NOTTINGHAM TRENT UNIVERSITY

EXPLORATORY STUDY INTO THE USE OF LAST PLANNER® SYSTEM AND COLLABORATIVE PLANNING FOR CONSTRUCTION PROCESS IMPROVEMENT

EMMANUEL ITODO DANIEL

A thesis submitted in partial fulfilment of the requirements of Nottingham Trent University for the degree of Doctor of Philosophy

May 2017

Copyright Statement

Declaration

I hereby, declare that this dissertation has not been submitted in part or in whole as paperwork for a degree at any other university. I hereby declare that this dissertation is entirely my own work and that all parts and thoughts which have been taken from other persons are marked and identified by reference.

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Abstract

The Egan report, generally called *Rethinking Construction*, challenged the lack of collaboration in planning, designing, and executing work on site, and recommended the adoption of lean production principles such as the Last Planner System (LPS) to enhance the image and efficiency of the industry. Recent evidence from different parts of the world suggests that the implementation of the LPS has gained prominence in the construction industry and its influence on the production system is rapid and significant. However, the application of this system in the UK construction industry has not been fully explored among industry practitioners. In addition, a systematic understanding of how Collaborative Planning (CP) practice in the UK aligns with the LPS is still lacking. The absence of authoritative research and empirical data makes it difficult for an appropriate approach to be developed to improve current practice.

In view of these problems, this research was under taken to unravel how the current application of CP for delivering construction projects in the UK align with the LPS principles and to develop an approach to support construction stakeholders in the implementation of the LPS. Both qualitative and quantitative methods were used in this investigation. Data were collected from across these sectors (building, highways infrastructure, and rail) of the UK construction industry. A total of 58 interviews were conducted, 15 projects observed, 3 case studies conducted and 10 evaluation surveys received. The study found that the current practice of CP as observed in the major sectors of the UK construction industry only align partially with some of the generally advocated principles of the LPS acknowledged in the literature. Analysis of the results reveals that the current practice of CP in the UK has not explored all components of the LPS and depth of application of the more complex attributes contained in the LPS is weak or missing.

The information gleaned from the finding uncovers and highlights the need to develop an approach to support construction stakeholders in the implementation of the LPS. Accordingly, this study developed the *Last Planner System Path Clearing Approach* (LPS-PCA) that includes organisational and external path clearing levels. This expands previous approaches to the implementation of the LPS in construction which focused more on the project level. Pilot implementation on a live project indicates that the developed LPS-PCA supports LPS implementation.

Dedication

This thesis is dedicated to my loving wife Dr. Oluwabukola Daniel for all her immeasurable support and to my daughter Covenant Daniel for the joy she has brought into our family.

"Let us hear the conclusion of the whole matter: Fear God, and keep his commandments: for this is the whole duty of man"

The Bible: Ecclesiastes 12:13

Acknowledgement

Glory to God in the highest heavens, for all his marvellous works! My utmost appreciation is to the almighty God for His guidance, wisdom, provision, and sustaining grace throughout my PhD Journey at Nottingham Trent University.

The effort of my Director of Studies; Professor Christine Pasquire cannot be overemphasised as without her, my research would not have started at NTU. Her motherly advice and supports during the course of my studies helped in making my PhD journey a lot smoother than envisaged. The guidance and mentorship received from her have greatly enhanced my knowledge on lean construction and the final output of this thesis. I equally like to thank my supervisor Dr. Graham Dickens for his critical but constructive review of all aspects of my work which has helped in the final output of this thesis. I cannot but mention your arranging visits and conveying me to numerous construction sites during the data collection period.

My appreciation goes to all lean construction professionals interviewed in this study and all those that contributed towards the success of the case studies such as Darren Raunen, Rob Sangster, Kate Seller; Martin Wing, and John Studd. I also acknowledge the contributions of the Lean Construction Institute UK and its Board of Directors chaired by Derek Drysdale, for providing travel allowance for my data collection. The advice and guidance received from lean construction community has helped in shaping this study, notable is that from Prof. Glenn Ballard, Prof. Lauri Koskela, and Alan Mossman among others. Thank you to all my friends and PhD colleagues at the Centre for Lean Project- you are kind. The support of friends such Olalekan Oshodi, and Agabi Yusuf is heart-warming. The spiritual support and encouragement from the members and leadership of Deeper Life Bible Church Nottingham is highly appreciated.

I would like to thank the entire Daniel Itodo family for their patience while I'm away from them. Especially my Mum; Esther Daniel and my Dad; late Mr Daniel Itodo for believing and instilling the faith in me that I would attain this height. I remember my late sister Hannah who was taken away by death during the course of this research. The support of my in-laws and their family cannot be forgotten; the Okes', the Idowus' and the Akintans' – you are awesome. Thank you to Mummy Oke for your prayers.

To my loving wife Dr. Oluwabukola Daniel; I lack words to express my appreciation; I value all your contributions to the success of this journey especially in reading through every piece of my writing. Also, for the emotional support you and my gorgeous daughter Covenant have provided. We did this together! - Thank you.

Table of Content

Copyright Statement	i
Declaration	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Content	v
List of Figures	xv
List of Tables	xvii
List of Abbreviations	xix
CHAPTER ONE: INTRODUCTION TO THE STUDY	1
1.1 Study Context	1
1.2 The Research Problem	3
1.3 Rationale and Justification of the Study	5
1.4 Research Questions	7
1.5 Research Aim	7
1.6 Research Objective	7
1.7 Scope of the Study	8
1.8 Overview of Work Done	8
1.8.1 Overview of Research Methodology.	8
1.8.2 Overview of Research Process	9
1.8.3 Overview of Research Contribution to Knowledge	11
1.8.4 Thesis Structure	11
1.9 Chapter Summary	14
CHAPTER 2: CONSTRUCTION PROCESS IMPROVEMENT AND THE DEVELOPMENT OF PRODUCTION PLANNING AND CONTROL BASED ON THE LAST PLANNER SYSTEM IN THE UK CONSTRUCTION INDUSTRY	15
2.1 Introduction	15
2.2 Process Improvement in the Construction Industry	15
2.2.1 The UK Construction Industry	15
2.2.2 The Concept of Construction Process Improvement	16
2.2.3 Current State of Construction Process Improvement in the Industry	18
2.2.5 Demand for Construction Process Improvement in the UK	18
2.2.6 Review of Construction Industry Reports	19
2.2.6.1 Latham Report: Constructing the Team	20
2.2.6.2 Egan Report: Rethinking Construction	21

2.2.6.3 Accelerating Change 21

2.2.6.4 Never Waste Good Crisis 22

2.2.6.5 Government Construction Strategy 22

2.2.6.6 Construction 2025 Report 23

2.2.6.7 Summaries and Major Outcomes of the Construction Industry Reports 23

2.3 Development of the Last Planner System in the UK 25

2.4 Emergence of Improvement Programmes in the UK Construction Industry 28

2.4.1 Overview of the Construction Lean Improvement Programme (CLIP) 28

2.4.2 Review of CLIP Pilot Projects 30

2.4.3 CLIP: Collaborative Planning Practice Review Discussed 35

2.5 Chapter Summary 36

CHAPTER THREE: COLLABORATION IN CONSTRUCTION AND THE DEVELOPMENTS OF COLLABORATION IN PLANNING IN OTHER FIELDS: IMPLICATION FOR CONSTRUCTION MANAGEMENT 38

3.1 Introduction 38

3.2 The Concept of Collaboration 38

3.2.1 Current State of Collaborative Working in the Construction Industry 40

3.3 Collaboration and Construction Planning 41

3.3.1 Concept of Planning 41

3.3.2 Overview of Construction Planning 42

3.3.3 The Current State Construction Planning and Collaboration 44

3.4 Development of Collaboration in Planning in other Fields 45

3.4.1 Historical Development of Collaboration in Urban Planning 45

3.4.1.1 The Rational Comprehensive Model of Planning 46

3.4.1.2 Advocacy Planning Model 46

3.4.1.3 Collaborative Planning Model in Urban Planning 47

3.4.2 Critical Path Method and Rational Comprehensive Model in Planning 48

3.5 Collaboration in Planning: Search in Software Design 49

3.5.1 Waterfall Process Model 50

3.5.2 Iterative Process Model. 51

3.5.3 Agile Process Models 51

3.5.3.1 Scrum 52

3.6 Comparing the CPM, RCM, Collaborative Planning and the LPS 53

3.7 Development of Collaboration in Planning in other Fields: Implication for Construction Project Management 56

3.7.1 Implication for Construction Project Management Practice 56

3.7.2 Implication for Construction Project Management Theory 58

3.8 Chapter Summary 60

CHAPTER FOUR: PRODUCTION PLANNING AND CONTROL IN CONSTRUCTION BASED ON THE LAST PLANNER SYSTEM 62

4.1 Introduction 62

4.2 Production Planning and Control 63

4.2.1 Production Planning: The Search in Management Science 63

4.2.2 Production Planning: The Search in Lean Production 63

4.2.3 Application of Lean Production Philosophy in Construction 64

4.2.4 Criticism of Lean Construction 65

4.2.5 Lean Philosophy in Production Planning and Control in Construction 67

4.2.6 Evaluating Production Planning and Control in construction 68

4.3 The Last Planner System of Production Control 69

4.3.1 The Last Planner System: An Overview 69

4.3.2 Components of the Last Planner System 70

4.3.2.1 The Master Plan or Milestone Planning 71

4.3.2.2 Phase Planning or Collaborative Programming 71

4.3.2.3 Look-Ahead Planning 73

4.3.2.4 Make-Ready Process 74

4.3.2.5 Weekly Work Plan (WWP) 75

4.3.2.6 First Run Studies 77

4.4 Theories used in Explaining the Last Planner System 78

4.4.1 Transformation and Flow Theory in the Last Planner System 79

4.4.2 Management-as-Planning and Management-as-Organising Theory in the LPS 80

4.4.3 Language/Action Perspective Theory in the Last Planner System 80

4.4.4 Scientific Experimental Model 81

4.5 Last Planner System Implementation and Developments- Review of IGLC papers 82

4.5.1 Overview of the Review 82

4.5.2 Review Framework 83

4.5.3 Last Planner System Implementation across Countries 86

4.5.4 Major Components of Last Planner System Implemented 87

4.5.5 Trends in the Implementation of LPS Components 88

4.5.6 Last Planner System Implementation Success Factors 88

4.5.7 Last Planner System Implementation Drivers 90

4.5.8 The Impact and Benefits Last Planner System on Construction Process Improvement 90

4.5.9 LPS Implementation Challenges in Construction 91

4.5.10 Past and Current Developments in the Last Planner System 93

4.6 Summary of Chapter 97

CHAPTER FIVE: RESEARCH METHODOLOGY AND DESIGN 99
5.1 Introduction 99
5.2 Understanding Research Methodology and Methods 99
5.3 Research Philosophy 100
5.3.1 Ontology 101
5.3.2 Epistemology 102
5.3.3 The Relationship between Ontology, Epistemology, Methodology, and Research Methods 103
5.4 Research Paradigms 104
5.4.1 Positivism 104
5.4.2 Interpretivism 105
5.4.3 The Chosen Paradigm and the Rationale 106
5.5 Research Strategy 107
5.5.1 Quantitative Approach 107
5.5.2 Qualitative Approach 108
5.6 Research Method Consideration and Choice of Research Method for the Study 110
5.6.1 Ethnography Evaluation 111
5.6.2 Design Science/ Action Research Evaluation 112
5.6.3 Surveys Approach Evaluation 113
5.6.4 Interviews 114
5.6.5 Case Study 116
5.6.6 Rationales for Choosing Mixed Method 118
5.7 Research Design and Phases 120
5.7.1 Stage 1: Literature Review 122
5.7.2 Stage 2: Semi-structured Interviews 124
5.7.2.1 Interview Plan 125
5.7.2.2 Interview Protocol 125
5.7.2.3 Sampling 127
5.7.2.4 Conducting the Interview 129
5.7.2.5 Interview Transcription 131
5.7.2.6 Analysis of Interview 131
5.7.3 Stage 3: Structured Observation 133
5.7.3.1 Observation Schedule 134
5.7.3.2 Observation Checklists 135
5.7.3.3 Structured Observation Sampling 136
5.7.3.4 Data Collection and Analysis of Structured Observation 137
5.7.4 Stage 4: Multiple Case Study 138

5.7.4.1 Case Study Planning 139
5.7.4.2 Case Study Selection 139
5.7.4.3 Data Collection Protocol 141
5.7.4.4 Data Collection 142
5.7.4.5 Data Analysis 145
5.7.4.6 Cross Case Analysis 148
5.7.4.7 Post Case Study Evaluation Survey 149
5.7.5 Phase 5: Development and Validation of Last Planner System Path Clearing Approach 149
5.8 Quality of Research 150
5.8.1 Credibility (Internal validity) 150
5.8.2 Transferability (External validity) 151
5.8.3 Dependability (Reliability) 151
5.8.4 Confirmability (Objectivity) 152
5.9 Summary of Chapter 152
CHAPTER SIX: RESULTS AND DISCUSSIONS ON EXPLORATORY INTERVIEWS AND STRUCTURED OBSERVATIONS 154
6.1 Introduction 154
6.2 Phase 2: Semi-Structured Interviews 154
6.2.1 Analysis, Presentation, and Discussion of Semi-Structured Interviews 154
6.2.2 Demographic Information of Interviewees 155
6.2.3 Current View on Construction Planning and Programming. 158
6.2.3.1 Un-collaboratively developed 159
6.2.3.2 Too much Assumption and Unrealistic 159
6.2.4 Current Industrial Perception of Last Planner System and Collaborative Planning in the UK 160
6.2.4.1 Use of the terms “Collaborative Planning” and “Last Planner System” 160
6.2.4.2 Meaning Ascribed to the Last Planner System and Collaborative Planning 162
6.2.4.3 Time and Programme Compression 164
6.2.4.4 Common Understanding of Construction Programme 164
6.2.4.5 Intervention Measure 164
6.2.5 Current Success Factors for Implementing LPS/CP in the UK 165
6.2.5.1 Early Engagement with the Supply Chain 166
6.2.5.2 Use of Integrated Supply Chain Model 166
6.2.5.3 Inclusion of LPS/CP in the Contract 167
6.2.5.4 Appointment of Lean Champions and Support from Lean Consultants 168
6.2.5.5 Procurement of Supply chain based Collaborative Practice 168
6.2.6 Current Drivers for Implementing LPS/CP in UK Construction 169

