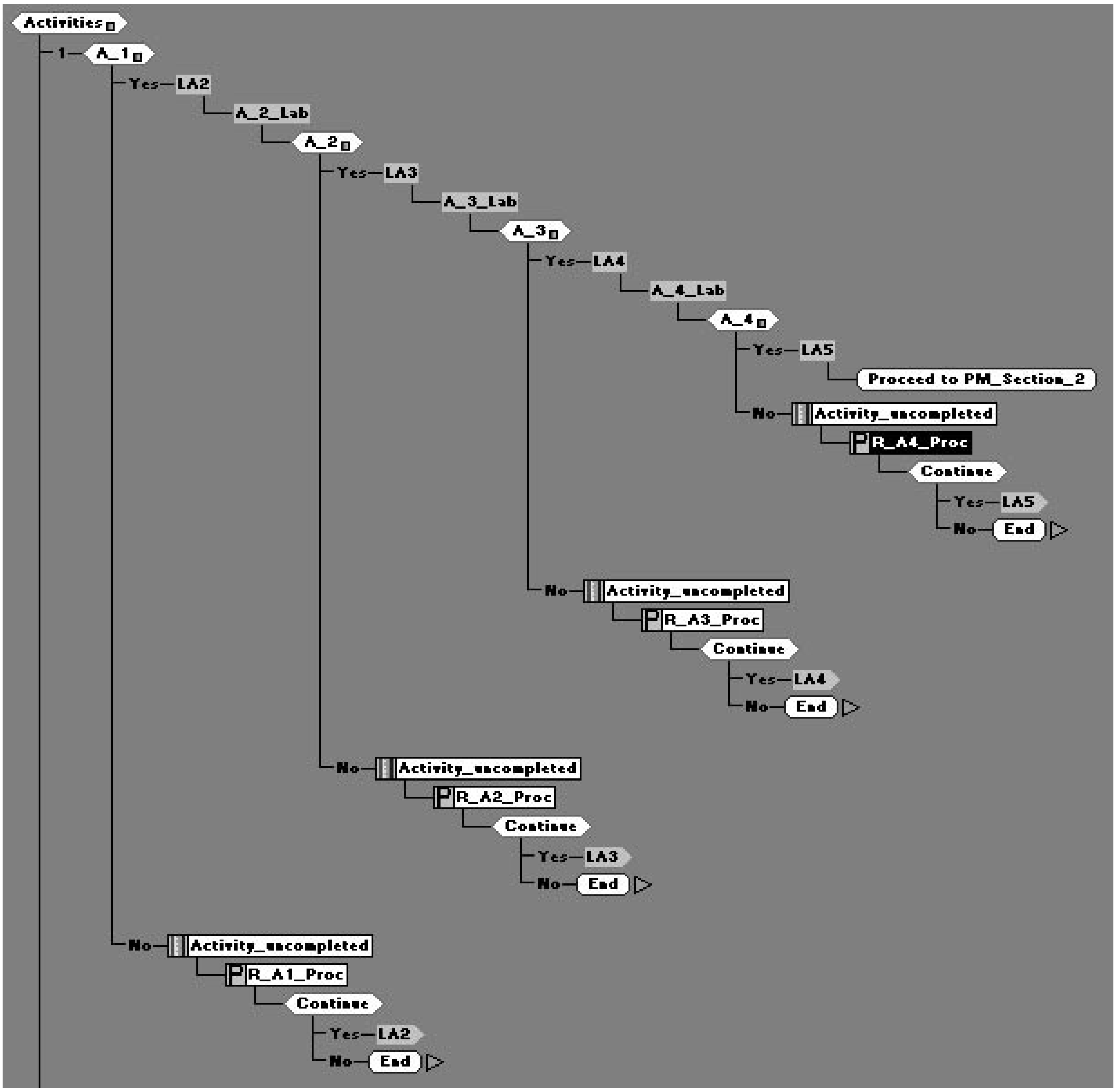


Figure 6.10 • **Operation of CONBPS**

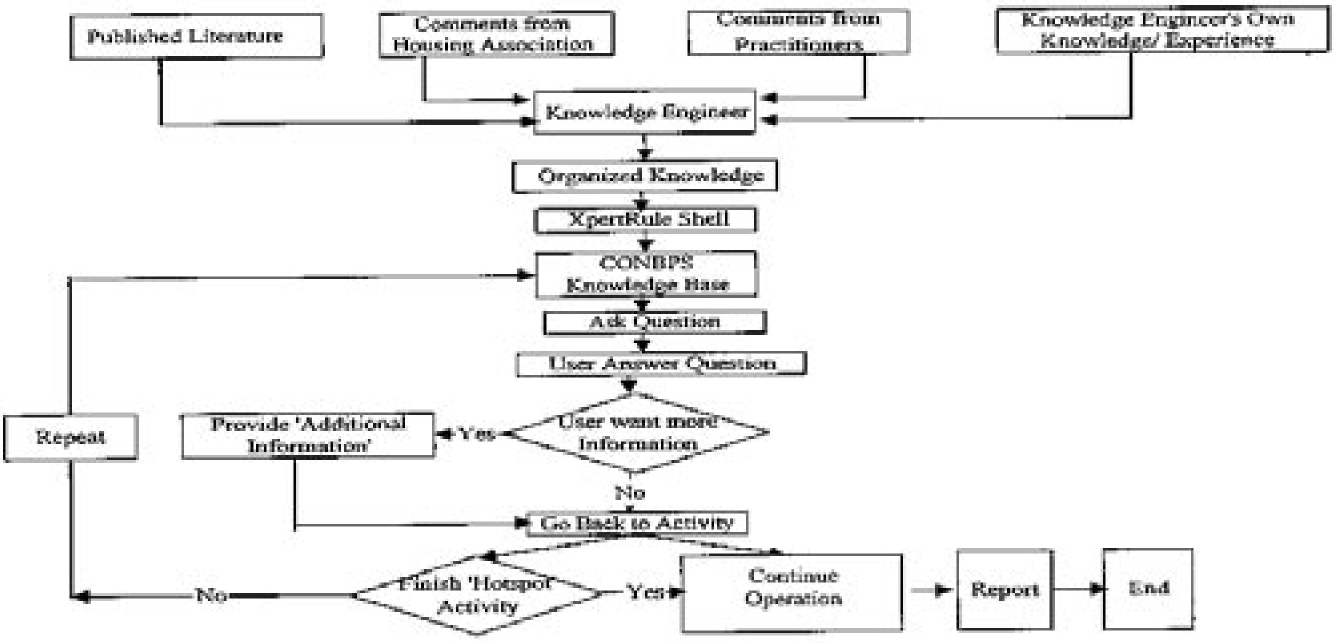


Figure 6.11 • **The introductory screen of CONBPS _A**

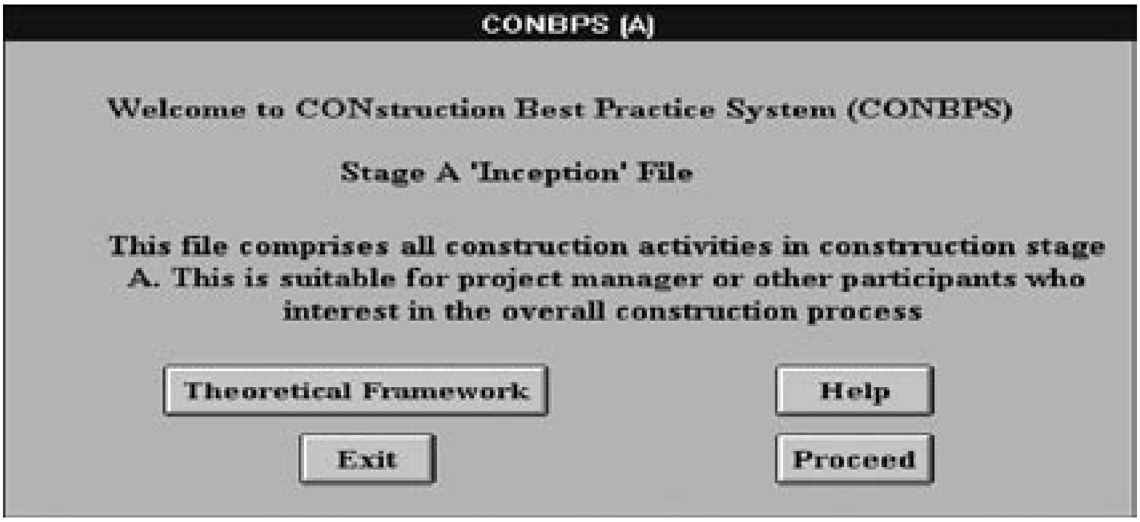


Figure 6.12 • **The screen which asks for the 'Project Number'**

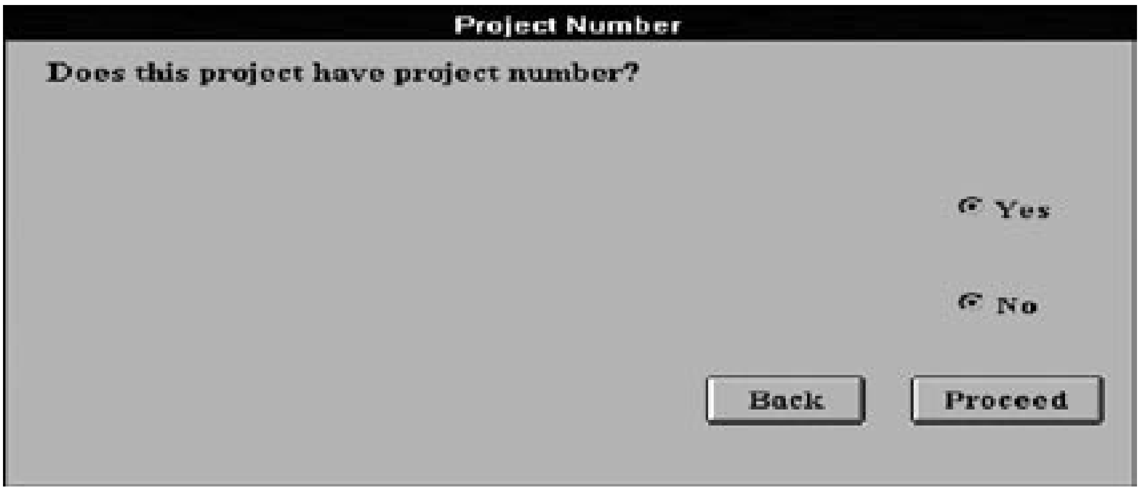