6.2.6.1 Client and Public sector Demand 170
6.2.6.2 Internal Drive for Continuous Improvement by Organisation 171
6.2.6.3 Benefit from Previous Implementation and Quest for Improved Working Relationship 171
6.2.6.4 Quest for on Time delivery of Project and to Overcome Past Failures 172
6.2.7 Benefits of Implementing LPS/CP Observed in the UK construction 172
6.2.7.1 General Benefits of Implementing LPS/CP Observed in the UK 173
6.1.7.2 Social Benefits of Implementing LPS/CP in Construction 174
6.2.7.3 Process Benefits of Implementing LPS/CP Observed in the UK 175
6.2.7.4 Level of Benefits from LPS/CP Implementation on Projects in the UK 176
6.2.7.5 Modelling the Benefits of Implementing LPS/CP Observed in the UK 177
6.2.8 Barriers to Implementing LPS/CP in the UK Construction 178
6.2.8.1 Cultural Issues at Project and Organisational Levels 178
6.2.8.2 The Use of Fragmented Subcontracting Model 180
6.2.8.3 Partial Involvement of Subcontractors 180
6.2.8.4 Time Pressure and Lack of Discipline 181
6.2.8.5 Self Protectionism 181
6.3 Stage 3: Structured Observations 182
6.3.1 Results and Discussion 182
6.3.2 Description of Projects Observed 182
6.3.3 Results of Record and Physical Condition Analysis 184
6.3.4 Results of Physical Process Analysis 186
6.3.4.1 Production Planning and Control Practices Observed 186
6.3.4.2 Effectiveness of Production Planning and Control Practices Observed Across Projects in the UK 189
6.3.5 Mapping of Collaborative Planning Practice in the UK with the Last Planner System 191
6.4 Discussion of Findings on Collaborative Planning Practice Observed with LPS Principles 192
6.5 Chapter Summary 194
CHAPTER SEVEN: MULTIPLE CASE STUDY DATA ANALYSIS, CROSS CASE-COMPARISON AND DISCUSSION 196
7.1 Introduction 196
7.2 Stage 4: Multiple Case Studies Overview 196
7.3 Case Study Project One (CSP01): Highways and Infrastructure 197
7.3.1 Last Planner/Collaborative Planning Practice on CSP01 199
7.3.1.1 Application of Last Planner/Collaborative Planning on CSP01 199
7.3.1.2 Pre-construction Practice 200

7.3.1.3 Nature of Last Planner/Collaborative Planning Meeting on CSP01 201

7.3.1.4 Percentage Plan Complete and Reason for Non-Completion Practice 201

7.3.2 Support required for LPS/CP Implementation as Observed on CSP01 203

7.3.2.1 Process and Support required at the Organisational Level. 203

7.3.2.2 Process and Support required at the Project Level 206

7.3.2.3 External Process Support Required 207

7.3.3 Procurement and LPS/CP on CSP01 208

7.3.3.1 Procurement Practice Observed on CSP01 208

7.3.3.2 Impact of Procurement Practice on LPS/CP on CSP01 209

7.3.4 Impact of LPS/CP Practice on Construction Process Improvement on CSP01 211

7.3.4.1 Impact on Time 212

7.3.4.2 Collaborative Working Practice, Communication, and Process Transparency 212

7.3.4.3 Impact on Re-work, Safety, and General Process Improvement 214

7.4 Case Study Project Two (CSP02): Highways Infrastructure 215

7.4.1 Last Planner/Collaborative Planning Practice Observed on CSP02 217

7.4.1.1 Application of Last Planner and Collaborative Planning on CSP02 217

7.4.1.2 Pre-construction Practice 217

7.4.1.3 Nature of Production Planning Meetings on CSP02 218

7.4.1.4 Percentage Plan Complete and Reason for Non-completion Practice 218

7.4.2 Support required for Last Planner/Collaborative Planning 220

7.4.2.1 Support required at the Organisational Level 220

7.4.2.2 Support Required at the Project Level 223

7.4.2.3 External Support required for LP and CP Implementation 224

7.4.3 Procurement and LPS/CP on CSP02 226

7.4.3.1 Procurement Practice on CSP02 226

7.4.3.2 Impact of Procurement on LPS/CP Practice on CSP02 226

7.4.4 Impact of LPS/ CP Practice on Construction Process Improvement on CSP02 228

7.4.4.1 Impact on Time and Programme 228

7.4.4.2 Collaborative Working Practice, Communication, and Process Transparency 229

7.4.4.3 Impact on Re-work, Safety, and General Process Improvement 231

7.5 Case Study Project Three (CSP03): Educational New Build 231

7.5.1 Last Planner /Collaborative Planning Practice Observed on CSP03 233

7.5.1.1 Application of Last Planner and Collaborative Planning on CSP03 233

7.5.1.2 Activity Scheduling as Observed on CSP03 234

7.5.1.3 Nature of Production Planning and Control Meetings on CSP03 234

7.5.2 Procurement and LPS/CP on CSP03 235

7.5.2.1 Pre-construction Practice 235

7.5.2.2 Impact of Procurement Practice on LPS/CP Implementation on CSP03 236
7.5.3 Support required for Last Planner/Collaborative Planning 237
7.5.3.1 Support required at the Organisational Level 237
7.5.3.2 Process and Support required at the Project Level on CSP03 239
7.5.3.3 External Support required for LPS/CP implementation 240
7.5.4 Impact of LPS/CP Practice on Construction Process Improvement 241
7. 5.4.1 Impact on Time and Programme 241
7.5.4.2 Collaborative Working Practice, Communication, and Process Transparency 243
7.5.4.3 Impact on Re-work, Safety, Non-value Adding Activities, and General Process Improvement 243
7.6 Cross Case Study Analysis and Discussion 244
7.6.1 Case Study Context and Description of Case Study Projects 244
7.6.2 Demographic Information of Research Participants 245
7.6.3 Cross-case Comparison of Last Planner/ Collaborative Planning Practice 246
7.6.4 Cross-case Comparison and Discussion on Procurement and LPS/CP Practice 249
7.6.5 Cross-case Comparison and Discussion on the nature of Support Required for LPS/CP Implementation. 251
7.6.5.1 Support Required for LPS/CP Successful Implementation at the Organisation Level 252
7.6.5.2 Support required for LPS/CP Successful Implementation at the Project Level 253
7.6.5.3 External Support Required for LPS/CP Successful Implementation 254
7.6.6 Cross-case Comparison and Discussion on the Impact of LPS/CP Implementation on Construction Improvement. 255
7.6.6.1 Impact on Time and Programme. 255
7.6.6.2 Impact on Collaborative Working Practice 256
7.6.6.3 Impact on Rework and Quality 256
7.6.6.4 Impact on Safety 257
7.7 Chapter Summary 257
CHAPTER 8: DEVELOPMENT AND EVALUATION OF THE LAST PLANNER SYSTEM PATH CLEARING APPROACH 259
8.1 Introduction 259
8.2 Rationale for the Last Planner System-Path Clearing Approach 259
8.3 Theoretical Overview of the Proposed Approach 260
8.4 Background to the Last Planner System Path Clearing Approach 261
8.4.1 The LPS Path Clearing Approach 261
8.4.2 What the proposed Approach is not 262
8.4.3 The Reason for Using LPS-PCA 262
8.4.4 Basic Diagram of LPS Path Clearing Approach 262

8.4.5 Schematic Diagram of LPS Path Clearing Approach 263
8.4.6 Definitions of Key Components in the LPS-PCA 264
8.5 Description of the Composition of the LPS-PCA 265
8.5.1 Organisational Level 265
8.5.1.1 Organisational Level Process Input Factors 265
8.5.1.2 Contextual Inputs Factors (Behaviours arising from the contract) 268
8.5.2 Project Level 270
8.5.2.1 Project Level Process Input Factors 270
8.5.2.2 Project Level Contextual Input Factors (Social Behaviour) 274
8.5.3 External Enablers 275
8.5.4 Continual Learning Action and Feedback Loop 275
8.6 Evaluation and Refinement of the LPS-PCA 276
8.6.1 Rationale for Evaluation of the Proposed Approach 276
8.6.2 LPS-PCA Evaluation Method 277
8.6.3 Demographic Information of Participants used in the Evaluation 278
8.6.4 Discussion of the Evaluation Results 279
8.6.4.1 Completeness of Components and Contents of the Proposed Approach 280
8.6.4.2 Application and Usefulness of the Proposed Approach 281
8.6.4.3 Refinements to LPS-PCA Following Evaluation Feedbacks 282
8.6.4.4 Emerging Influence of the LPS-PCA and the Pilot Implementation 282
8.6.4.4 Feedback on Pilot Implementation LPS-PCA in a Client Organisation 283
8.7 Chapter Summary 284
CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS 285
9.1 Introduction 285
9.2 Re-statement of Research Aim, Objectives and Process 285
9.3 Summary of Research Findings 285
9.4 Conclusions on Research Objectives 287
9.4.1 Objective 1 288
9.4.2 Objective 2 289
9.4.3 Objective 3 290
9.4.4 Objective 4 290
9.4.5 Objective 5 291
9.4.6 Objective 6 292
9.5 Conclusion on Research Questions 292
9.6 Original Contribution of Research to Knowledge 293
9.6.1 Contribution to Theory. 293
9.6.2 Contribution to Practice 294

9.6 Research Publications 294
9.6.3 Conference papers 294
9.6.4 Journal Publications 295
9.6.5 Future Publication Plan 295
9.7 Research Limitations 296
9.8 Recommendations 296
9.8.1 Recommendation for Industry Practitioners 296
9.8.2 Recommendation for Further Research 297
References 299
APPENDICES 341
Appendix 1: Sample of Semi –structured interview guide 341
Appendix 2: Approval Letter from College Ethical Committee 343
Appendix 3: Sample of Interview Invitation/Consent Letter Issued 344
Appendix 4: Transcribed Interview Sample 345
Appendix 5: Last Planner System Practice Evaluation Instrument 350
Appendix 6: Sample of Case Study Consent Letter Issued 351
Appendix 7: Case Study Interview Guide 352
Appendix 8: Post Case Study Survey Instrument 354
Appendix 9: Last Planner Path Clearing Approach Evaluation Survey Guide 357
Appendix 10: Last Planner System Path Clearing Approach A3 Size 359
Appendix 11: Last Planner System Path Clearing Approach Industry Guide 360

List of Figures

Figure 1.1: Thesis Structure **12**

Figure 2. 1: Timeline of construction industry report that magnify the need for Collaboration in the delivery of construction projects 20

Figure 2. 2: Timeline highlighting the development of the Last Planner System and Collaborative Planning in the UK **26**

Figure 2. 3: Fundamental Approach of CLIP **30**

Figure 3.1: Development of collaborative planning model in Urban and Regional planning 46

Figure 3.2: Development of collaborative planning in software design **49**

Figure 3.3: Waterfall process model **50**

Figure 3.4: The Scrum Process **52**

Figure 4.1: The Last Planner System of Production Control Model 71

Figure 4.2: The learning loop in the Last Planner System **77**

Figure 4.3: The review framework **83**

Figure 4.4: Components of LPS reported in the review **87**

Figure 4.5: Trend in LPS Elements Implemented across the Years **88**

Figure 4.6: Last Planner System implementation success factors in construction **89**

Figure 4.7: LPS Implementation Benefits in Construction **91**

Figure 4.8: Last Planner Implementation Challenges in Construction **93**

Figure 4.9: Timeline highlighting major developments in the Last Planner System **95**

Figure 5.1: The relationship between research philosophy and methods 100

Figure 5.2: The Logic of Research building block **103**

Figure 5.3: Research Design and Process **121**

Figure 5.4: Literature Review Chapter Flowchart **123**

Figure 5.5: Interview Process **125**

Figure 5.6: Interview Questions Development Protocol **127**

Figure 5.7: Interview Data Analysis Process used in the Study **132**

Figure 5.8: Case Study Research Design **138**

Figure 5.9: Case Study Data Collection Sources **142**

Figure 5.10: Case Study Analysis Process **145**

Figure 5.11: Distribution of Interviewees across the Case Studies **146**

Figure 5.12: Emerging Concept and Theme Tree **147**

Figure 5.13: Result of procurement practice on CSP01 graphically presented with ‘model tool’ as exported from NVivo 10 **148**

Figure 6.1: Positions Occupied by Interviewees 157

Figure 6.2: Current View on Master Programme 158

Figure 6.3: Current industrial perceptions on LPS and CP in the UK 160

Figure 6.4: LPS/CP success factors in the UK Construction industry 165

Figure 6.5: Drivers for implementing LPS/CP in the UK construction industry 170

Figure 6.6: Categorisation of the benefits of implementing LPS/CP in the UK 173

Figure 6.7: Current LPS/CP implementation barriers in the UK 179

Figure 6.8: Pull Planning or Collaborative Programming board with Sticky-Notes for scheduling 184

Figure 6.9: Pull Planning or Collaborative Programming board with temporary marker for scheduling 184

Figure 6.10: Visual Management Board to Communicate Progress of Work 186

Figure 6.11: Level of Implementation of production planning and control principles on projects observed 187

Figure 6.12: Comparing Collaborative Planning in the UK with the Last Planner System Components 191

Figure 7.1: Average PPC on CSP01 (A sample of document analysed) 202

Figure 7.3: Reason for non-completion of activities on CSP01 **202**

Figure 7.4: Support for successful implementation of Last Planner/Collaborative Planning **205**

Figure 7.5: Impacts of LPS/CP on CPI observed on CSP01 (interview results) **211**

Figure 7.6: Last Planner/Collaborative planning impacts on construction process improvement on CSP01 **213**

Figure 7.7: Average PPC chart on CSP02 (A sample of document analysed). **219**

Figure 7.8: Reasons for non-completion of activities (A sample of document analysed) **219**

Figure 7.9: Support for successful implementation of LPS/CP **222**

Figure 7.10: Impacts of LPS/CP practice on CPI observed on CSP02 (interview results) **228**

Figure 7.11: Last Planner/Collaborative planning impacts on construction process improvement on CSP02 **230**

Figure 7.12: Support required for successful implementation of LPS/CP Observed on CSP03 **238**

Figure 7.13: Impacts of LPS/CP on CPI observed CSP03 (interview results) **241**

Figure 7.14: Last Planner/Collaborative planning impacts on construction process improvement on CSP03 **242**

Figure 7.15: Cross Case-comparison of research participants **246**

Figure 8.1: LPS Path Clearing Approach Block Diagram 262

Figure 8.2: LPS Path Clearing Approach **264**

List of Tables

Table 2 1: Major Construction Industry Reports showing the need for Collaboration in the Design, Planning, and Execution of Work 24

Table 2.2: The Seven CLIP Focus Development Areas 29

Table 2.3: Collaborative Planning Practice Reported on CLIP Demonstration Projects 31

Table 3.1: Rational Comprehensive Model Compared with Collaborative Planning Model 47

Table 3.2: Comparing CPM, RCM, Collaborative Planning in UP, Agile process model and the Last Planner System 55

Table 4.1: Underlying Theories of the Last Planner System 79

Table 4.2: IGLC Papers on LPS Implementation between 1993 and 2014 Retrieved 84

Table 4.3: Last Planner System Implementation across Countries 86

Table 5.1: Comparing Positivist and Interpretivist Research Philosophies 106

Table 5.2: Differences between Quantitative and Qualitative Strategies 109

Table 5.3: Strengths and Weaknesses of the Interview Approach 115

Table 5.4: Interview Type in Relation to the Nature of the Study 115

Table 5.5: Strengths and Weaknesses of Sources of Evidence in Case Study 117

Table 5.6: Relationship between the Research Objectives and Phases of the Study 122

Table 5.7: Research Quality Criteria 150

Table 6. 1: Descriptions and Distribution of Interviewees across the UK Construction Sector 155

Table 6.2: Meaning ascribed to the Last Planner System and Collaborative Planning 162

Table 6.3: Prioritisation of LPS/CP benefits using the lens of the stakeholders 177

Table 6.4: Description of project observed & evaluated for production planning and control Practice 183

Table 6.5: Practices observed across projects 190

Table 7.1: CSPO1 Project Attributes 197

Table 7.3: Description of respondents interviewed CSP01 199

Table 7.4: CSPO2 Project Attributes 215

Table 7.5: Demographic Information of the Respondents on CSP02 216

Table 7.6: CSP01 Project Attributes 232

Table 7.7: Demographic information of respondents interviewed on CSP03 233

Table 7.8: Cross -case Comparison of Project Attributes 244

Table 7. 9: Cross-case Analysis of Last Planner System/Collaborative Planning 246