Figure 6.13 • **The screen which asks the user to enter 'Project Number'**

Figure 6.14 • **Activity 2 of CONBPS_A 'Inception'**

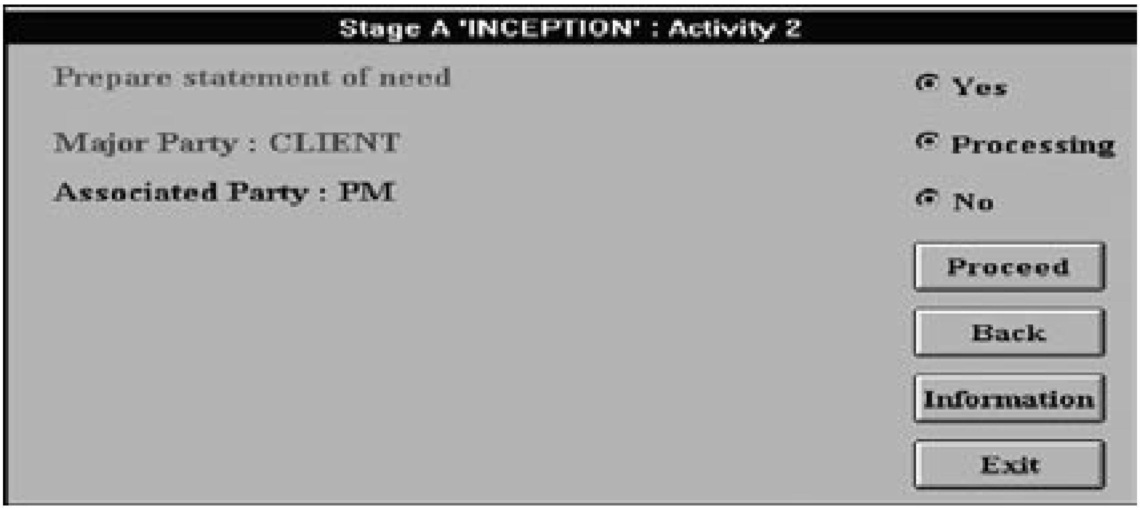


Figure 6.15 • **Activity uncompleted**

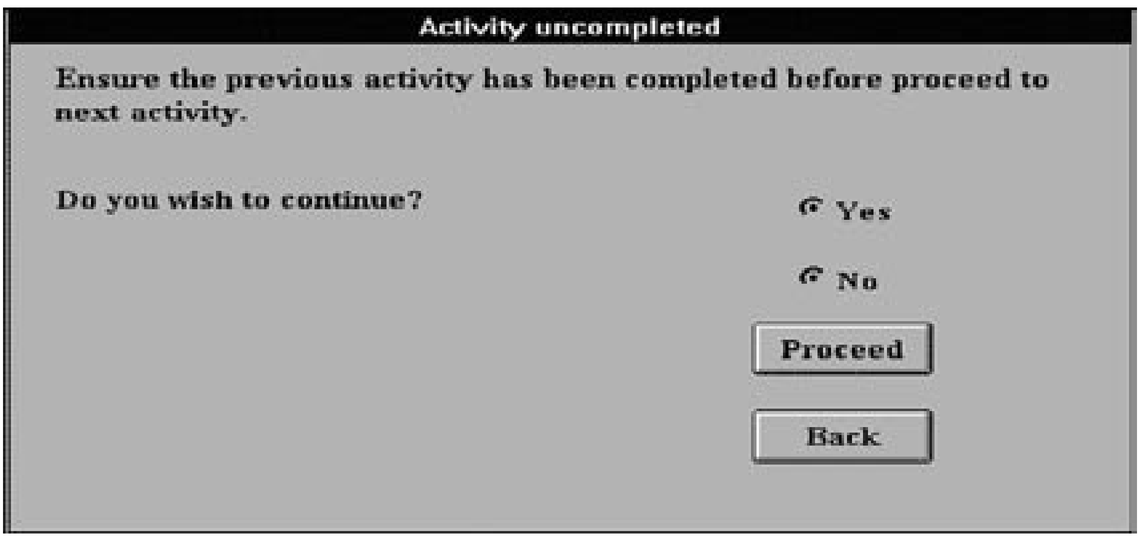


Figure 6.16 • **Additional information 1 of Activity 2 of Stage A 'Inception'**

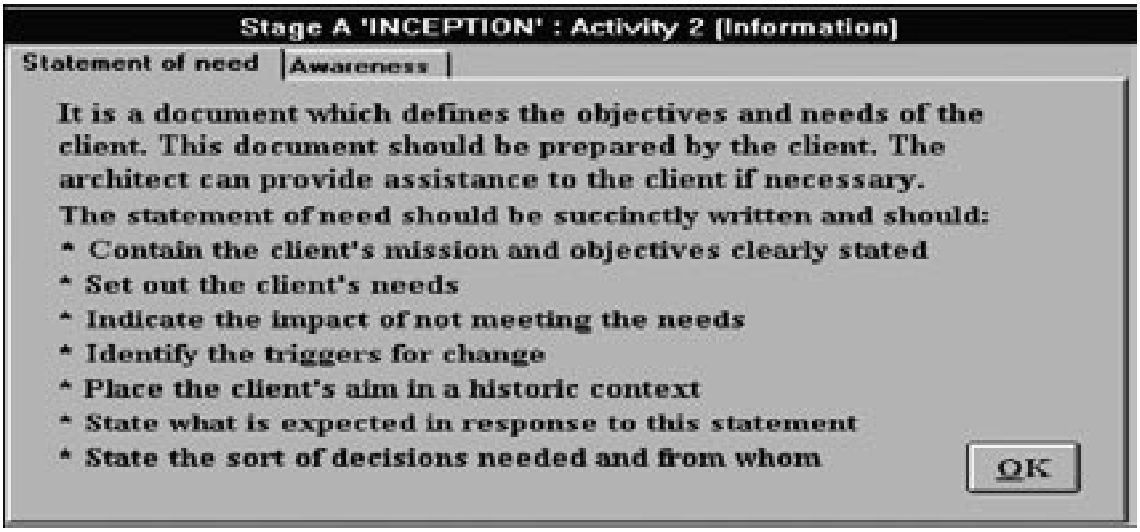


Figure 6.17 • **Additional information 2 of Activity 2 of Stage A 'Inception'**

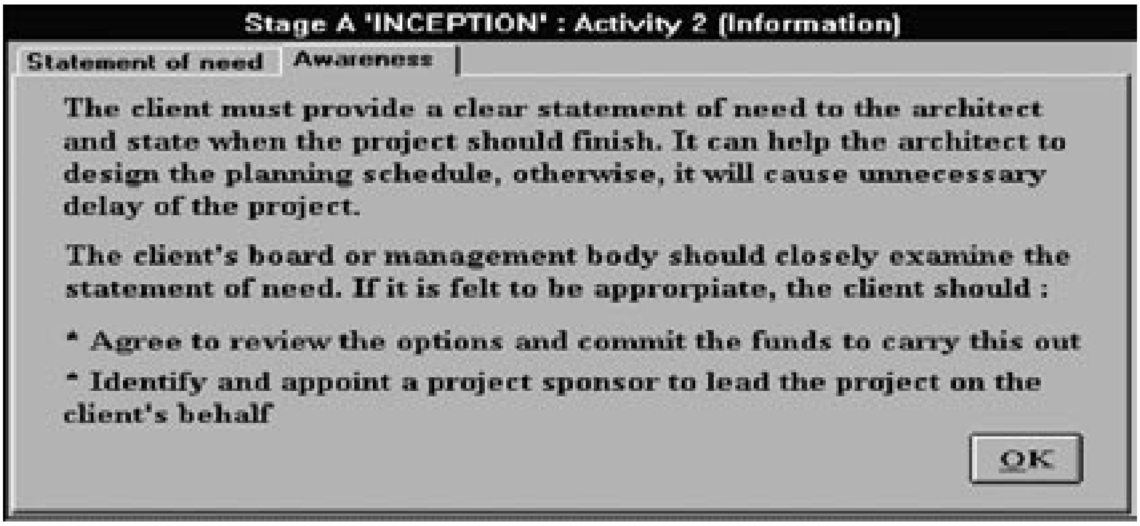


Figure 6.18 • **The screen for choosing to proceed to either activity 23 or 24**

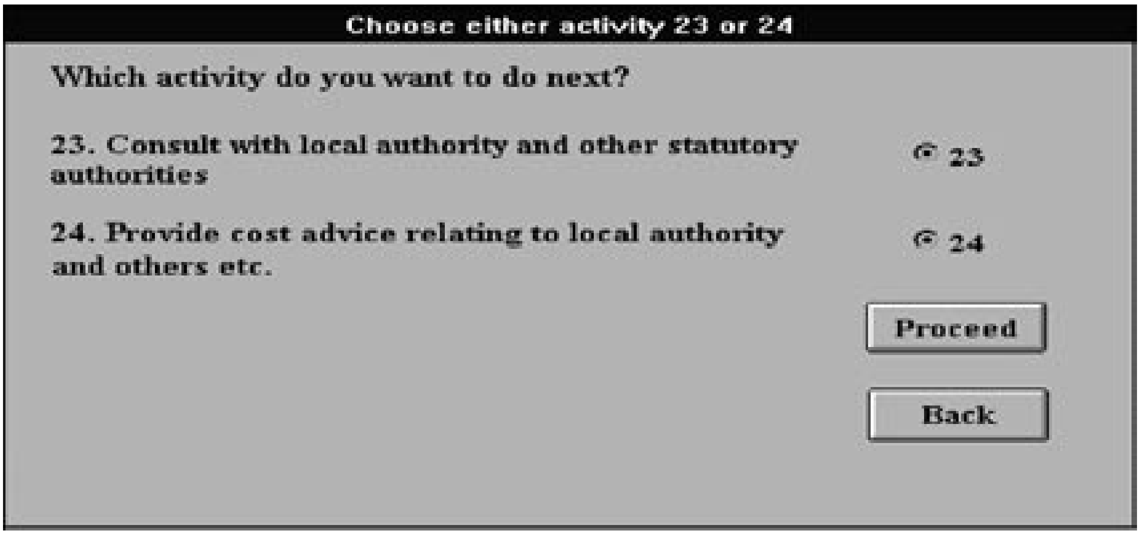


Figure 6.19 • **The screen shows the connection to 'MS Word' and 'On-line help'**