Table 7.10: Cross-case Comparison of Procurement Practice 250

Table 7.11: Summary of the nature support required for LPS/CP implementation from the Case Studies 251

Table 8. 1: Background Information of the Participant used for the evaluation 278

Table 8. 2: Results of LPS-PCA Evaluation 279

Table 9. 1: Research Objectives and How they were Achieved 287

List of Abbreviations

AR	Action Research
BAA	British Air Authority
BEA	Bureau of Economic Analysis
BIM	Building Information Modelling
BRE	Building Research Establishment
CDM	Construction (Design and Management)
CIOB	Charted Institute of Building
CL	Client
CLIP	Construction Lean Improvement Programme
CO	Consultant
CP	Collaborative Planning
CPI	Construction Process Improvement
CPM	Critical Path Method
CSP	Case Study Project
CW	Collaborative Working
D&B	Design and Build
DBB	Design Bid Build
DSR	Design Science Research
DTI	Department of Trade and Industry
ECI	Early Contractor Involvement
EU	European Union
FRS	First Run Studies
GDP	Gross Domestic Product
HE	Highways England
IGLC	International Group for Lean Construction
JIT	Just In Time
JV	Joint Venture
LAP	Language /Action Perspective
LC	Lean Construction

LCI	Lean Construction Institute
LPS	Last Planner System
LPS/CP	Last Planner System/Collaborative Planning
MAO	Management-as- Organising
MAP	Management-as- Planning
MC	Main Contractor
MM	Middle Manager
NSP	Non Study Participant
NTU	Nottingham Trent University
OL	Organisational Level
OP	Operational Planning
PBP	Planning Best Practice
PL	Project Level
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PP&C	Production Planning and Control
PPC	Percent Plan Complete
RNC	Reasons for Non- Completion
SC	Subcontractor
SE	Software Engineering
SM	Senior Manager
SP	Study Participant
TA	Task Anticipated
TFV	Transformation Flow and Value
TMR	Task Made Ready
TPS	Toyota Production System
UK	United Kingdom
UP	Urban Planning
US	United States
VFRS	Virtual First Run Studies

WWP	Weekly Work Plan

CHAPTER ONE: INTRODUCTION TO THE STUDY

1.1 Study Context

Globally, the construction industry plays a significant role in economic development of any nation. For instance, the construction industry accounts for approximately 6.5 % of the UK's GDP (Rhodes 2014); 3.7% of GDP in US (US BEA, 2014); 8% of GDP in Australia (Toth *et al.,* 2015) and 4.1% of GDP in Nigeria (Oluwakiyesi, 2011). This shows the importance of the industry in the economy. However, its efficiency is low when compared to other sectors such as the manufacturing industry (Gann, 1996; Love, and Gunasekaran, 1996; Koskela, 1992). It has been acknowledged that the construction industry has the most dented image in the eyes of the public when compared with other sectors, due to its inefficiency (Santos *et al.*, 2000). The inefficiency in the construction industry has been a thing of concern in the past and has steered different construction reports globally. Cain, (2004) identified these reports in the case of Canada, America, Australia, Singapore and the UK.

In the UK, the call for improvement in the construction industry and the dissatisfaction from stakeholders has been a subject of debate over many years with the first report to review the performance of the UK construction industry commissioned back in 1929 (Cain, 2004). The Egan report, generally called Rethinking Construction, challenged the lack of collaboration in planning, designing, and executing work on site, and recommended the adoption of lean production principles to enhance the image and efficiency of the industry (Egan, 1998).

However, the prevailing approach to planning does not support lean production principles (Ballard and Howell, 1997). According to Ballard and Howell, (1998), Ballard and Howell, (1994), the current model used in planning and managing the execution of work in the construction industry is 'project' control rather than 'production' control. This contributes to the non-achievement of tasks as planned. The problem with this is that planned tasks are not achieved as planned due to the lack of collaboration and involvement of stakeholders in the planning process

(Ballard and Howell, 1994; Ballard, 2000). These stakeholders include the client, designers, subcontractors, main contractors, and site operatives among others.

The impact of poor performance is evident in the construction industry globally (Nasir *et al.* ., 2013; Cain, 2004), including the UK. For instance, it has been reported that about 50% of construction projects suffer both cost and time overrun in the UK (Crotty, 2012). To overcome this irregularity and engender construction process improvement (CPI), a paradigm shift is required from functional activity thinking to system thinking, based on production philosophy (Koskela and Howell, 2002; Ballard and Howell, 1998; Jeong, 2004).

The Last Planner® System (LPS) (a lean production approach) invented by Ballard and Howell in the 1990s has been identified as a production planning and control (PP&C) methodology for construction, that engenders collaboration among the project stakeholders (Papke, 2013; Ballard, 2000). Over the years, planning and control have been understood to be among the core management functions in construction management (Burke, 2013). However, while planning and control are separated in traditional construction project management, they are seen as an integrated process in the LPS of construction management (Ballard and Howell, 2004; Ballard, 1997). This makes the planned construction programme more predictable and reliable, thus leading to reduction in lead time in the construction phase (Alsehaimi *et al.*, 2014; Ballard *et al.*, 2009; Alarcón *et al.*, 2005; Ballard and Howell, 1997).

In practice, the LPS stabilises the production (construction) process on a project by identifying relationships, matching them with plans and balancing resources (Mossman, 2014; Ballard and Howell, 2003). The LPS establishes relationships between people, tasks, locations, materials, drawings, time, information, and resources, so as to develop a common understanding of the project goals among stakeholders (Pasquire, 2012; Koskela, 2000). This supports smooth flow of work, collaboration, and commitment from all project participants, thus delivering value for all the stakeholders on the project (Koskela and Ballard, 2006).

1.2 The Research Problem

The implementation of the LPS has gained prominence in the construction industry and its influence on the production system seems to be rapid and significant (LCI, 2015; Daniel *et al.,* 2015). The impact of its implementation on construction process improvement is enormous. Mossman, (2014), Fernandez-Solis *et al.,* (2012) asserted that the implementation of the LPS helps in creating overriding improvement in project programme predictions, productivity, workflow, reduces project time and site accidents, increases profit, enhanced collaboration among project stakeholders, while giving due consideration to employee satisfaction among others. A comprehensive review of conference papers published by the International Group for Lean Construction (IGLC) indicates that the LPS has been implemented in 16 countries (Daniel *et al.,* 2015). Also, the Lean Construction Institute (LCI) and the IGLC have documented the implementation of the LPS on over 200 case study projects (Fernandez-Solis *et al.,* 2012). In addition to this, Shang and Pheng, (2014); McGraw-Hill report (2013) identified that the LPS is the most implemented lean construction technique on construction projects. According to McGraw-Hill report (2013) the LPS is one of the lean techniques with prospects of higher future implementation by construction stakeholders such as clients and main contractors. However, the application of this system in the UK construction industry has not been fully explored among industry practitioners (Sarhan and Fox, 2013; Mossman, 2009; Common *et al.,* 2000).

In the UK, there is confusion in the use of the terms "Collaborative Planning" (CP) and "Last Planner" and what happens in practice (Daniel *et al.,* 2015a; Koch *et al.,* 2015; Drysdale 2013; BRE, 2006). The term Collaborative Planning and Last Planner are used interchangeably to describe the application of production planning and control principles based on the LPS by construction practitioners in the UK (Daniel *et al*., 2016; Dave *et al*, 2015; Zemina and Pasquire, 2012). However, it is not clear how the current use of the CP approach for delivering construction projects in the UK align with the advocated principles and practice of the LPS.

In fact, there is dearth of empirical studies that examine the practice across the major sectors of the construction industry. For instance Mossman, (2009) only speculated that the practice of the LPS in the UK was largely stalled at collaborative planning or collaborative programming. Also, Sarhan (2013) and Mossman, (2009) opined that the LPS is viewed as activity scheduling tools in the UK, rather than an integrated system with many components. The lack of authoritative research and empirical data makes it difficult for an appropriate approach to be developed to improve current practice.

Furthermore, recent studies reveal that the application of LPS principles (also known as CP in UK) in the UK construction industry is fragmented (Daniel *et al.,* 2016; Daniel *et al.,* 2015a; Dave *et al.,* 2015; Koch *et al.,* 2015). Daniel *et al.,* (2016) observed that the more complex and crucial elements of the LPS are not implemented in current practice in the UK. The danger with such application is that the intended benefits of the implementation would not be realised both in the organisation and at the project level (Daniel *et al.,* 2014). According to Mcconaughy and Shirkey (2013), lack of full implementation has adverse effects on both the upstream and downstream flow of construction activities.

However, the fragmentation in the implementation of the LPS is not only in the UK construction industry, as this has been reported in; a Norwegian study (Kalsaas *et al.,* 2014); a Vietnamese study (Khanh and Kim, 2015) and a Danish study (Lindhard and Wandahl, 2014) among others. While this is not meant to rationalise the current practice in the UK, it demonstrates the need to develop an approach to support construction stakeholders in the implementation of the LPS, even at the global level. At the global front, previous approaches developed to support LPS implementation focused more on the project level, which is not holistic (Lindhard and Wandahl, 2014; Hamzeh, 2011; Dombrowski *et al.,* 2010). However, to develop a representative approach to generate such needed support, empirical evidence on the current practice is essential.

In the light of these problems, this study focuses on investigating the current application of Collaborative Planning for delivering construction projects in the UK construction industry from production planning and control practice across the major sectors of the UK construction industry using the LPS lens. This is important as it directs the development of an approach that supports construction stakeholders in the implementation of the LPS.

1.3 Rationale and Justification of the Study

This study is compelled by two main factors:

- The need for an all-inclusive approach to support construction stakeholders in their LPS implementation journey.
- The dearth in studies that examine the application of production planning and control practice based on the LPS across the major sectors of the UK construction industry.

The need for supporting the implementation of new techniques, and practice using some sets of guidelines, frameworks, roadmaps, approaches, or success factors have been acknowledged in the literature (Nesensohn, 2014; Ogunbiyi, 2014, Sacks *et al.*, 2009). Various frameworks have been developed to support lean implementation in the construction industry; however, these frameworks are too general and less technique specific. For instance, Nesensohn (2014) developed a framework for assessing lean maturity, with focus on how to assess an organisation's lean journey. Ogunbiyi, (2014) developed a framework for lean and sustainable construction, that focused on integrating lean construction with sustainable construction. Sacks *et al.*, (2009) suggested a research framework to relate lean to BIM; Forbes (2002) developed a framework to provide technical support for implementing lean. All these show the need for developing a framework or roadmap for guiding organisations in implementing lean principles.

However, in the UK, very limited studies have been conducted to investigate the application of the Last Planner System/Collaborative Planning (LPS/CP). No study has examined LPS practice across the major sectors of the UK construction industry with a view to generate an approach to support construction stakeholders in its implementation. Previous studies on LPS/CP in the UK construction industry reported pilot implementation while others are organisation specific (Drysdale, 2013; Ryall *et al.*, 2012, BRE, 2006; Johansen and Porter, 2003). Most of these studies are too narrow and unable to reflect the current practice of LPS/CP across the major sectors. Hence, they cannot be used as a basis to develop an approach to support LPS implementation.

For instance, in the UK, Ballard (2000) piloted LPS concepts in precast concrete production; the focus was to stabilise production. Johansen and Porter (2003) piloted the LPS on a building construction project, BRE (2006) reported CP practice on a demonstration project; while Drysdale (2013) reported the application of CP on a pilot project. Similarly, Dave *et al.,* (2015) reported an LPS application on a case study project and Koch *et al.,* (2015) reported the application of CP on a case study project. However, the focus of these studies was not to create an approach that would support construction stakeholders in the implementation of the LPS. In contrast, the study reported in this thesis examined the current LPS/CP practice across the major construction sectors (building, highways infrastructure, and rail) in the UK, thus offering a more comprehensive view on the current practice. The findings directed the development of an approach to support construction stakeholders in the implementation of the LPS.

At the global level, studies have attempted to propose an approach for implementing specific lean techniques such as LPS in construction, but they tend to focus more on the project level (Lindhard and Wandahl, 2014; Hamzeh,2011; Hamzeh and Bergstrom (2010), Dombrowski *et al.,* 2010). For instance, Lindhard and Wandahl (2014) developed a framework that focused on supporting on-site scheduling; Dombrowski *et al.'s* (2010) framework focused on the implementation of LPS components at the project level. Ballard *et al.,* (2007) suggested a general roadmap for lean implementation with focus on the project level, while Hamzeh, (2011), Hamzeh and Bergstrom's (2010) framework provided an operational guideline for LPS implementation that focused more on the project level.

This is despite the fact that it has been suggested that the implementation of lean techniques should expand beyond project focus and include other organisational and human factors that could influence the process (Pevez and Alarcon, 2006). The study reported in this thesis fills this gap by developing an approach to direct LPS implementation known as Last Planner System Path Clearing Approach (LPS-PCA) that incorporates an organisational path clearing level and external enablers alongside the project path clearing level. The approach is not intended for a one off improvement, as common with the implementation of lean tools and methodologies (Pevez and Alarcon, 2006), rather, it supports embedding the process into the organisation through the learning loops. According to Howell and Ballard, (1998) lean implementation does not only impact on how the project is managed, it also influences the organisation's behaviour.

Furthermore, since the LPS-PCA is developed based on empirical findings from across the UK construction industry, it recognises cultural, structural, and contextual issues germane to it, which are not addressed by other approaches developed elsewhere. Johansen *et al.*, (2004) Johansen and Porter, (2003) and Seymour, (1998) posited that an understanding of cultural context is important for the successful implementation of lean principles in the UK construction industry. This does not mean that the use of the proposed approach is limited to the UK construction industry alone, as evaluation result have shown that the proposed approach could be adopted anywhere.

1.4 Research Questions

The study seeks to answer the following overarching questions:

1. *How does the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK align with the advocated principles of the LPS?*

2. *How can construction stakeholders (client, main contractors, and subcontractors) be supported for rapid and successful implementation of the LPS to achieve construction process improvement.*

1.5 Research Aim

The aim of this research is to develop an approach to support construction stakeholders for a rapid and successful implementation of the Last Planner System for a sustainable construction process improvement.

1.6 Research Objective

The following objectives are used to achieve the aim of this study.

1. To critically review the need for construction process improvement (CPI) and the development of production planning and control practice in the UK construction industry.
2. To critically evaluate the development of collaboration in design, planning and execution of work in other fields and identify the implication for collaboration in construction planning practice and theory

3. To critically evaluate the applications and developments in the Last Planner System for managing project production in the construction industry globally.
4. To investigate the current understanding and application of Collaborative Planning for delivering current projects in the UK from a production planning and control perspective through the lens of the LPS
5. To determine the nature of support needed for rapid and successful implementation of the LPS and to identify the impacts of LPS implementation on CPI.
6. To propose and validate an approach to support construction stakeholders in implementing the LPS.

1.7 Scope of the Study

This research focuses on the UK construction industry. The research respondents were drawn from England, Scotland, and Wales, however the study was unable to engage with research participants from Northern Ireland. Also, only the top construction companies participated in the study. This means that supply chain companies who do not work for top contractors are omitted in this study. Furthermore, the empirical data for this research are mainly on the construction phase. This indicates that the application of production planning and control principles explored did not capture the practice in the design phase sufficiently. It is worth noting that the production planning and control (PP&C) practices investigated are those based on the Last Planner System principles and did not include other production planning and control practices such as Line of Balance , and critical path method among others.

1.8 Overview of Work Done

This section gives a high level overview on the work done as reported in this thesis.

1.8.1 Overview of Research Methodology.

It has been observed that the success of every research lies on the appropriateness of the research methodology and methods used in the investigation. This is also influenced by the research philosophical stance. The ontological position of this study is a combination of social constructivism and objectivism. Thus, it relies on the epistemology of interpretivism and positivism to answer the research question, though largely concentrating on interpretivism. The effective combination of interpretivism and positivism in conducting construction management research has been widely reported in the literature (Dainty, 2008; Fellow and Liu, 2008). Dainty, (2008) asserted that both positivism (quantitative) and interpretivism (qualitative) research have their root in ontology and epistemology, thus they can be combined. Accordingly, both qualitative and quantitative methods were used in collecting data for the study. Specifically, data were collected via interviews, structured observations, case studies, and surveys.

These approaches were used to complement each other and to strengthen the research contribution to knowledge. Some of the qualitative data were analysed using qualitative data software known as [1]NVivo 10 while the quantitative data were analysed using [2]SPSS 22. An overview of the research stages are highlighted below.

1.8.2 Overview of Research Process

There are five key stages in this study.

Stage 1: Literature review

The literature review examined literature on Collaborative Planning approach in the UK construction industry, production planning and control principles using the lens of the LPS, construction process improvement, the development of collaboration in planning in urban planning and software engineering. From the literature review, the knowledge gap for the study was identified. Publications and collections sourced from databases such as Emerald, Elsevier, Construction Industry Institute , the International Group for Lean Group for Lean Construction (IGLC), Construction Economics and Management Journals, Journals of construction engineering and management, and Lean Construction Journals among others were reviewed.

Stage 2: Exploratory Semi-Structured Interviews

Following the literature review, the research instrument was developed to investigate the current practice of Collaborative Planning for delivering construction projects from a production planning and control (PP&C) perspective in the UK. Purposive sampling was used in selecting the research participants. The research participants

[1] Software that supports in the analysis of qualitative data
[2] Statistical Package for the Social Science for analysing quantitative data

include; clients, main contractors, subcontractors, and lean construction consultants. The respondents were drawn from building, highways infrastructure and rail sectors of the UK construction industry. Thirty in-depth interviews were conducted over a 12 month period comprising 18 main contractors, 2 clients, 4 lean construction consultants, and 6 subcontractors.

Stage 3: Structured Observations

At the end of the interviews, further exploration was done to obtain objective data on how the application of PP&C principles in the UK, align with the advocated principles of LPS. Evidence on this was obtained from the physical process analysis using the Planning Best Practice (PBP) checklist; a survey tool used in evaluating production planning practice based on the LPS (Bernades and Formoso, 2002). The PBP consists of 15 practices associated with the LPS. The assessments was done using three Likert Scale where 1= full implementation 0.5= partial implementations and 0= no evidence of implementation. In all, 15 projects drawn from building, highways infrastructure, and rail were evaluated. Simple descriptive statistics were used in the analysis of survey data. Evidences were also sourced from record analysis, and physical condition analysis.

Stage 4: Case Study

The aim of the case study is to identify the nature of support required for the effective implementation of the LPS and the impact of implementing PP&C principles based on LPS principles on construction process improvement in the UK. This was done using three case studies. The case studies were conducted over a 10 month period. Two of the projects studied were highways infrastructure projects and one a building project. On each project, evidences were sourced through interviews, document analysis, observations, and a post-implementation survey. All these were done for triangulation of research findings.

Stage 5: Development and Evaluation of Last Planner Path Clearing Approach

Following the activities in Stages 1 to 4, an approach was developed to support construction stakeholders in the implementations of the LPS for sustainable construction process improvement. The developed approach is known as Last Planner System Path Clearing Approach (LPS-PCA), and includes organisational and project path clearing levels, and external enablers. To determine its functionality, LPS-PCA was introduced, evaluated, and validated by 10 construction industry practitioners. Also, the LPS-PCA was piloted on a live project. Following feedback from the evaluation and the preliminary findings from the pilot implementation, the LPS-PCA was refined. A guidance note was also developed to support construction stakeholders in using the LPS-PCA following the evaluation feedback.

1.8.3 Overview of Research Contribution to Knowledge

The contribution of this research emerges from revealing the mismatches in current applications of Collaborative Planning for delivering construction projects in the UK using the lens of the LPS. This informed the development of an approach known as "*Last Planner System Path Clearing Approach*" to support construction stakeholders in the implementation of the LPS.

1.8.4 Thesis Structure

Figure 1.1 presents the structure of this thesis. It comprises of nine chapters, a brief overview on each chapters is presented below.

Chapter One: Introduction to the Study

This chapter presents the background to the study and captures the knowledge gap for the study. It identifies the research aims, objectives, and the research questions. It also presents the rationale and justification for the study. Furthermore, an overview of the study contribution to knowledge, overview of work done and the thesis structure are also presented in this chapter.

Chapter Two: Construction Process Improvement and Production Planning Control in the UK Construction Industry

This chapter explores the need for construction process improvement (CPI) in both design and construction phases and the development of production planning and control (PP&C) practice in the UK construction industry.

It presents the nature of the construction industry and examines the concept of CPI in the industry. It further discusses the development of PP&C practice based on the Last Planner System (LPS) in the UK, by presenting the historical perspectives of the LPS and collaborative planning (CP) in the UK construction industry.

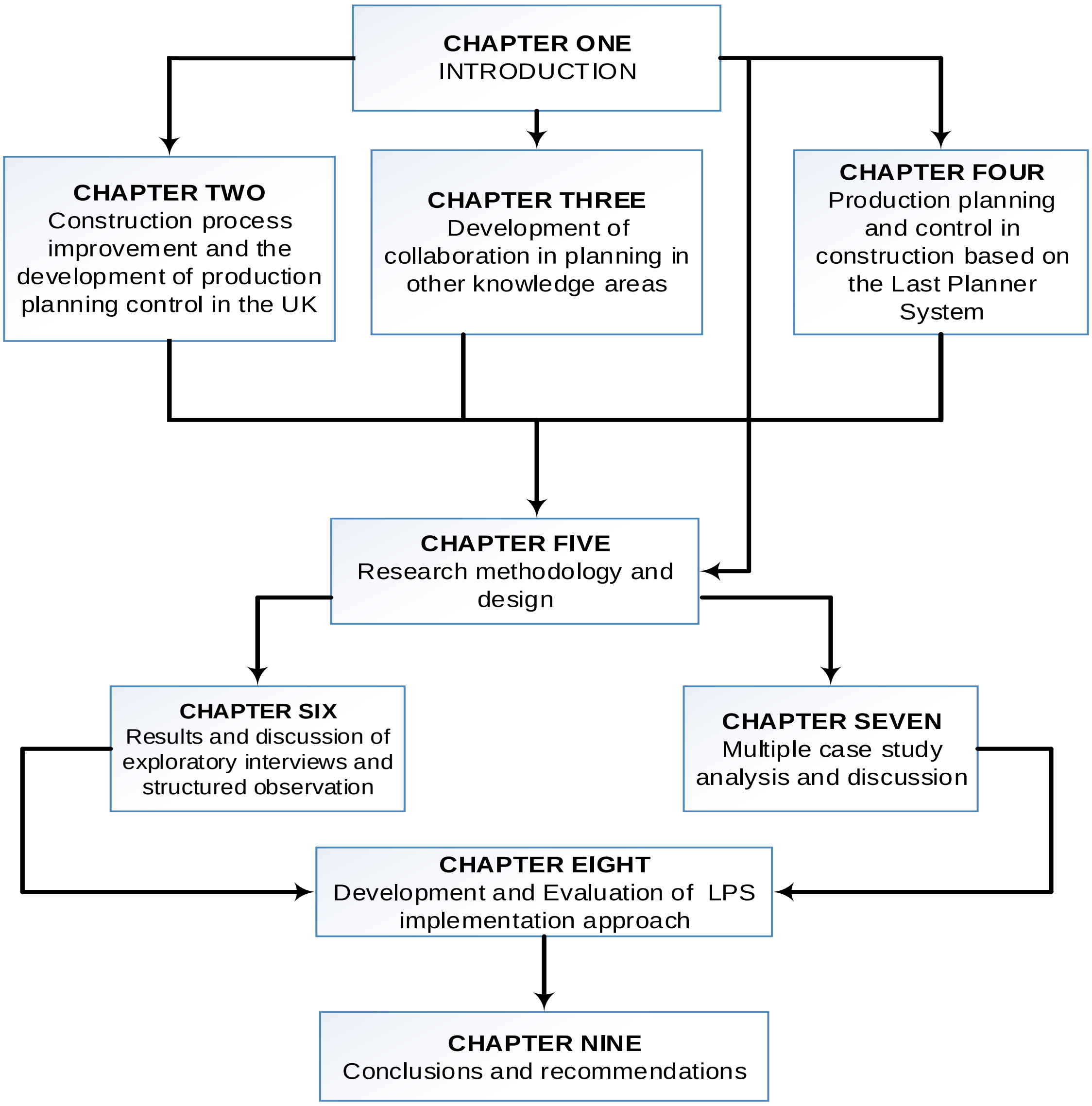

Figure 1.1: Thesis Structure

Chapter Three: Development of Collaboration in Planning in Other Knowledge Areas

This chapter brings in a broader standpoint on the need for collaboration in construction planning by exploring the concept of collaboration and collaborative working (CW), and the development of collaboration in design, planning, and execution of work in other fields. Precisely, it reviews the development of collaboration in planning, in urban planning (UP) and in software engineering (SE) development. The implications of the developments of collaboration in design, planning, and execution of work in these knowledge areas are examined for construction project management

Chapter Four: Production Planning and Control in Construction Based on the Last Planner System

This chapter examines the LPS of production control in details as a production planning and control (PP&C) methodology in construction, with focus on its evolutions and its practical implementation in construction. It highlights the development of PP&C in construction with focus on the LPS and its supportive components. The chapter also presents the theories that explain the effectiveness of the implementation of the LPS in construction. The chapter highlights the practical implementation of the LPS in construction projects through a comprehensive and systematic review of the International Group for lean Construction (IGLC) papers on LPS implementations.

Chapter Five: Research Methodology and Design

This chapter presents a detailed account on the research methodology and design used in capturing the evidences in answering the objectives proposed in Chapter One. It also justifies the research methodology and design used. The chapter presents the overall research design and discusses the five major stages involved in the study in detail.

Chapter Six: Results and Discussion of Exploratory Interviews and Structured Observation

This chapter presents and discusses the findings from the semi-structured interview on the current use of Collaborative Planning for delivering construction project from production planning and control perspective in the UK construction industry. It also presents and discusses the structured survey on PP&C practice using the lens of the LPS.

Chapter Seven: Multiple Case Study Analysis and Discussion

This chapter analyses, presents and discusses the findings from the three case studies. It also presents a cross case study analysis and discussion.

Chapter Eight: Development and Evaluation of LPS Implementation Approach

This chapter presents the LPS-PCA approach developed based on the empirical data from Stages 3 and 4 of this study. It presents both the quantitative and qualitative evaluation feedback on the LPS-PCA received from construction professionals. In addition, the chapter reports the preliminary findings from a pilot implementation of the LPS-PCA.

Chapter Nine: Conclusions and Recommendations

This final chapter captures the main conclusions and recommendations from this study. The chapter presents the conclusions on each research objective and the research questions and itemises the original contribution of the study to knowledge. It identifies the study limitations and made recommendations for further research and for the industry.

1.9 Chapter Summary

This first chapter provided a high level overview of the research reported in this thesis including the contributions of the study to knowledge. The next chapter (Chapter Two) presents the literature review on construction process improvement and development of the production planning and control practice in the UK construction industry.

CHAPTER 2: CONSTRUCTION PROCESS IMPROVEMENT AND THE DEVELOPMENT OF PRODUCTION PLANNING AND CONTROL BASED ON THE LAST PLANNER SYSTEM IN THE UK CONSTRUCTION INDUSTRY

2.1 Introduction

This chapter explores the need for construction process improvement (CPI) in both design and construction phases and the development of production planning and control (PP&C) practice in the UK construction industry. Firstly, it presents the nature of the construction industry and examines the concept of CPI in the industry. The chapter highlights the demand for an integrated approach in the design, planning, and execution of projects for an enhanced construction process improvement from a review of UK construction industry reports. It further discusses the development of PP&C practice based on the Last Planner System (LPS) in the UK, by presenting the historical perspective on the Last Planner System and collaborative planning (CP) in the UK construction industry. The chapter partly compares CP practice on UK Construction Lean Improvement programme (CLIP) demonstration projects with the LPS components. The chapter also presents the knowledge gap for the study and thus, sets the foundation for further explorations on the application of PP&C for construction process improvement in the UK.

2.2 Process Improvement in the Construction Industry

2.2.1 The UK Construction Industry

The construction industry activities have been identified among the major drivers commonly used in measuring the performance of the economy of a nation (Ofori, 2001). Globally, the construction industry plays a significant role in economic development of any nation. In the UK the construction industry plays a significant role in the country's economic growth and development. The Gross Value Added by the UK construction industry to the overall economy in 2011 was £89.5 billion; this amounts to 6.7% contribution to the overall economy. A current report indicates that the sector contributes about 6% to the overall GDP of the UK (Rhodes, 2014). In the UK, the industry comprises of over 280,000 companies and employs over 3 million workers (Construction 2025 Report, 2013). The public sector is the single largest client in the UK construction industry (House of Commons, 2008; Egan, 1998).

The smaller construction firms in the UK construction industry are more in number compared to the larger firms. But their contribution to the economic output and employment is low (House of Commons, 2008). For instance, some of the smaller companies employ less than eight people (Construction Satistics Annual, 2007). The larger firms on the other hand contribute about 12% to value output and provide about 10% of employment in the sector (Construction Statistics Annual, 2007). Again, all these show the level of fragmentation in the sector. This has led to a consistent call for collaborative working in the design, planning, and execution of work among stakeholders in order to achieve enhanced construction process improvement.

2.2.2 The Concept of Construction Process Improvement

Process improvement has remained an object of focus in various disciplines for many decades. This includes manufacturing, business management, process engineering and more recently in the construction industry. The quest for process improvement could be traced to "The Scientific Management Principles" proposed by Frederick Taylor (Taylor, 1911). In his search to achieve increased productivity and faster output, Taylor embarked on a study that investigated work process scientifically (Taylor, 1911). Many attempts have been made to define the term 'process'. Jeong *et al.,* (2004) observed that people give different meaning to the term which seems to be based on the sector, function and the market in which they operate. This implies that the meaning accrued to the term 'process' could vary from one sector to another. Nevertheless, the Cambridge Dictionary, (2015) defines process as "a series of actions that you take in order to achieve a result". This suggests that process relates to structured actions to be adhered to in order to achieve a result.

According to Harrington, (1991) process consists of activities that take inputs, enhance them, and provide output to both internal and external customers. However, Ould, (1995) opined that a process comprises of activities, people, and equipment which are required to work collaboratively. Shingo (1998) also asserted that production comprises of network of processes and operations, that is processes and operations are opposite sides of the same coin. Process is not merely a collection of activities but also involves materials, men, and machines which must be connected collaboratively for better output. In view of this, Jeong *et al.*, (2004) argued that since a process involves a wide range of actors, it must be clearly defined to all the actors involved in order to achieve the needed improvement. To realise this, the focus should be on all the various steps identified in the process.