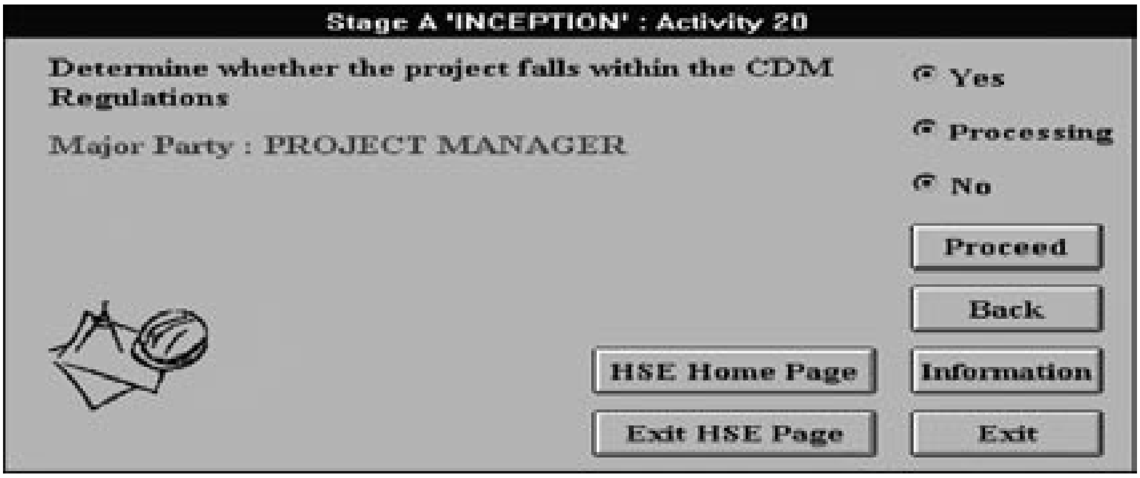


Figure 6.20 • **The 'comment' screen for interim report 1 (version 1)**

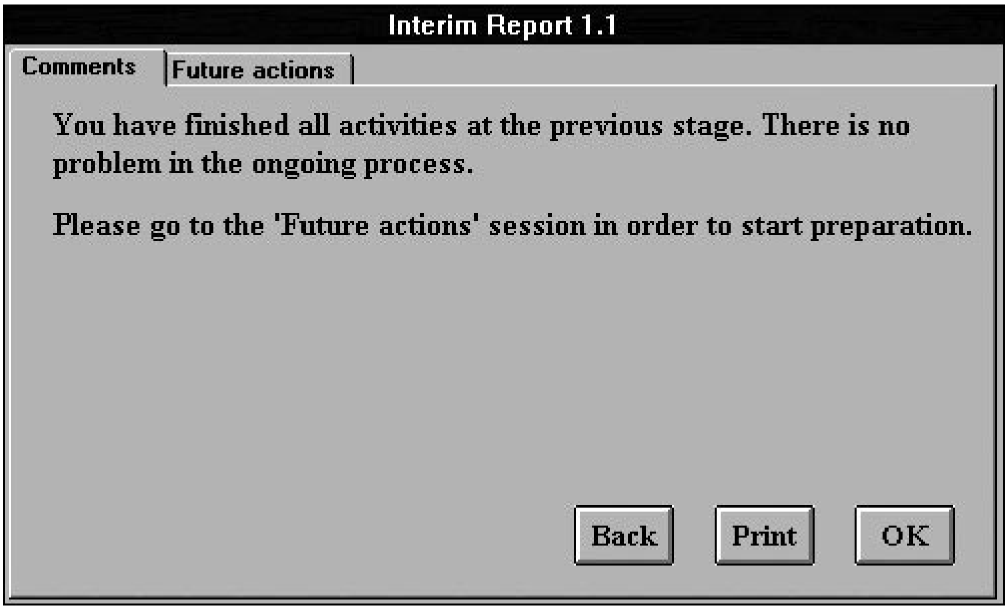


Figure 6.21 • **THe 'future actions' screen for interim report 1**

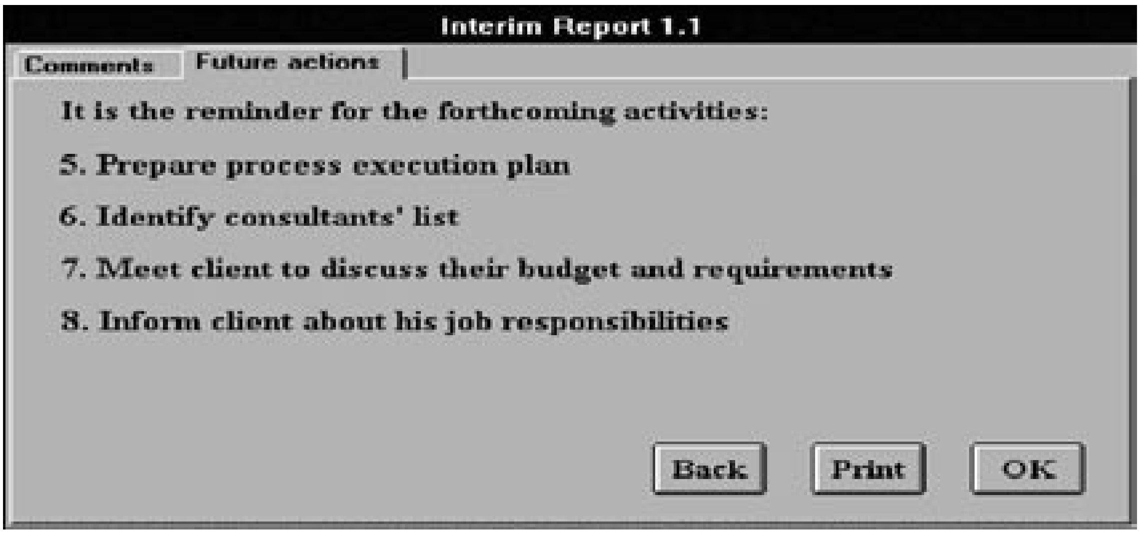


Figure 6.22 • **The 'comment' screen for interim report 1 (version 2)**

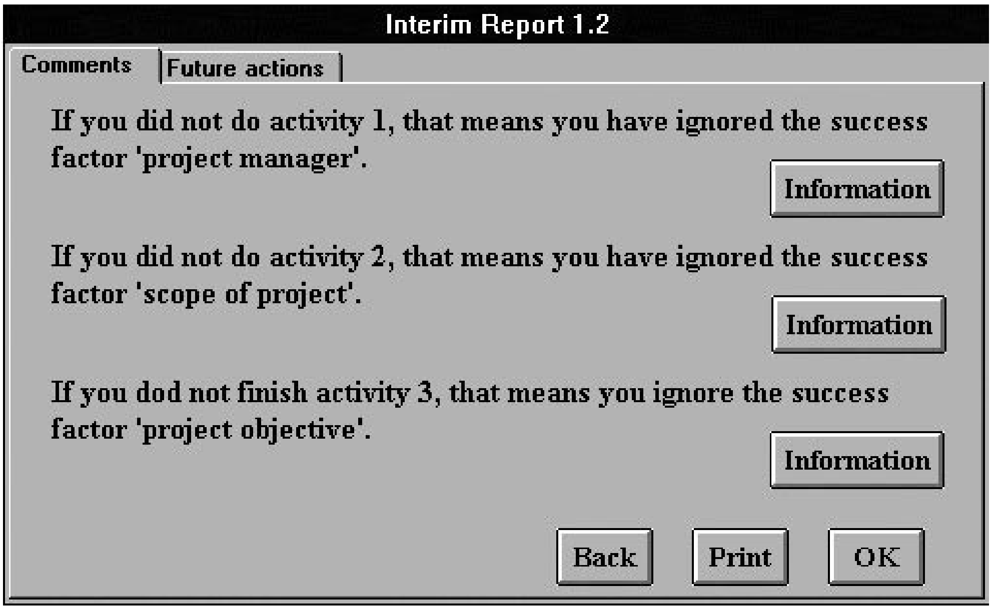


Figure 6.23 • **The screen of information for interim report**