Paulk *et al.,* (1995) and Imai (1986) pointed out that continuous process improvement relies on many steps in the production process and not a revolution of the system as thought by some. This suggests that process improvement should follow defined procedures. For example, Juran, (1992) and Deming (1986) suggested that process improvement should follow a series of steps starting with the visible which could be later made repeatable and measurable. Generally, construction projects occur in various steps and stages. According to Austen and Neale (1984), construction consists of several steps known as processes. This suggests that the final output of a construction project relies greatly on how these interphases or series of steps are effectively managed.

In view of this, Stewart and Spencer, (2006) emphasised the need for managing these series of steps effectively as it supports productivity, efficiency, and capacity development in the industry. This implies that productivity and efficiency will remain unachievable if these series of steps in the construction process are not well managed. However, managing this series of steps must be done collaboratively as each process involves materials, men, machines, and information among others. In addition, since construction and process involves a lot of actors, each process must be clearly defined to all parties at the earliest possible moment for a collective improvement and development of each process (Jeong, 2004; Ould, 1995).

2.2.3 Current State of Construction Process Improvement in the Industry

It has been observed that the construction industry lacks a defined approach for managing its processes. According to Van der Aalst *et al.,* (2003) construction processes keep changing especially in the execution phase. The lack of involvement of the actors in developing the process and the inherent variability in construction could have contributed to this (Ballard and Howell, 1998). Also, Stewart and Spencer, (2006) identified the absence of a clear framework and guideline to support process improvement in the construction industry. This implies that benefits from the process are seen in isolation and thus, cannot be coordinated. This does not only retard CPI initiative in the industry, but also hinders any repetition of such initiative. It is no surprise that the process improvement initiative varies from project to project even within the same organisation. Hence, a framework to support CPI using a systematic approach is required in the industry. For instance, Sarshar *et al*., (2000) observed that the construction industry is unable to coordinate CPI because it is yet to assess construction process, prioritise CPI and allocate resources to it as required.

The absence of a clear framework for managing construction among other things informed Egan's recommendation for the adoption of lean production principles in the UK construction industry (Egan, 1998). Prior to Egan's report, various reports had been commissioned in the UK, which all called for collaboration and construction process improvement in the planning, design, and execution phases of projects.

2.2.5 Demand for Construction Process Improvement in the UK

The demand for improvement in the UK construction industry and the dissatisfaction from end users has been a topic for debate over many years. To be precise, the first construction industry report to review the performance of the UK construction industry was commissioned in the 1930s (Cain, 2004). The government in its effort to keep the construction industry on the firing line, considering its significant contribution to economic growth and development, has never relented its effort in reviewing the performance of the industry; so as to identify areas for improvement. For instance, between 1929 and 2009, over 14 construction industry reports were produced in the UK. These reports emphasised the removal of inefficiency and waste from the construction industry through collaboration and early involvement of stakeholders.

The earliest among these reports is "*Reaching for the skies"* by Alfred Bosom in 1934 (Cain, 2004). He argued that construction is like every engineering process which should be planned adequately in advance with work executed on an agreed time scale. Unfortunately, this was not the situation in the UK construction industry as of the time of the report. Describing the UK construction industry at the time, he stated that: "All rents and costs of production throughout Great Britain are higher than should be because houses and factories cost too much and take too long to build" (Cain, 2004 pp. 20). The picture painted here is no doubt, that of cost and time overrun, in an industry that is marked with fragmentation and unproductiveness. Chan and Chan, (2004) and Kumaraswamy, (1997) observed that the major causes of time and cost overrun are poor project planning and scheduling, and inadequate control of change.

The above report gives an early description of the UK construction industry and the earliest call for collaborative approach in planning, design, and execution of work in the UK construction industry. Subsequently, other construction industry reports were commissioned to better understand the need for construction process improvement through collaboration and collaborative working approaches.

2.2.6 Review of Construction Industry Reports

Figure 2.1 presents a timeline of the construction industry reports commissioned by the UK Government between the 1930s and 2014. Again, this shows the level of attention the UK Government pays to the sector. A critical examination of these reports indicate that they all emphasise the need for collaboration and collaborative working in design, planning and execution of work for better construction process in the industry. Among the reports shown in the figure, the Latham and Egan reports in particular, mounted pressure on the UK construction industry to embrace or adopt collaborative approaches at all stages of procuring construction projects. Also, the figure reveals that there has been an increase in the number of reports commissioned in recent times compared to the earlier years. This could mean that the industry is

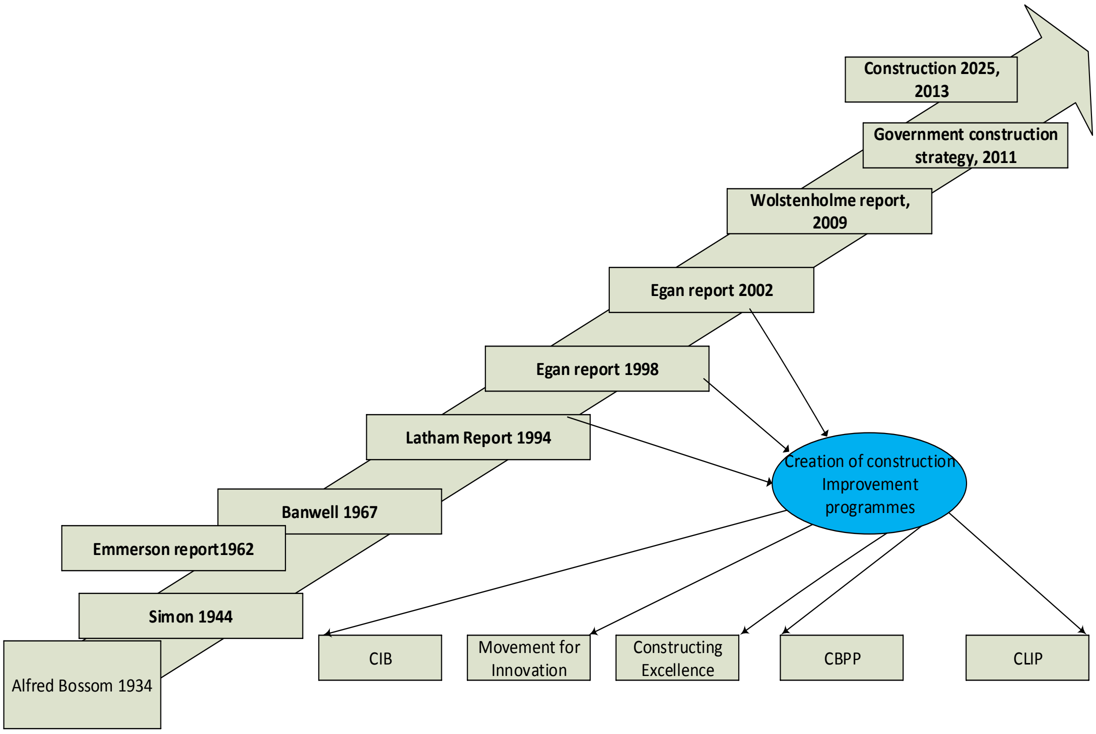

Figure 2. 1: Timeline of construction industry report that magnify the need for Collaboration in the delivery of construction projects

still not performing as expected and could still be driven to perform better. Some of these reports are reviewed below.

2.2.6.1 Latham Report: Constructing the Team

The Latham report, also known as "*Constructing the Team"* made over twenty recommendations for the UK construction industry to ensure more efficient project delivery. It reveals that previous reports such as Simon report, Harold Emmerson report and Banwell report failed to address the identified problems. It went further to recommend a turning point for the UK construction industry, which should start from building better relationship between clients, contractors, consultants and subcontractors. The report emphasised that contracts should be based on the principle of fairness, mutual trust, and team work rather than low price alone and adversarial nature which used to be the common practice. The report originates and magnifies the need for collaboration in the UK construction industry. This is not to say that the need for collaboration in construction was limited to the Latham report as other reports such as the 1998 Egan report: Rethinking Construction; the 2002 Egan report: Accelerating Change; and the 2009 Wolstenholme report: Never Waste Good Crisis among others also discuss the need for collaboration.

2.2.6.2 Egan Report: Rethinking Construction

The Egan report was commissioned as a result of the slow implementation of the Latham report and the inability of the industry to meet the expectations of clients (Wolstenholme, 2009; Egan, 1998). The report did not only highlight the problems the industry was facing, but went further to identify major drivers for change. Interestingly, the five drivers identified revolve around collaboration. These are; committed leadership, focus on the customer, integrating the process and the team around the product, quality driven agenda, and commitment to people. The report also identified four project process improvements drivers which are: product development, partnering the supply chain, project implementation, and production of components. In addition, it highlighted seven specific improvement targets.

The focus of the five drivers is to effectively integrate both the demand and supply arms of the project chain. According to Cain, (2004) all the construction industry reports placed great emphasis on collaboration in the procurement and execution of construction projects. This can be attributed to the fragmented nature of the construction industry and the one-off nature of its product (Oliva and Granja, 2013). However, current reports indicate increased awareness and potentials in delivering value for clients and end users through collaboration in the design, planning, and execution of work.

2.2.6.3 Accelerating Change

Building on the 'Rethinking Construction' report, 'Accelerating Change' was commissioned in 2002. The essence of the report was to assess the progress of the Egan 1998 report (Egan, 2002). According to Wolsteholme, (2009) the report identified the various impact made by the 'Rethinking Construction' report and defines a headline goal that 20% of construction projects must be executed by an integrated project team and supply chain by 2004. This was expected to increase to 50% in a three year period.

Again, the call for the use of an integrated team in project delivery in the report further magnifies the need for collaborative planning among the stakeholders in the industry. This move could be due to the improvement experienced on the demonstration projects executed as part of the implementation process of the 'Rethinking construction' report (Wolsteholme, 2009). In fact, the call for partnering with the supply chain especially in planning and execution of complex projects is because of its obvious benefits for all the stakeholders. According to Kastali and Neely, (2006); Barlow, (2000), complex situations on a project can easily be solved with innovative solutions that could emerge in the collaborative planning process.

2.2.6.4 Never Waste Good Crisis

The report examined the progress of the Egan report after its ten years of inauguration. More importantly, it identified five blockers that had retarded the implementation of the Egan report (Wolsteholme, 2009). The result of the survey indicated the various improvements made since the implementation of Egan's recommendations. For instance, the report showed an increasing level of awareness on the need for collaboration in planning and team working among major stakeholders in the construction industry. The report indicated that 56% of the respondents considered an integrated approach in project delivery to be very important for the most desired improvement process in the construction industry to occur (Wolsteholme, 2009). This shows that there is an increase in understanding among construction stakeholders in the UK on the need for collaboration and integrated working approach in achieving CPI following the Egan report.

2.2.6.5 Government Construction Strategy

In May 2011, the Government construction strategy report was published. The report acknowledged the importance of the construction industry to the economic growth of the country and further highlights some of the improvements made in the sector following recommendations of the Latham report. More importantly, the report pointed out the inability of the sector to deliver value for its customers and end users due to its unwholesome practices (Construction Strategy Report, 2011). For instance, the report challenged the prevalent adversarial relationship that has become a norm in the industry and calls for a replacement with collaborative approach. This renewed call is a pointer that the industry has not fully embraced previous calls from previous construction industry reports for integrated working among the stakeholders. It could also mean that the industry is slow to change. Sabol, (2007) argued that the construction industry is slow to adopt innovation and change thus making the industry to underperform when compared with other sectors. However, Wilkerson, (2005) identified architects as early adapters of innovation in the construction industry.

The report further magnified the need for designers and constructors to work together as a team to develop integrated solutions in project delivery. Although these points are not in any way new to what has been highlighted by the previous reports, it establishes the relevance of collaborative effort such as in planning, design, and in project execution for meaningful progress to be made in the construction industry.

2.2.6.6 Construction 2025 Report

The ‘Construction 2025’ report was a product of over six months of extensive evaluation of the industry by the government and other major stakeholders in the UK construction industry. The report identified the strategic position of the UK construction industry, both locally and globally, especially its competitive edge over other sectors. The aim of the report is to empower all the stakeholders in the construction industry with valuable information on the available opportunities and threats to the industry which need to be harnessed collaboratively to better position the industry to contribute more to the economy. The report was not written in isolation; indeed the report acknowledged the improvements made in the industry as a result of other construction industry reports such as Latham, Egan and Wolsteholme’s reports. This clearly suggests that all the construction industry needs is to build on earlier foundations that have been laid. Again, this re-emphasises the importance of previous reports and its correlation to the present construction industry report. The report identified there is weakness in collaborative strength across the supply chain due to fragmentation, lack of trust and the absence of a sense of belonging.

2.2.6.7 Summaries and Major Outcomes of the Construction Industry Reports

Table 2.1 summarises the various construction industry reports and identifies the need for collaboration in design, planning, and execution of work. This is done to clearly present the picture of the need for collaboration in the design, planning, and execution as emphasised in the past and present. Table 2.1 reveals that the need for collaboration in the construction industry has been and still is emphasised in all the construction industry reports. However, in reality, collaborative practice within the industry is still patchy. This could be due to the individualistic tendencies among the stakeholders procuring construction projects. According to Pasquire et al., (2015) construction stakeholders always seek to protect their self-interest on the project rather than the overall goal of the project.

Table 2 1: Major Construction Industry Reports showing the need for Collaboration in the Design, Planning, and Execution of Work

Year	**Construction Industry Report**	**Collaborative Approach Emphasised in the Design, Planning & Construction Phases**
1934	**Bossom Report:** *Reaching for the Skies*	▪ Raised concern about fragmentation and adversarial relationship ▪ Highlighted time and cost overrun due to inadequate planning
1944	**Simon's Report**: *Placing and Management of Building Contracts*	▪ Called for collaborative approach to design and construction ▪ Recommended early contractor involvement
1962	**Emmerson Report:** *Survey of Problems Before the Construction Industry*	▪ Identified lack of cohesion between parties procuring construction projects ▪ Suggested the adoption of a common form of contract
1967	**Banwell Report:** *The Placing and Management of Contracts for Building and Civil Engineering Work*	▪ Criticised the separation between design and construction ▪ Emphasised more focus on team working and relationship building
1994	**Latham Report:** *Constructing the Team*	▪ Called for an integrated approach to work ▪ Called for partnering at all levels of the project ▪ Recommended the use of forms of contracts that encourage team working
1998	**Egan Report:** *Rethinking Construction*	▪ Integrating the process and the team around the product ▪ Strong focus on customer and commitment to people ▪ Called for strong partnering across the supply chain
2002	**Egan Report:** '*Accelerating Change*'	▪ Called for 20% of all construction projects to be executed by an integrated team and supply chain ▪ Emphasised client leadership in the execution of construction project
2009	***Wolstenholme Report:*** *'Never Waste Good Crisis'*	▪ Called for a collaborative and integrated team ▪ Highlighted lack of an integrated process for delivering project ▪ Stated that pushing down of risk by contractors along the supply chain prevents team working ▪ Identified the need for lean approach in pre-planning activities and procurement from a case study visit in Japan
2011	*Government Construction Strategy*	▪ Called for the adoption of procurement options that enhance integration of the supply chain (NECs) ▪ Developing a collaborative and integrated relationship to minimise waste ▪ Called for use of BIM to enhance collaboration in planning and execution of project ▪ Created lean supply chain/product

2013	Construction 2025	▪ Created procurement /lean client task force ▪ Called for effective and clear communication of work during plan. ▪ Called for partnership at all levels among the stakeholders in the industry to reduce construction cost by 33%, and time by 50% ▪ Observed low integration and a call to create resilient supply ▪ Highlighted lost opportunities to innovate due to lack of integration between design and construction management ▪ Called for early and continuous involvement of contractors and supply chain in design development

As shown in Table 2.1, all the reports highlighted the need for collaboration in design, planning and execution phases of the project before meaningful achievement of construction process improvement. However, the call for collaboration by successive reports presents a picture that these calls have not been fully adopted in the UK construction industry. This could be due to the age long use of the traditional project management approaches that do not support genuine collaboration (*adversarialism*) (Latham, 1994; Ballard and Howell, 1998). With this understanding, Sir John Egan in *Rethinking Construction report,* 1998 brought a new perspective with a categorical recommendation for the adoption of *lean production techniques* in the UK construction industry. Specifically, the Last Planner System (LPS) which is a lean technique was recommended in the report for use in production planning and control for delivering construction projects (Egan, 1998).

2.3 Development of the Last Planner System in the UK

Figure 2.2 shows the major timeline in the development of the Last Planner System in the UK construction industry. It reveals that the application of the LPS in the UK is as a result of Egan's 1998 report recommendations. The practical application of this production planning and control methodology in the UK dates back to its use on Heathrow Terminal projects by the British Airport Authority (BAA) in the late 1990s and in the early 2000 (BAA, 2000). According to Reynolds, (1999) the approach was tried on the construction of Heathrow - T4 Coaching Gate, T1 British Midland, T4 Arrivals Phase 2, and T1 International Arrivals. It was reported that the LPS approach was beneficial as it allowed the team to be in full control of the project programme, with two weeks gain on T4 arrival phase of the project.

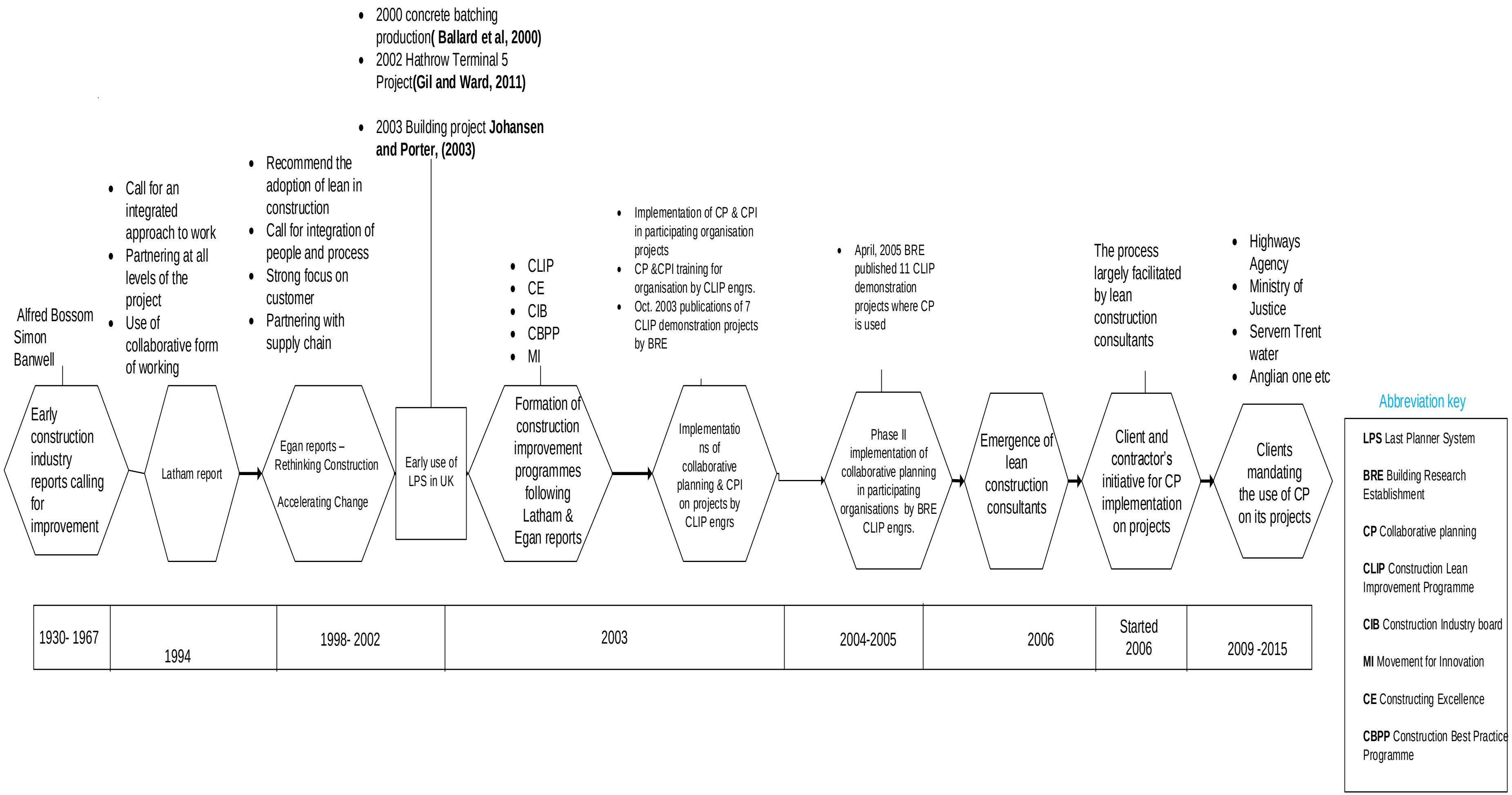

Figure 2. 2: Timeline highlighting the development of the Last Planner System and Collaborative Planning in the UK

Also, Gerry Chick of BAA commented that the LPS helped in "*delivering bad news early"* (Mossman, 2005), but keeps on top of what is happening.

Building on these early successes, the LPS was used in managing all the phases of construction on the Heathrow Terminal 5 project (BAA, 2000). The £4.2 billion mega project that lasted between 2002 and 2008 was managed with the LPS (Gil and Ward, 2011). Gil and Ward, (2011) observed that the Heathrow Terminal 5 project is viewed as an example of a successful mega project in the UK. At this point in time, Sir John Egan was the CEO of the British Airport Authority.

It is important to note that the early application of LPS in the UK is not limited to this alone, as other studies have reported the application of the LPS in the UK. For instance, Ballard *et al.,* (2000) reported the application of the LPS in concrete batching production for a UK contractor, while Johansen and Porter, (2003) reported the pilot implementation of the LPS on building construction project for a contractor- a joint research with the Northumbria University.

Following early application and benefits of this approach in construction, an increased call for the application of the approach was made. Various construction process improvement programmes were initiated to support the approaches of managing construction from lean production perspectives in 2003 as shown in Figure 2.2. Specifically, the formation of the Construction Lean Improvement Programme (CLIP) by the Building Research Establishment (BRE) in 2003, led to the implementation of "Collaborative Planning" (CP). CP was the name given to the approach used by CLIP for delivering process improvement on the demonstration projects. However, before this time, as shown on the timeline, the LPS and its collaborative planning elements had been developed, and also implemented in the UK construction industry (Ballard and Howell, 1998; Ballard *et al.,* 2002; Gil and Ward, 2011).

Furthermore, a comparison between elements of LPS in its earlier implementations in the UK with collaborative planning implemented by CLIP revealed some variations (Daniel *et al.*, 2014). The use of the term CP for describing the management of construction from a production planning and control perspective in the UK could be traced to the work Ballard and Howell on the LPS and the CLIP(Gil and Ward, 2011; Ballard et al., 2000; Clip report, 2006). Figure 2.2 reveals that in the

UK, big clients and contractors such as the Highways England (formerly Highways Agency), Ministry of Justice, Severn Trent Water, Anglian One, Carillion Plc, Shepherd Construction, and Costain Plc also use the CP approach. This is claimed to be based on the LPS principles. For instance, a current report claims that the LPS is commonly known as collaborative planning workflow within Highways England (HE) and across its supply chains (Atkins, 2013). Drysdale, (2013) and Fullalove, (2013) also reported that the LPS is commonly known as collaborative planning in the HE. However, how this claimed practice aligns with the advocated principles and theory of the LPS in reality is unclear, as it has been speculated that the LPS practice in the UK is stalled at collaborative programming (phase planning) (Sarhan and Fox, 2013; Mossman, 2009; Common *et al.,* 2000).

2.4 Emergence of Improvement Programmes in the UK Construction Industry

As shown in Figure 2.3, various construction improvement programmes were initiated to drive the recommended construction process improvement practice suggested in the reports. Some of these construction improvement programmes include; Movement for Innovation (MI), Constructing Excellence (CE), Construction Best Practice Programme (CBPP), and Construction Lean Improvement Programme (CLIP) among others. Most of these programmes were initiated following the recommendation of Latham report in 1994 and Egan reports in 1998 and 2002. Specifically, CLIP was formed in 2003 following Sir John Egan's recommendations for the adoption of lean principles in the UK construction industry (BRE, 2006).

2.4.1 Overview of the Construction Lean Improvement Programme (CLIP)

The Construction Lean Improvement Programme (CLIP) was established in 2003, by the Building Research Establishment (BRE) and Department of Trade and Industry (DTI). The creation of CLIP was a direct response to Egan report in *Rethinking Construction* that charged the construction industry to adopt lean practices from the manufacturing sector (Egan, 1998, Egan, 2002; Cain; 2004). According to Cain, (2004) the resistance of the construction industry to change is due to lack of migration of its managers to other sectors of the economy. Embracing lean philosophy, the CLIP objectives include: to improve UK Construction industry profit margin, address skills gap and offering of improved service to end users. It was argued that alot of lean literature seem to be theoretical. In view of this, BRE and DTI proposed a practical lean approach for skills development which they hope will bring change in the construction industry for greater benefit.

CLIP Engineers are those responsible for the implementation on site and in boardroom on practical basis. This is done in conjunction with the project team and staff of the company that intend to implement CLIP. From the pilot implementations on demonstration projects, it has been claimed that CLIP implementation has led to measurable progress on projects in terms of quality, cost, project delivery time, and improved relationship between the demand and supply chains (BRE, 2006). Although most of these benefits seem to be limited to the demonstration projects and subject to bias, it shows that with properly tailored programmes, the construction industry could also improve like every other industry. This result could mean that collaborative approaches have the potentials to improve the performance of the construction industry. According to Margerum, (2002) collaborative planning makes implementation of all phases of the project easy.

Generally, CLIP programme is designed to suit the need of the organisation, although it focuses on seven development areas in order to bring about the desired change in the organisation. The seven focus areas are shown in Table 2.2.

Table 2.2: The Seven CLIP Focus Development Areas

1	Product and process benchmarking and recommendations
2	Strategy development programme
3	Process improvement
4	Integrated supply chain development programme
5	Communication and team work development
6	Lean assessment
7	Company and project team roll-out programme

Source: BRE, 2006

Focusing on these seven areas shown in Table 2.2, CLIP expert engineers, in collaboration with the organisation, identify the problem areas in order to develop the right strategy. To achieve these set objectives, two fundamental approaches were commonly adopted by the CLIP engineers. These are; process improvement and collaborative planning, and integrated supply chain working as shown in Figure 2.3. The focus of this study is on the collaborative planning element.

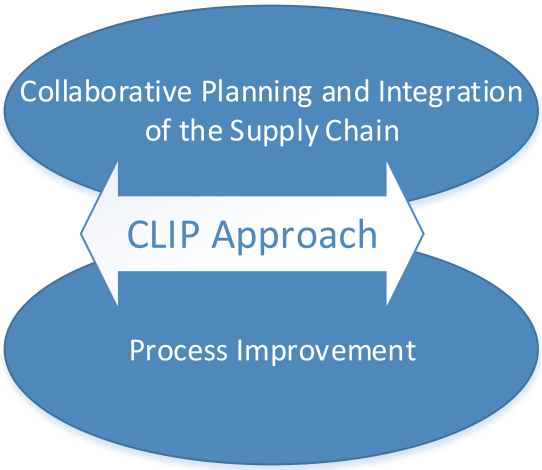

Figure 2. 3: Fundamental Approach of CLIP

Through this approach, CLIP has been implemented by over 100 UK based construction companies on demonstration projects. However, this is a small percentage of the over 280,000 construction businesses in the UK (Construction 2025 report, 2013).

2.4.2 Review of CLIP Pilot Projects

To understand the practice of production planning and control (PP&C) in the CLIP in relation to the LPS, the published CLIP demonstration projects reports were retrieved and analysed. Some of the CLIP demonstration projects are available at; http://www.constructingexcellence.org.uk/resources/themes/clip/clip.jsp, http://www.bre.co.uk/page.jsp?id=355. The aim is to understand the specific practice with regard to PP&C and the name given to the process. Twenty seven CLIP demonstration projects were analysed. From the review, it emerged that the practice of PP&C on the CLIP pilot projects is known as "Collaborative Planning" (CP). The CP practice reported from the demonstration projects are presented in Table 2.3. For confidentiality, the name of the organisations involved in the demonstration projects are not mentioned in this review, the projects are simply identified as demonstration project 1, 2, 3, …, 27.

Table 2.3: Collaborative Planning Practice Reported on CLIP Demonstration Projects

CLIP Demonstration Project	Collaborative Planning Practice Reported
Demonstration Project 1	• Initial workshop facilitated • Receiving feedback to identify value and culture • Early involvement of designer, contractor and suppliers • Open book and honesty • Planning with management team
Demonstration Project 2	• Relationship improvement with client • Collaboration in material planning and procurement • Collaboratively agree on milestones • Collaboratively plan and agree on project lead time • Virtual chart to help in collaborative planning • Brainstorming with all team members • Collaboration at pre-construction stage
Demonstration Project 3	• Collaborative agreement with client • Single specification sheet for suppliers with detail design
Demonstration Project 4	• Collaboration at pre-construction stage • Strategic thinking among team • Agreeing and breaking the project into manageable phases • Improved framework between client, contactor and supplier • Use of virtual framework
Demonstration Project 5	• Feedback to management and project teams • Analyse risk with client at early stage of project • Visual site management for better communication
Demonstration Project 6	• Display two week project plan on visual notice board • Involve client, supplier and supplier in planning process • Develop relationship with subcontractor • Identify common goal with team
Demonstration Project 7	• Get subcontractor involved early • Visual management board to improve communication • Bring subcontractor together to avoid conflict

	• Feedback to management and project teams
Demonstration Project 8	• Collaboration with suppliers • Working together to solve common problem • Improve in level and type of communication • Willingness to change • Management support
Demonstration Project 9	• Training and facilitation in form of workshops • Developing collaborative plan with team • Place collaborative plan on board
Demonstration Project 10	• Post-it note to show sequence of work • Display work plan over the next 5-6 weeks on board • Weekly site meeting to review progress • KPI to monitor contractor progress on board • Display productivity quality and H&S
Demonstration Project 11	• Tradesmen collaborative deliberation on H&S • Visual production board • Early involvement of Designer, contractor and suppliers • Holding of workshop to explain initiative • Using champions to monitor progress • Visual board for communication • Feedback to management and project team
Demonstration Project 12	• Involvement of client • Regular meeting with team members • Setting up work group • Subcontractors sharing office to build trust
Demonstration Project 13	• Visual management to aid communication • Site map photos, planned sequence of work • Safety report • Team commitment to work from the identification of project goals • Foremen, subcontractor involvement in weekly site meeting • Planning in details next activities in weekly site meeting • Workshop process facilitator