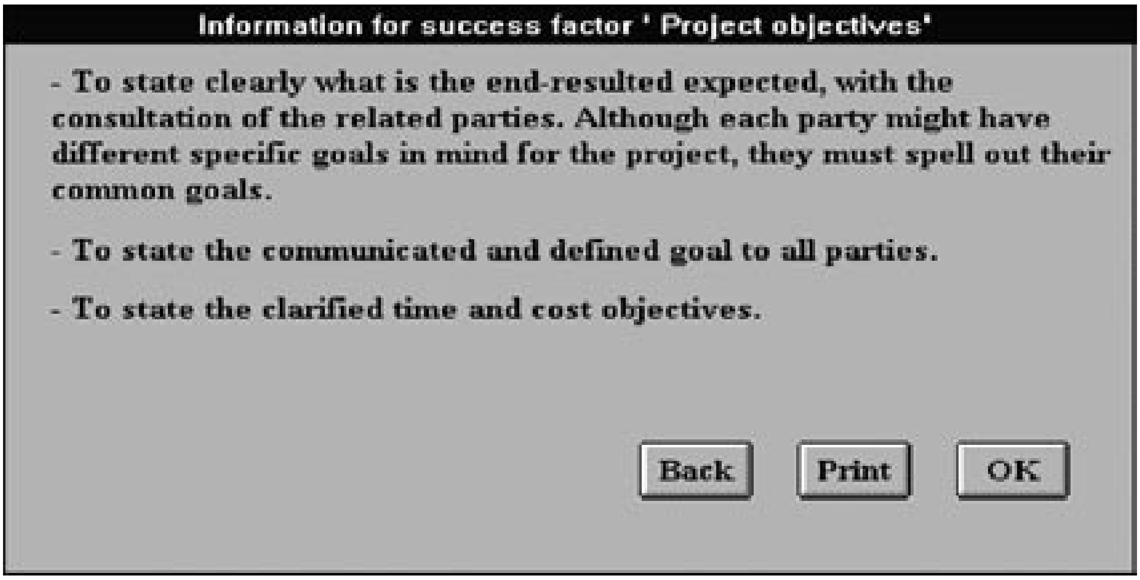


Figure 6.24 • **Report of the system**

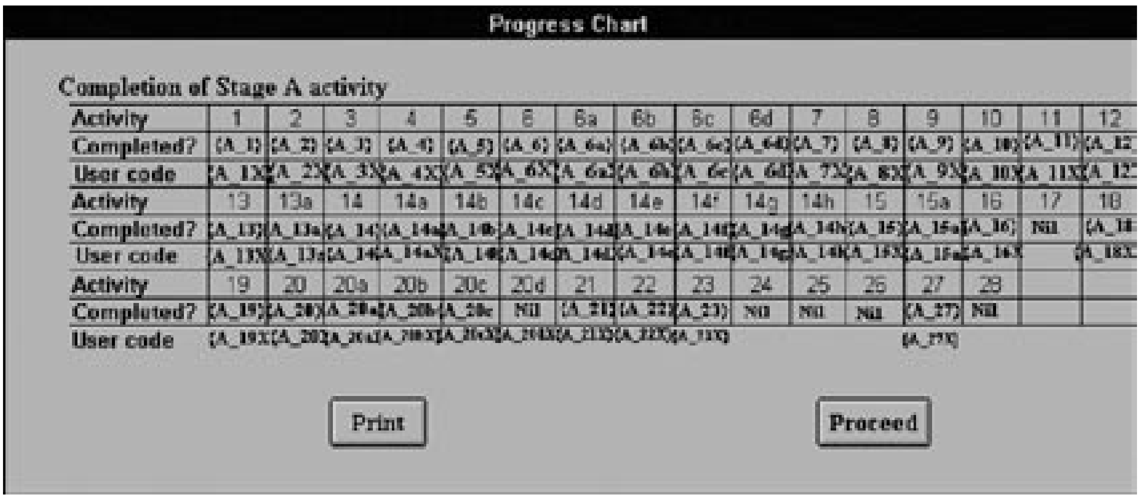


Figure 6.25 • **Report of the system - finish all activity**

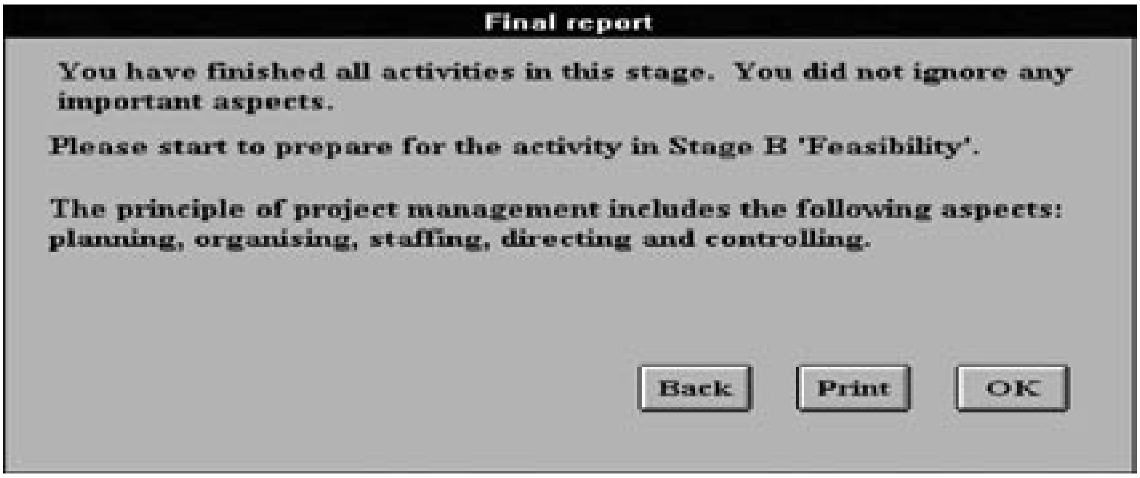


Figure 6.26 • **Report of the system - ignore success factor 'project team'**

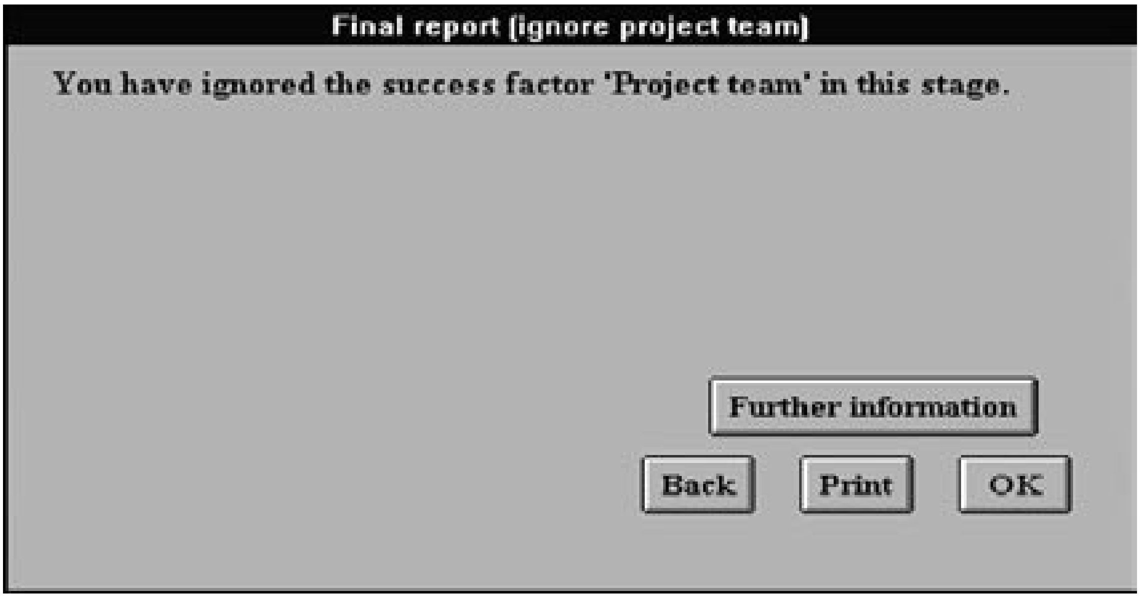


Figure 6.27 • **Report of the system - ignore sucess factor 'project team' repetitively**