	• Early involvement of subcontractors to bring their expertise to bare
Demonstration Project 14	• Involvement of management in pre-diagnostic workshop • Weekly site meeting to review progress • Four week plan with all • Detailed plan of next week work with all • Use of visual management board • Early involvement of client to aid partnering • Involvement of all project team in site meeting to communicate 1 month project plan • Discussing in detail next week project plan • Early involvement of team and communication of benefits
Demonstration Project 15	• Involvement of subcontractor at the early stage of the project • Development of clear strategy for spreading lean • Pre-design planning to involve all team members • Allow all to make contribution to keep team committed
Demonstration Project 16	• Create sense of team ownership in the end product • Collaborative agree on project time scale • Plan information by CP • Common approach to working • Early agreement on aim, time and scale of project • CP on information and activities of work • CP in detailed planning of activities
Demonstration Project 17	• Greater involvement of subcontractors in project planning • Team work and communication • Team produce weekly plan • Review of previous plan by team to identify areas for improvement • Visual planning tool based on CP • Use of facilitator • Display of project status on board
Demonstration Project 18	• Planning with client, consultant and facilitator • Input from all project team at planning stage

	• Collectively identify problem • Specifying means of improvement collaboratively • Openness in planning • Trusting in team work
Demonstration Project 19	• Collaborative approach used to make order in advance • Collaborative approach used to improve flow of material to site
Demonstration Project 20	• Collaborative planning with designer, contractor and facility manager
Demonstration Project 21	• Participatory planning process by all • Trade men contribution • Sharing of lessons learnt • Team involvement and openness
Demonstration Project 22	• Early involvement of tradesmen • Working as an integrated team • Explaining benefit to all • Detailed planning • Use of facilitator
Demonstration Project 23	• Collaborative planning workshop with suppliers • Collaborative identification of what needs to be done • Group discussion on work plan • Daily site meeting • Weekly site meeting • Team working • Having time will suppliers to build relationship
Demonstration Project 24	• Use of facilitator • Visual management board to improve communication • Early involvement of subcontractor for input at planning • Documenting lessons learned
Demonstration Project 25	• Creating a collaborative environment • Team member interaction • Ownership of work belongs to team members

Demonstration Project 26	• Collaborative discussion of problems • Develop common understanding of what to be done • Feedback to project team • Stating lesson learned • Harnessing of ideas from team
Demonstration Project 27	• Detailed review of construction process at early stage

The report claimed that the use of CP on these demonstration projects supports construction process improvement. The approach encourages learning, prompt feedback on performance for participating organisation, and develops and sustains the skill of site operatives (Constructing Excellence, 2007). However, it is unclear from the reports where the learning occurs; if it is during or at the end of the project. This needs to be investigated empirically.

2.4.3 CLIP: Collaborative Planning Practice Review Discussed

Some of the CP practices in CLIP demonstration projects report as presented in Table 2.3 include; developing a collaborative programme with the project stakeholders from master programme, having 4-8 weeks look-ahead planning meeting sessions, having of weekly planning meeting to review previous week's work and plan for the coming week, display of work plan using post-it note to show sequence of works, collaborative working to identify and solve problems, use of visual management device to communicate progress, documentation and learning among others. However, the practices vary from one demonstration project to another. This shows that the current CP practice is not systematic.

The LPS process is based on five components which support collaboration through social conversations and the planning and execution of work with all the stakeholders on the project. LPS integrated components include; master plan, collaborative programming or phases planning, make ready process, production planning, production management and learning (Mossman, 2014; Ballard, 2000). The concept of LPS, its theories, and principles among others are fully discussed in Chapter Four.

Some of the production planning and control practices identified from the review such as the 4-8 weeks look-ahead planning, collaborative development of construction programme, and weekly planning meeting seen in the report could be likened to some LPS practices. However, the way this was done practically on the CLIP demonstration projects could not be ascertained from the review of the reports. The review indicated that other practices associated with the LPS such as make ready process, development of workable backlog, phase planning, measuring percentage plan complete, and recording reasons for non-completion among others were not mentioned in the report. This further makes it difficult to ascertain from the review, if the term "Collaborative Planning" used for delivering construction project from production planning and control perspective in the UK relates to the LPS of production control.

Furthermore, it has been speculated that the LPS is stalled at collaborative programming (phase planning) in the UK and it is viewed in the UK construction industry as an activity scheduling tool (Sarhan and Fox (2013; Mossman, 2009; Common, 2000). However, this claim is not based on empirical data. Also, no conclusive statement could be made based on the observed CP practices in the CLIP reports as they are based on desktop reviews. For instance, there is likelihood of bias in the CLIP CP practice reported since they are meant to be demonstration projects. Similarly, there is the possibility of omission of other practices from the report. This identified gap needs to be substantiated with empirical data through an industry wide study. This is also important considering that earlier implementations of collaborative planning in the UK through the CLIP revealed some variations (Daniel *et al.*, 2014).

2.5 Chapter Summary

This chapter explored the concept of collaboration, construction process improvement, and the development of collaborative planning in the UK construction industry. The review established that the demand for construction process improvement is not limited to the UK construction industry alone; rather it is a global call. More importantly, the review showed that the demand for construction process improvement was hinged on collaboration in the design, planning and in the execution of the planned task, especially as detailed in the UK construction industry reports. However, the lack of genuine framework for CP has retarded its application in the industry.

Furthermore, the review demonstrated that in order to achieve construction process improvement, an integrated approach in design, planning, and execution of task is essential. The chapter also revealed that though various construction industry reports were commissioned, the recommendations were not implemented, unless supported by the Government. Again, this shows the reluctance to change in the industry.

The review established that the earliest application of the LPS for delivering construction projects from a PP&C perspective in the UK was on the Heathrow T4 coaching gate, T4 Arrival phase 2 projects in 1999 and fully on Heathrow T5 project in 2001 by the BAA. This was followed by the Lean Construction Improvement Programme (CLIP) under the term "Collaborative Planning" (CP) which was implemented on demonstration projects. The review showed that the reported practice of CP on the demonstration project has some resemblance with the LPS while other elements of the LPS were not reported. However, this could not be substantiated from the review as empirical data from the industry is required for authentication. This became one of the knowledge gaps which informed research question one for the study, as presented below and also in Chapter One.

How does the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK align with the advocated principles and theories of the Last Planner System (LPS)?"

Among other things, this chapter contributes to literature on the need for an integrated approach in design, planning, and in the execution phase of construction projects and the vital role of collaboration in achieving construction process improvement. The next chapter (Chapter Three) brings in a wider perspective on the need for collaboration in planning by examining its development in other knowledge areas.

CHAPTER THREE: COLLABORATION IN CONSTRUCTION AND THE DEVELOPMENTS OF COLLABORATION IN PLANNING IN OTHER FIELDS: IMPLICATION FOR CONSTRUCTION MANAGEMENT

3.1 Introduction

Chapter Two explored the need for construction process improvement and the development of production planning and control practice based on the LPS in the UK construction industry. This chapter brings in a wider perspective to this, by exploring the concept of collaboration and collaborative working (CW), and the development of collaboration in design, planning, and execution of work in other fields. Specifically, it reviews the development of collaboration in Urban Planning (UP) and in software development. The first section examines the current state of collaboration and CW in the construction industry. It further reviews and presents the current state of construction planning. The chapter highlights the development of collaboration in planning in UP.

It also examines how software development progressed from the use of the waterfall process model to the agile process models. The Rational Comprehensive Model (RCM) used in UP is compared with the Critical Path Method (CPM) in construction. This chapter contributes to construction planning theory and construction project management practice, and analyses how collaboration in construction planning can be improved using learning from other knowledge areas.

3.2 The Concept of Collaboration

The term collaboration or to collaborate is gaining prominence in businesses such as information technology, organisation development and service delivery because of its unifying role and its benefits. According to Shelbourn *et al.,* (2005) various researches on collaboration with regard to information technology have been conducted and the crucial role the human element plays in achieving collaboration has been recognised. Wilkinson, (2005) observed that collaboration is not restricted to information technology alone, as there is the human and organisational aspect of collaboration. The Cambridge Business dictionary (2015) states that "collaboration is the act of working together with other people or organisations to create or achieve something". However, this definition varies from how the term is used in the construction industry (Xue *et al.,* 2010).

Schrage, (1990 pp20) defined collaboration as "the process of shared creation between two or more individuals with complementary skills interacting to create shared understanding that none had previously shared or could have come to on their own". This implies that the underlying principle of collaboration is that there must be an interaction between the parties which will culminate in the creation of shared understanding for both parties. Similarly, Shelbourne *et al.,* (2012) opined that collaboration is a process in which a group of people or organisations agree to deliver a task by sharing their expertise, information, and knowledge, with all, working as a team to achieve the intended product in a shared environment. The shared environment could use physical (human interactions), digital or virtual resources in the collaboration process. Collaboration also implies that the team is properly integrated to work, so as to achieve the overall project goal. It is worth noting that integrated working tends to be used in relation to information technology in a virtual environment while collaborative working is used in relation to face to face meetings. However, in this study, both terms are used interchangeably to explain the concept of collaboration.

Attaran and Attaran, (2007) maintained that collaboration does not only include the joint working of two or more organisations. They went further to state three core criteria that must be satisfied which are; (1) having shared common information (2) ensuring plans are made based on the shared information and (3) executing the planned task collectively rather than individually. Again, this suggests that collaboration does not just occur by going into joint venture with an organisation in which each organisation still acts independently with the aim of achieving the goal of their individual organisations in the joint venture.

3.2.1 Current State of Collaborative Working in the Construction Industry

Collaborative working (CW) is a common term used to denote collaboration in the construction industry. CW is concerned with the joint working of all stakeholders on the construction project, to efficiently and effectively deliver the project to the specified standard (Xue *et al.*, 2010). Another closely used concept with regard to CW is partnering. According to Wu et *al*., (2008) partnering is a type of CW. But, they however, argued that partnering is only an aspect or an element in CW. This means CW is wider in scope than partnering. It is worth noting that it is possible for organisations to claim to be partnering, but never work collaboratively (Pasquire *et al*., 2015a; Udom, 2013; Wu *et al*., 2008). The concept of collaborative working is gaining more attention in the construction industry, both at the organisational and project levels. This is because the knowledge and technical ability needed to deliver a project is dispersed across the project team members (Hayek, 1945). However, some organisations who claim to be involved in collaborative working still base their working practices on the traditional project management model. Wilkinson, (2005) argued that collaboration cannot be easily achieved in the traditional hierarchical organisational system which characterises the construction industry.

Also, Xue *et al.*, (2010) and Baiden *et al.*, (2006) opined that in the current traditional approach to procuring projects, construction project stakeholders tend to seek their individual benefit at the expense of the collective goal of the project; this hinders CW among the stakeholders. In reality, this approach to working will hinder the industry from reaping the benefits of CW. According to Baiden *et al.*, (2006) and Evbuomwan and Anumba, (1998), time and cost overruns are common occurrences on construction projects, which is partly due to the lack of collaborative working among the stakeholders. For instance, in the UK construction industry, a current report indicates that about 50% of construction projects experience both cost and time overruns (Crotty, 2012).

It can be argued that some so called CW arrangements put in place by organisations lack the capacity to develop into genuine collaborative relationships among the stakeholders on the project due to adversarial attitudes and hierarchical structures. This is because some of the projects still operate based on a claim and blame culture with a focus on individual benefit. This characterises the traditional approach of managing construction projects and is a coherent paradigm (Pasquire *et al.,* 2015a). Udom, (2013) observed that CW seems to exist in principle rather than in practice. It was further observed that on some of the projects that claim to be applying CW, not all the participants on the project were allowed to sign into the collaborative contract. This could be due to the quest by the parties on the project to safeguard their individual interests which promotes a transaction rather than relational approach (Pasquire *et al.,* 2015a).

According to Briscoe and Dainty, (2005) construction clients distrust their main contractors while the main contractors also keep their subcontractors at a distance This implies that for genuine CW to develop, trust and openness must exist among the stakeholders (Latham, 1994). Udom, (2013) suggested that in developing CW beyond the contractual provisions, soft skills such as having regular meetings with all the stakeholders on the project should be encouraged. This is an integral part of the LPS that focuses on managing of tasks and networks of relationships in production (construction) from a production perspective (Ballard *et al.,* 2009).

In this approach, construction planning is done collaboratively with those executing the work. However, this seems to rarely exist in the current state of collaboration in the construction industry. For instance, Daniel *et al.,* (2016), Daniel *et al.,* (2015a) in a study in the UK observed that subcontractors are not fully involved in the planning of task on a project that claims to be using some form of CW. This will not only result into the development of unrealistic plan, but also lower commitment to the plan by the subcontractor. This implies that without a realistic and genuine CW culture, collaboration in construction planning in the project environment cannot be achieved.

3.3 Collaboration and Construction Planning

3.3.1 Concept of Planning

Planning has been identified as a major project management function. The Project Management Body of Knowledge (PMBOK) defines planning as “the process of devising and maintaining a workable scheme to accomplish the business need that the project was undertaken to address” (PMI, 2015). Planning entails the various course of actions required for successful completion of a task. According to Cardwell and Redican, (2009, pp 1) “Planning is an activity devoted to clearly identifying, defining, and determining courses of action before their initiation, and necessary to achieve predetermined goals and objectives”. These definitions of planning suggest that planning alone cannot guarantee the achievement and the quality of the planned task. In view of this, Morton, (2007) argued that planning at its best could meet the yearning of the people and at the other times it could generate conflict. This implies that not all forms of planning benefits the stakeholders equally.

There are compendium of literatures on various forms of planning such as communicative planning, argumentative planning, planning through debate, inclusionary discourse, and collaborative planning in different fields (Guton and Day, 2003; Allmendinger, 2002; Mortun, 2007). According to Johansen, (1995) there is no general definition for planning.

For instance, Lichfield, (2013) remarked that planning refers to series of activities designed to provide an understanding on a problem that needs examination. While the Cambridge Advanced Learner’s Dictionary (2015) defines planning as “the act of deciding how to do something”. This shows that the term planning could have different meanings in different fields. Basically, there are three levels of planning; strategic planning, tactical planning and operational planning (PMI, 2015). While strategic planning, also known as ‘management planning’ focuses on the long-term plan of the organisation, operational planning focuses on the short-term plan with specific objectives for a particular section or area of work (Shrader *et al.*, 1989). Tactical and operational plans support the achievement of the strategic plan. In practice, day to day operational planning is usually done by the field and lower level management. For example, operational planning (OP) is used in managing the day to day activities on construction projects and also in the military on the battle front.

3.3.2 Overview of Construction Planning

Planning is an essential undertaking in construction project management. For instance, Stevens (1993) and Turner, (1993) observed that without planning, construction projects cannot be managed successfully. Little wonder a lot of time is committed to planning when beginning projects generally. It has been observed that construction and project managers spend 33% of their time in planning and coordination (Mustapha and Langford, 1990). This shows the vital role of planning in construction management. According to Faniran *et al.*, (1998) construction planning is the approach used to arrive at the right strategies to be used in achieving the predefined project goals and objectives. Also, Hayes-Roth and Hayes-Roth, (1979) opined that planning is concerned with the predetermination of what is to be done with the sole aim of achieving the specific goal of the project, but predominantly people goals. The definition of planning in Hayes-Roth and Hayes-Roth, (1979 pp 275-276) seemed to be highly supported and used in construction management research by the likes of Birrel, (1980); Laufer and Tucker, (1987); Johansen (1995); and Ballard, (2000).