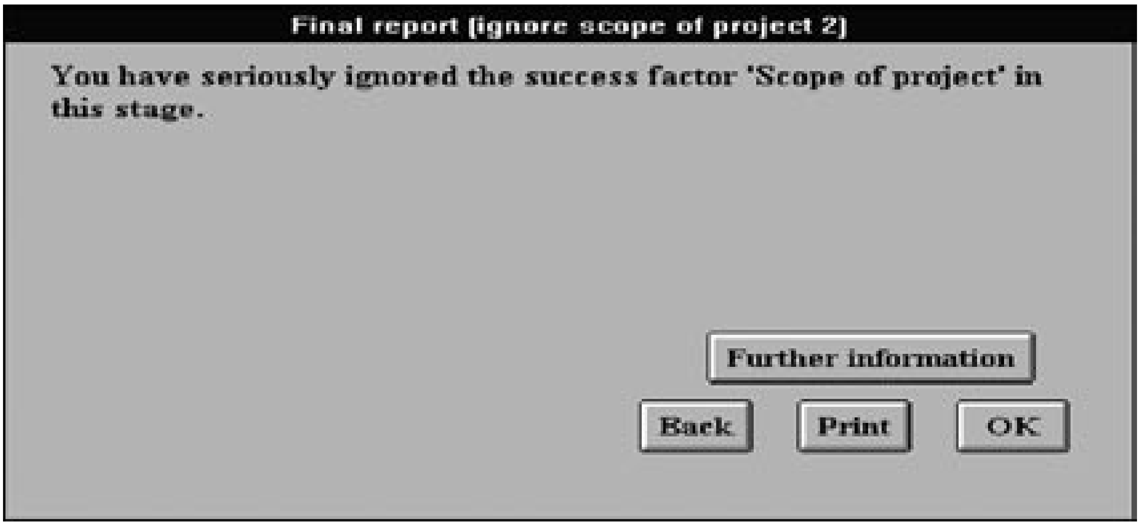


Figure 6.28 • **Report of the system - second level reporting**

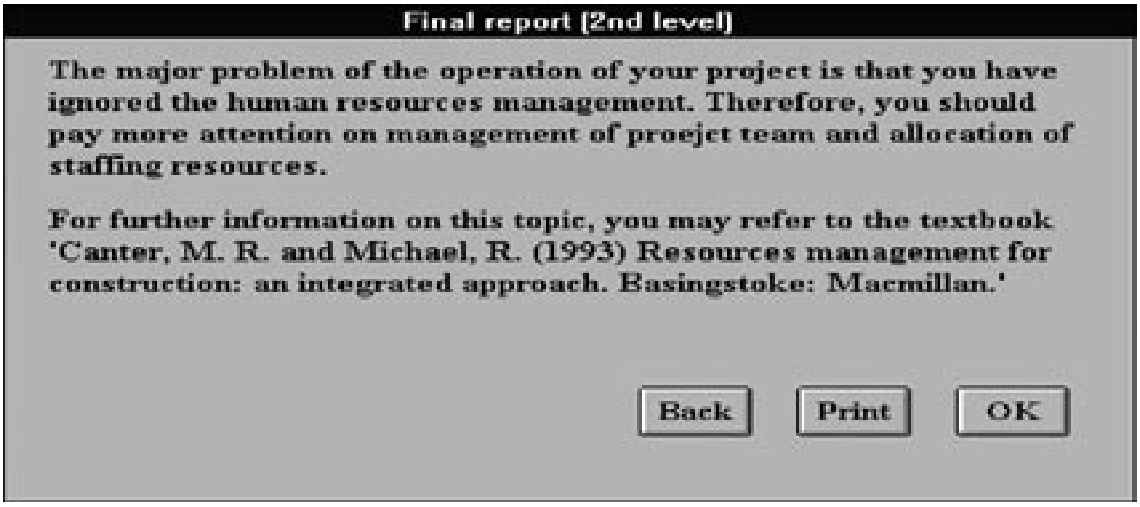


Figure 6.29 • **Selection of construction participant**

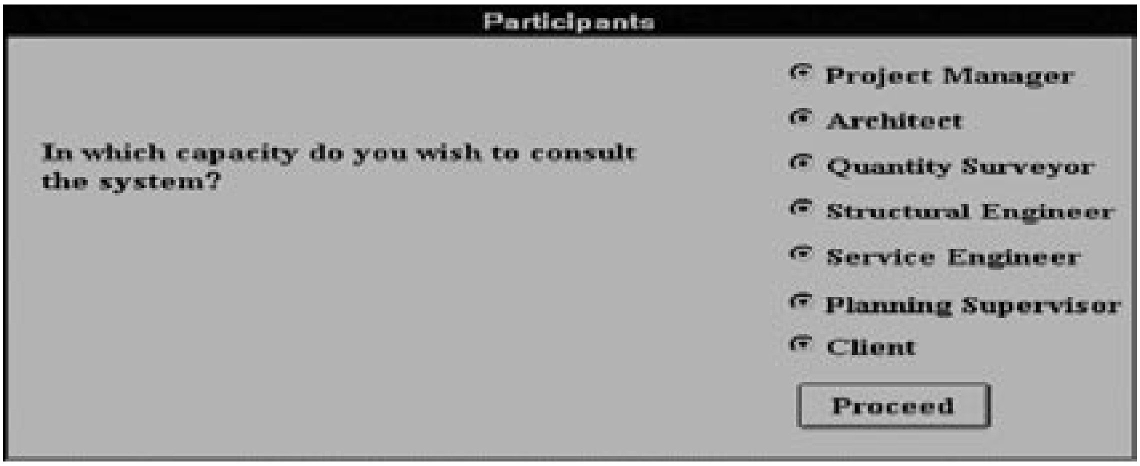


Figure 6.30 • **Selection of construction activities**

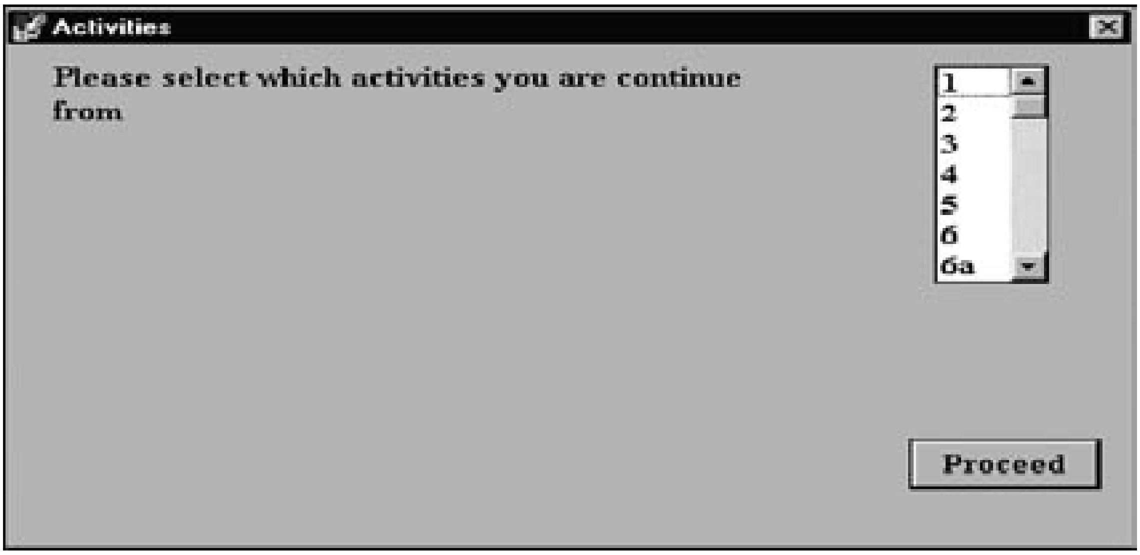


Table 6.1 • **Success factors and the related activities**

Success factor	**Activity**
Project Manager	1. Appoint a project manager
Scope of project	2. Prepare a statement of need 11. Establish the project scope
Project objective	3. Assisting the client in order to identify the objectives
Project team	6. Identify consultants' list
Communication and information management	12. Communicate to the consultants about the requirements of the Client's Brief
Control	14. Set up targets and monitoring procedures for the Project
Health and Safety	20. Determine whether the project falls within the CDM Regulations

Figure 6.8 shows the decision tree for the project manager. As with the decision tree for the others, it also proceeds from one stage to the next until it has been ended.

Figure 6.9 shows the decision tree of section 1 activities for the project manager. As the user should be able to choose any activity, apart from 'yes' or 'no', it should add the 'otherwise' section in order to achieve this purpose.

As the basic operation of A_Main is same as A_All, therefore, it will not be discussed separately in this section.

OPERATION OF CONBPS

CONBPS acts as a totally interactive procedure where users communicate with the system through a user interface. The first five levels (from the knowledge acquisition process to the CONBPS knowledge base) reflect the process of developing the knowledge base.

The lower part of figure 6.10 shows the operation of CONBPS. CONBPS states the construction activity and asks whether the user has finished the task described. If the user wants more information, then it will link to the explanatory facilities and provide more information. If the users do not ask for more information, it will continue to the next activity. If the 'hotspot' activity has been achieved and the user has not finished that activity, the system will loop back and re-start the mini-cycle again.

The detailed description of the system will be further discussed in the following paragraphs.

Before proceeding to the independent process file, it is advisable to run the independent 'Introduction' file at first as it gives a brief overview of these three files. This file will provide the brief description of the system, definition of the terminology which will appear in the system and its basic operation.

After completing the viewing of the explanation in the introduction file, it is being advised to proceed to the 'core' files. The operation of each knowledge-based system will be discussed individually.

As previous mentioned, 'CONBPS_A' is the knowledge-based system which shows the construction process in a sequential order. Figure 6.11 shows the introductory screen of the final version of CONBPS. If the users choose the icon 'Theoretical Framework', it connects to a Word file which shows the 'Theoretical Framework' of CONBPS. If the users choose the icon 'Help', it links to the 'on-line help' screen of the system.

The next screen asks whether the project has a project number. If it is an old project, it should have a project number (see figure 6.12). The user chooses 'yes' icon, then it will open the file which saved the previous record. For example, if the previous operation stopped at activity 4, then the system will start at activity 5 if it is opened again. The answer of the previous operation was saved in the report. The function of the report will be further discussed at the later section.

Otherwise, the system will ask the user to provide a project number for the current operation (see figure 6.13).

After asking for the background information for the project, the system will start to state the activities. Figure 6.14 shows activity two of stage A.

In order to help the user, the current stage and the current activity has been clearly stated in each screen. The major party and the associated party are mentioned. As this activity is the 'hotspot' activity, the whole sentence is pink. The 'hotspots' are the 'critical activities', to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage.

If the user chooses ‘yes’ or ‘processing’, the system will continue and go to the next activity. If the user chooses ‘no’, the ‘Activity Uncompleted’ screen will appear (see figure 6.15).

If the user chooses ‘continue’ in the activity uncompleted screen, the project will continue to the next activity. On the other hand, if the user chooses ‘not continue’, the operation of the system will be finished and it will go to the ‘report’ screen (see figure 6.24).

Additionally, there is also the explanatory facility which has been built into the system. Other than ‘yes’ or ‘no’, the user can choose the icon ‘information’ (see figure 6.16). This icon provides an explanation of the terminology and additional information about the project.

There are two pages in the ‘Additional Information’ screen. Apart from information, the page of awareness is also included, as this activity is the ‘hotspot’ activity (see figure 6.17).

If the user chooses ‘exit’, the system will go to the report (see figure 6.24). It will show the record of the answer for the activities.

This is the basic operation of updated CONBPS; however there are some exceptions on certain activities.

For example, the answer for the question 6d: ‘Has the client discussed with consultants about the terms of appointment?’ is ‘No’, that means there is no agreement on the terms of appointment of consultants. The advised procedure is to discuss the terms of appointment with the selected consultants again. Therefore, the expert system will suggest that the user goes back to the relevant activity, i.e. activity 6a.

Another example is activities 23 and 24. These two activities are operated at the same time, and the system will ask which activity they are interested in (see figure 6.18). If the user chooses activity 23, then it will go to activity 23. Otherwise, it will go to activity 24.

As mentioned in section 6.1, the system will provide interim reports and final reports. The relationship between the activities and the reports is dynamic. Based on the answer of the users to the system, CONBPS provides different interim and final reports.

Figure 6.19 is the sampling screen which shows the function of connecting to ‘Internet Explorer’. This activity is related to CDM Regulation and it connects to the Health and Safety Executive (HSE) Home Page in order to facilitate the user to retrieve the updated information on health and safety. The user can connect to the HSE website by simply pressing the related icon.

An interim report will be shown after finishing every four activities.

Figures 6.20 and 6.21 are the screens for interim report 1, which relates to activities 1 to 4. It consists of two screens, and the first screen shown will be based on the answer for the activities. Figure 6.20 is the screen which will be shown if the user has finished all activities. Figure 6.21 is the reminder for the future actions. It lists what are the activities that need to be done in the coming future.

Figure 6.22 will be shown if the user does not finish some activities in section 1. It will list which success factor is related if they do not finish a certain activity. The ‘information’ icon links to the screen on further information. Figure 6.23 is the screen on further information of the factor ‘project objectives’.

Figure 6.23 shows the detailed information for the success factor ‘project objectives’. The process for identifying success factors for construction process has been discussed in Poon et. al. (2001b).

The relationship between the factors and the activities is shown in table 6.1. The reason for choosing these factors is because their relationship to the activities is straightforward.

After finishing the operation of the process, the system will provide the report to the user at the end (see figure 6.24). The row ‘activity’ lists the number of each activity and the row ‘completed?’ reports the answers to each activity, that is ‘yes’, ‘processing’ or ‘no’. The row ‘Completed?’ reports the status of answer. The ‘User code’ row shows who is the responsible party.

If this is the first time for operating the system, the activities which are unanswered will be left blank. If this is a second time for operation, the activities which are still unanswered will be filled as ‘Ukn’ as the system requires some default value for the unanswered question, therefore, it will show ‘Ukn’ to classify that it is an unanswered activity.

Apart from simply reporting the answers of the user, the report section will also identify if the user has ignored key issues in their response. Figures 6.25 to 6.27 show the first level reports of the system.

Figure 6.25 will appear when the user has finished all activities. Figure 6.26 will be shown if the user does not finish the activities which are related to success factor ‘project team’ where as figure 6.27 will be shown if the user ignores the activities that relate to one success factor repetitively.

There is also the second level reporting screen of the system. Figure 6.28 shows the second level report of the success factor ‘scope of project’. It gives further information of the consequence of ignoring that success factor. Besides, it will provide the source of further reading on the related topic.

In this content, the operation of the knowledge-based system ‘A_All’ will be discussed in the following sections.

As in ‘CONBPS_A’, there is the introductory screen at the beginning. Besides, it also asks the project number of the project. Afterwards, the system will ask which participant they would like to search and the system will only show the activities in which the selected participants are involved (see figure 6.29).

After the user selects the construction participant, the screen shows the list of activities for that particular participant. The user can choose any particular activity that he would like to start (see figure 6.30).

After this, the system connects to the activity session. It only shows the activities which the particular participants need to participate in. Similar to CONBPS_A, it will provide an interim report after finishing every four construction activities.

After finishing the activity session, it will also link to show the report. As the involvement of the participants on different activities varies, therefore, each participant will have their individual report. The activities that they are not involved in containing ‘Nil’ in the answer section. Apart from the ‘tabling’ report, it will also provide the text report.

The third file of this system is A_Main. The operation of this system is the same as A_All. The only difference is that the A_Main file shows the major activities of the responsible party while the A_All file shows all the activities which are the responsibility of the particular party.

7

Discussion of the contribution of CONBPS

CONBPS has clearly identified the roles and responsibilities of the major parties of the building team and identified the issues within the project cycle which can prove critical to project success. The use of CONBPS is beneficial in both practical and academic terms. Besides, it also represents a modest contribution to the improvement of the construction process.

From a practical point of view, various construction participants can use this model. Firstly, the project manager can consult the system to check the sequence of work and the responsible parties for each activity. Before finishing one activity, they will know what they should do and who is the responsible party for the next activity; therefore they can better plan the project cycle before execution.

For the construction parties, they can consult the system to check when they need to participate and what should they do. They can also check who is the respondent for the previous activity and the next activity, so they can communicate with them if necessary. Moreover, there is 'Additional Information' for each activity. The responsible party can refer to the information if they have some queries on the construction process.

For the arbitrators or the person who need to sort out the claims issues in the construction projects, they can consult the system on an ad hoc basis. They can use this system to counter-check whether the project has followed the advised construction procedure.

From an academic point of view, CONBPS can be used as an aid of teaching for the subjects such as construction management and project planning. As CONBPS identifies the construction activities in a sequence, providing additional information for each activity, the learners or students on construction-related courses can become familiar with the whole construction process by studying a single model. Also, they can understand the role and responsibilities of individual participants by viewing the same model. Furthermore, the presentation of this by an expert system provides a user-friendly interface to the user.

Apart from these, certain functions will benefit all individual types of participants. First, is the identification of the criteria for each activity. The user will know what is the impact on time, cost, quality or safety if they don't finish that particular activity. Besides, the system will provide the reminder list indicating what activities should be completed in the short term. Therefore, both the project manager and the related parties can do some preparation for these activities. Furthermore, the system will also give an interim report throughout the construction process and a final report at the end of each construction stage. The users can learn from experience so as to improve on future projects. The system can therefore be used to improve the efficiency of the design and construction process.

CONBPS has been evaluated on a real construction project, which was designed and managed by the Wolverhampton Borough Council - a Technology Block for a school. Each participant, including the architect, quantity surveyor, planning supervisor, client, structural engineer, mechanical and services engineer, on the case-study project has run the CONBPS separately. They provided the answers to each activity mentioned in the system based on the experience that they obtained from the case-study project. Afterwards, they were asked whether they performed all the activities that were mentioned in the system and followed on the same sequence as advised by the system. Moreover, they also commented on the usefulness of the explanatory facilities, interim reports and final report in order that they could improve their practice. Besides, the participants were also requested to comment on the design of system interface.

On the case study, the participants executed all the activities that were mentioned in the system and in the same sequence as advised. Besides, they generally appreciated that it is a user-friendly computer system. They commented that it is a good checklist and records all the construction activities in great detail. They also found that the 'explanatory facilities' and the 'interim report' provided some useful advice throughout the project process. Furthermore, they recognized the value of the final report in identifying the key lessons learnt from the finished project.

The research has led to certain advances in construction process modelling through several distinct ways.

Firstly, it converts artificial intelligence tools capable of transforming ill-defined and piece-meal information of construction activities and its related information associated with them, into an operational expert system.

The second important advance of this study is through the synthesis of construction activities and their responsible participants that enable the project manager to manage the project. The sequence of construction activities represented in this system is not committed to a single project or case, as they are considered conceptual in nature. Therefore, it can be applied to the great majority of construction projects. In this way, the synthesised concepts of the construction process model with identified participants can be used as the guidelines for starting new building projects.

The third advance produced by this research is the integration of the construction process model and the artificial intelligence environment. The advantage of such integration will be especially important for educating and training inexperienced construction participants.

The fourth advance of this study is the attachment of 'knowledge management' to construction process model. Knowledge management is a newly raised topic in recent years. The aim of knowledge management is to learn from the previous experience of the product development process in order to improve the quality and the production process of product. The success factors for construction process have been generated based on literature review and these factors have been 'linked' to the relevant activities. Therefore, it has set up the 'warning' system for the user to alert what success factors they have ignored or if they did not finish a certain activity. The use of this tactic reminds the user what factors have been ignored if they have not done certain activities.

Finally, the fifth advance exemplified by this study is of an application nature. The prototype system developed in a PC computer using the 'XpertRule' shell endorses the proposition that artificial intelligence technology offers techniques, which facilitates the representation and manipulation of the construction process model. The concept of knowledge representation and elicitation methods provided by this prototype system will be of value during the future development of a commercially viable knowledge based system in construction process modelling.

8 Conclusion

This paper has set out the development of CONstruction Best Practice System (CONBPS). It is an expert system, which lists the sequence of the construction activities and the responsibilities of the parties.

The system should provide the above information via interim reports. Additionally at the end of the project the system should provide a report explaining which tasks have been skipped and the possible consequences.

Expert system tools have great potential in solving ill-structured problems commonly encountered in construction. CONBPS is capable of transforming ill defined and piece-meal knowledge about construction activity and other related information into an operational prototype system. The advice provided is not committed to a single project or case, but is considered at conceptual level. Therefore, it can be applied to a wide variety of construction projects. The costs of consultation with experts can also be limited with such an expert system and time could be saved in waiting for the expert to arrive on site. Additionally, although textbooks can provide an important and valuable source of information, having on-line advice from a real expert is more practical and user-friendly.

The benefits of the system can be divided into two sections: the design of the system and the presentation of the system.

CONBPS has converted the information from the RIBA Plan of Work and the modern construction literature into the sequence of activities. Apart from listing the sequence of activities, the responsible participants and parties have also been identified. Moreover, the success criteria of each activity is stated. The advantage of this arrangement is that the user knows when they should participate, what they should do and what the impact will be if they don't finish their activity. It pinpoints the reason for inefficient construction. Besides, the system provides 'Additional Information' for the activity and can therefore help inexperienced construction participants when they are managing the construction project.

Apart from the design, the presentation of the system also has several advantages. The method of presentation of this model is via an expert system. An expert system attempts to model the intelligent reasoning and the problem-solving capability of the domain experts. It is capable of transferring expert knowledge about the construction process to less experienced personnel. This appears to be a useful area associated with expert system development because the continued evolution of portable computers will allow professionals to use these programs in the field. Besides, it is an interactive program, which contains expert knowledge. It can also be used on the construction site which has the potential to improve the quality of construction.

The software for developing CONBPS also has its advantages. XpertRule was used as the software for developing this system. It is a decision tree based environment. This environment is good for prototype development as the whole structure is shown in a 'map' and it can be viewed easily. It is very easy for practitioners to view the whole structure of the system, therefore, it is more convenient for them to make comments as they can view the structure easily.

For the construction process, the primarily benefit of this system is the dissemination to the participants or inexperienced professionals of advice on the sequence of construction process, factors for construction process, guidance on what they should do in the short-term and additional information etc. Therefore, it assists in enabling quicker recognition of these issues and earlier preparation.

On the economic front, CONBPS also has its advantage. The system can run on comparatively low cost hardware (PCs) and will stand alone, which will make the technology particularly useful to small companies. Besides, as the interface of the system is simple and user-friendly, the user will not need to be a computing expert.

In summary, the benefits of CONBPS include
1. 'Focus' and the 'detail' – It focusses on a particular procurement strategy, it lists the construction activities in detail and identifies the relevant parties. Additionally, it also provides information on the activities.
2. Practicability – It uses the well-known RIBA Plan of work as the framework, so the operations are easier to follow. The design of the interface is user-friendly.

FUTURE RESEARCH

The development of a knowledge-based system is an exploratory and evolutionary process. It is obvious that the quality and the completeness of a knowledge base will determine the validity and accuracy of a viable operational knowledge based system. With this in mind, the outcome of this research can only provide a starting point for future system development. The following are proposed as possible areas for further research.

The development of CONBPS focusses on the conceptual design stage at the preliminary version and completed CONBPS focusses on inception stage only. This research can be extended to the tender and construction stages. Moreover, it focusses on new building projects which use the traditional procurement strategy. This research idea can be expanded to other procurement strategies and other types of construction works.

The second aspect is to put CONBPS into an 'accessible' location for the users, for example, on the web, which will enable users to access the system at the same time. Also, it is more convenient for them to access the most updated information.

The third aspect that should be considered in the future research is to incorporate the comprehensive list of success factors in the construction process model. This paper has incorporate several factors from a comprehensive list of success factors for construction process (Poon et. al., 2001a). The suggested way for linking all the factors to the construction activities is to do a comprehensive questionnaire survey. The list of the success factors and the list of activities are sent out to all the identified participants with a request to match the factors and the activities. Afterwards, some analysis is needed in order to identify the pattern of matching between the factors and activities.

The fourth aspect of future research is to improve the system so as to be able to let it add the parties and activities. In order to achieve this purpose, it is necessary to partially re-write the current system in traditional programming language, like Visual Basic. This is because there is an established linkage between XpertRule and Visual Basic, therefore, it is easier to establish the connection between these two programming languages.

The final aspect of future research is to provide the related recommendation to the invalid answer at the interim report. For example, if the user provided an invalid answer for activity one, it should provide the recommendation for activity one only instead of providing recommendation for all activities in section one. As with the fourth area of future research, this function can be easily added to a traditional programming language. The advised method for achieving this purpose is to rewrite the interim report section by another programming language. Again, the advised programming language is 'Visual Basic'.

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