Planning in construction could be viewed from two perspectives; the first part being "planning" and the second "control" (Hayes-Roth and Hayes-Roth, 1979). Planning determines what needs to be done and control focuses on monitoring the task that has been planned and modifying it as information evolves. Furthermore, Johansen, (1995) observed that researchers in construction management view construction planning from two perspectives; planning techniques and their improvement, and the planning process. This explains why construction planners and managers tend to separate project planning from project control which dominates the traditional approach to managing project.

Faniran *et al.*, (1998) argued that the goal of construction planning is to execute the prescribed amount of work at the right time, on cost and to the specified quality standard. However, previous studies confirm that most construction planning efforts have not truly achieved the target (Laufer and Tucker, 1987; Coheca *et al.*, 1989; Ballard and Howell, 2004). For instance, Ballard and Howell, (2004); Ballard and Howell, (1988) observed that in construction, only 54% of planned task are achieved as planned. This could be due to too much focus on planning techniques rather on the planning process, or lack of collaboration. Also, the attempt to separate "planning" from "control" could contribute to this (Ballard, 2000; Faniran *et al.*, 1994). In view of this, Faniran *et al.*, (1997) suggested that the research focus in construction planning should be tailored towards improving the planning process rather than on planning techniques through the adoption of lean production principles that support collaboration.

3.3.3 The Current State Construction Planning and Collaboration

The current state of planning in the construction industry has been criticised. Faniran *et al.,* (1997) observed that the current focus of construction planning is on forecasting project performance based on the specified milestone, with less regard to the process to achieve it. Due to this, planned tasks are usually pushed to conform to the predetermined milestones. Also, only a little time is invested in the planning, while much emphasis is on project control as soon as construction commences on site. For instance, Johansen, (1996) observed that construction managers and project managers complain of lack of time to engage in detailed planning. In addition to this, there could be insufficient details while developing the plan. All these further heightening the uncertainty in the construction process.

Uncertainty and variability are common features associated with construction planning. Laufer *et al.*, (1992) observed that uncertainty is an integral element in construction, and further argue that the higher the uncertainty, the less effective the planning. The impact of uncertainty and variability in workflow in construction has been identified. Tommelein *et al.,* (1999) showed the effect of variability on the performance of construction trade through simulation. Ashley, (1999) revealed the impact of the uncertainty on construction planning and cost. Even with these empirical evidences, current construction planners and managers seem not to acknowledge this in the planning process. Most times, plans are too detailed, too early, and too rigid with less care for inherent uncertainty in the construction environment (Faniran *et al.,* 1998; Ballard, 1995). Also, it has been observed that construction planners tend to ignore the inherent uncertainty in the construction process in planning (Ballard and Howell, 2004; Arditi, 1981).

Johansen, (1995) presented two opposing views to the concept of uncertainty in construction; hard and soft approach. He argued that the hard system approach school of thought centres the success of the construction programme around a rigid production of plan based on network analysis and monitoring of the critical path. While the soft system approach school thought believes that the rigid approach cannot yield the intended result because of the inherent uncertainty and complexity in the project environment. This soft approach to construction planning is deficient in the current planning practice in the industry as observed in Johansen, (1996).

Daniel *et al.,* (2014) observed that the current approach used in construction planning is based on Rational Compressive Model (RCM). The RCM view planning as a rigid and scientific process and claims that the knowledge needed for planning is with planners alone. The RCM approach dominates the Critical Path Method (CPM) which is now used in construction planning. This approach hinders collaboration and barriers other stakeholders from contributing to the planning process. However, Hayek, (1945) argued that the knowledge needed for planning is usually dispersed among the stakeholders. Due to the inability of the hard approach and RCM model to support collaboration and manage uncertainty, other soft approaches such as the LPS are increasingly used in managing construction project (Daniel *et al.,* 2015; LCI, 2015; Gonzalez *et al.,* 2007; Alarcon *et al.,* 2005).The LPS is described in Chapter Four.

It can be argued that the level of collaboration in construction planning is very low compared to other industries, thus hindering the performance of the construction industry. The next sections examine the development of collaboration in planning outside construction management literature and identify the implications for construction project management practice and theory.

3.4 Development of Collaboration in Planning in other Fields

3.4.1 Historical Development of Collaboration in Urban Planning

The approach to planning in North America at the end of World War II was based on what is called Rational Comprehensive Model (RCM) or technocratic planning (Guton and Day, 2003 Mortun, 2007). This school of thought views planning as a technical and scientific discipline which can only be performed by experts without any form of input from the community (Guton, 1984; Susskind, 2000; Wondolleck and Yaffe, 2000). According to Susskind *et al.,* (2003) technocratic planning is mainly concerned about the efficient use of resources. In view of this, government through the planners imposes planning decisions on the community without stakeholders' participation.

Figure 3.1: Development of collaborative planning model in Urban and Regional planning

Source: Susskind *et al*., 2000.

However, in the 1960's the technocratic model of planning was greatly challenged because of its many shortfalls, especially, the lack of representation of stakeholders' views in the decision making processes (Guton and Day, 2003 Mortun, 2007). Figure 3.1 shows the progression from the RCM to the collaborative planning model in UP.

3.4.1.1 The Rational Comprehensive Model of Planning

As earlier mentioned, the RCM dominated UP in North America after World War II. According to Susskind *et al.,* (2000) the RCM views planning as the singular responsibility of the planner who is seen to be the expert in making major decisions on assignments to be executed. The champions of the RCM believe that planning is a technical undertaking that uses scientific principles, thus decisions should be left in the hands of the planning experts (Guton, 1984; Beierle and Cayford, 2002). The fundamental contention is in the area of individual rationality and collective rationality (Stiftel, 2000). While collaborative planning model in UP believes in collective rationality, the RCM does not.

The failure of RCM led to the development of other models that allow for collective public participation in the planning and decision making process such as advocacy planning and collaborative planning models.

3.4.1.2 Advocacy Planning Model

Advocacy planning came into being due to the shortfall of the RCM. The origin of advocacy planning could be traced to the work of Davideoff published in 1965 in the Journal of American Institute of Planners (Mazziotti, 1971). According to Susskind *et al.*, (2000) the proponents of advocacy planning aim at empowering the stakeholders or interest group to fully represent themselves in the decision making process. This approach gives stakeholders an opportunity to contribute to the planning process, and could lead to innovation.

However, Stiftel, (2000) argued that this approach could be taxing and demanding. This suggests that adopting collaborative approach in the advocacy planning model requires commitment from all the stakeholders.

3.4.1.3 Collaborative Planning Model in Urban Planning

The collaborative planning model is a step ahead of advocacy planning, although both are based on a singular goal; that is the collective participation of the stakeholders in the planning and decision making process (Stiftel, 2000; Susskind *et al.*, 2000). The collaborative planning model has its unique characteristic that distinguishes it from other forms of planning as shown in Table 3.1. The collaborative planning model is a consensus based planning approach that brings all the stakeholders together with the sole aim of collectively devising the best means of attaining the intended goal (Morton, 2009; Cardwell and Redican, 2009). The major target of collaborative planning is to create a platform for stakeholders' participation before decisions are made. Although this approach to planning has been criticised, that it tends to take away power from those it has been vested with (Allmendiger, 2002; Hearley, 2003).

Table 3.1: Rational Comprehensive Model Compared with Collaborative Planning Model

Descriptors	**Technocratic (Traditional) Planning Model**	**Collaborative Planning Model**
Tasks	Planner operates as technically skilled decision maker.	The planner is concerned with achieving efficiency through trust and concession building.
Focus of Activity	Plan produced based on best solution assumed by selected decision makers.	Ensures interest of all stakeholders is considered.
Products/Solution	Comprehensive plan for allocation of resources.	Negotiated agreement that is fair and achievable.
Skills	Technical skill in preparing efficient plans.	Facilitation of interaction with stakeholders to produce detailed plan.
Primary Client	City planning commission and decision makers.	All stakeholders.

Basis of Planned Task Legitimacy	Having technical expertise in the chosen work.	Achieving mutual agreement with all stakeholders.

Source: Hearley, 2003; Allmendiger, 2002; Susskind *et al.*, 2000.

It has been observed that the increased understanding developed through the collaborative planning process contributes to effective CW and support innovations (Kastalli and Neely, 2006

3.4.2 Critical Path Method and Rational Comprehensive Model in Planning

The use of RCM in decision making in UP is similar in the use of CPM in construction planning. The CPM developed in the 1950s was used to develop formal construction programmes (Koskela *et al.*, 2014; Senior, 2007; Kelley and Walker 1959). The CPM approach is the process of developing construction programme right from pre-construction to commissioning using activity breakdown structure to generate list of activities. It is usually done by the expert construction planner. According to Koskela *et al.,* (2014) the CPM has been hailed as one of the most important innovations in construction management in the 20th Century. It is not only advocated for by clients and construction professionals, but also taught in most construction management programmes (Senior, 2007). Despite its popularity, it is less used by field workers in managing the construction process on site. Senior (2009) observed that the low use of CPM by site workers is due to its unrealistic nature emanating from the non-involvement of those doing work (the site workers) in the planning process.

According to Happin, (1993) the CPM approach focuses on the “What” instead of the “how” of an activity which makes programmes developed based on it of no value to workers on site. The focus of the CPM includes, but is not limited to; what is the start date? and what is the finish date?. These are usually arrived at based on the planner’s experience. The approach used in scheduling activities in CPM is a prototype of how planners make planning decisions in UP using the RCM, where only the planner decides what is best for the community. As expected, most planning decisions made based on the RCM are of low benefit to the community. So also is the scheduling decision made based on CPM to the team working on site.

Docherty, (1972) observed that programmes developed, based on the CPM tend to decorate the site office wall, while work execution on site are usually managed by short term planning by site workers. This suggests that the CPM in construction lacks the capacity to develop a collaborative relationship. This was also evident in the use of RCM in UP. This shortfall in the RCM informed the agitation for the adoption of more collaborative approaches in planning and allocation of resources in the UP in the 1960s. However, in construction collaboration in planning needs to be supported with a standard operational planning framework, such as the LPS for construction projects.

3.5 Collaboration in Planning: Search in Software Design

The term "Software engineering or design" came into limelight in the late 1950's and 1960's. Specifically, it is believed to have become an official profession following the NATO Science Committee conference held in Germany in 1969 (Rayl, 2008). Software engineering is the process of designing and managing the complex processes involved in the development of programmes to meet customer satisfaction (NATO Science Committee, 1968). In a bid to satisfy its users, software engineering design has experienced various forms of challenges which was termed "software crisis" which resulted in both extreme time and cost overruns especially in 1968, 1979, and 1985 (NATO Science Committee, 1968).

The approach used in planning and developing of software was also among the factors that contributed to the crisis experienced. According to Highsmith and Cockburn, (2001) the traditional approach used in software design tends to focus on how to conform design to plan, which in reality is not achievable and contributes to time and cost overruns. To overcome these challenges, various planning models have been adopted in the software development process as shown Figure 3.2.

Figure 3.2: Development of collaborative planning in software design

Source: Munassar and Govardhan, 2010; Dyba and Dingsoyr, 2008.

These process model includes the waterfall model, V-Model, Incremental model, iterative and the agile models such as Extreme programming, Scrum, and Adaptive software development among others.

3.5.1 Waterfall Process Model

It is the oldest classical model used in the planning of software engineering design. Munassar and Govardhan, (2010) observed that the model is used extensively in government projects and in many organisations. The approach is based on sequential and structured steps which must be adhered to by the designer as indicated in Figure 3.3.

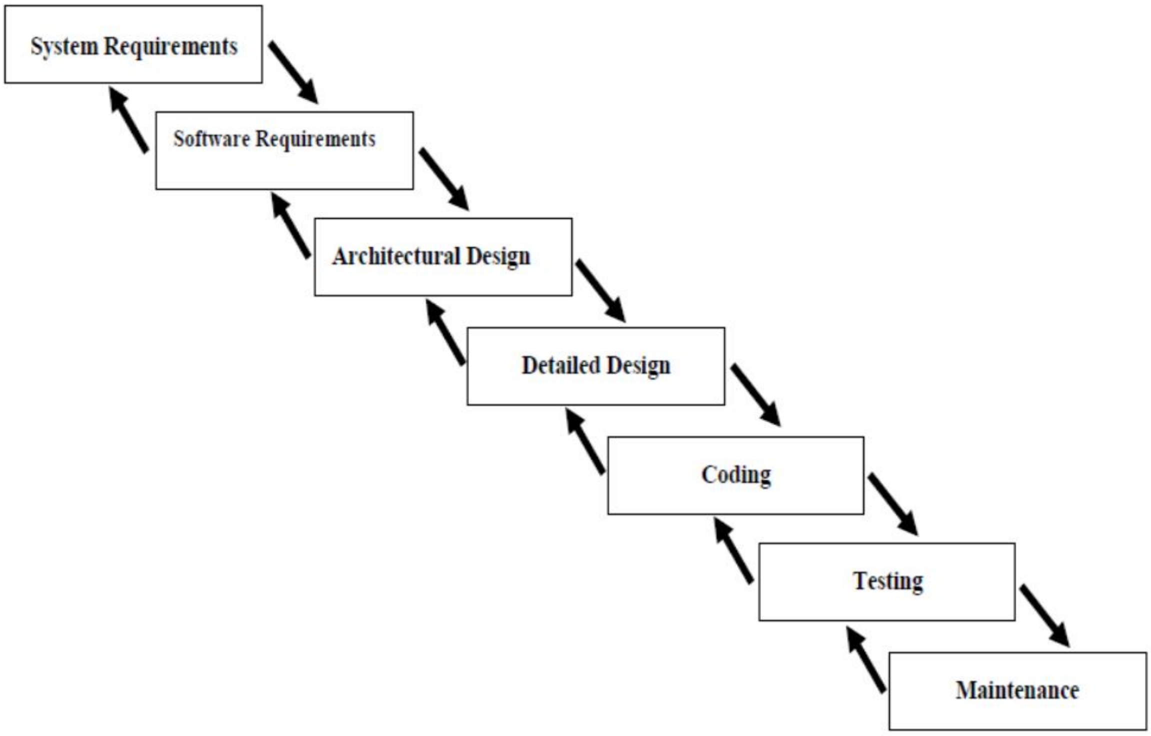

Figure 3.3: Waterfall process model

Source: Munassar and Govardhan, 2010

According to Jaitly, (2014) the traditional waterfall software programming or planning approach focuses on the process rather than on the people and the customer. As shown in Figure 3.3, the process could be likened to the network diagram used in construction programming which is based on the critical path method, where the focus seems to be on the link between each activity. For instance, Hahmann, (2006) stated that the model enables customers to get a defined process at the beginning of the product development. In reality, it is usually impossible to obtain all the requirements for software development at the onset of the project due to external factors that could arise from the environment (Highsmith and Cockburn, 2001).

The task of defining the entire goal of the project (detail planning) at the onset is similar to the assumption used in designing construction programmes based on the CPM. In CPM, no consideration is given for the inherent variability and uncertainty in the production process and information is based on previous projects, so it looks backward rather than forward.

3.5.2 Iterative Process Model.

The iterative process model focuses on overcoming the problems presented in the waterfall process model. The goal of the iterative process model is to allow for flexibility in the planning process while also providing quicker information to the team and reducing upfront information overload (Munassar and Govardhan, 2010). This is opposed to the waterfall process model in which the planning process is structured and rigid. Marciniak, (2001) and Wirth, (1971) opined that in the iterative process model, development occurs through the refinement and improvement of the successive process using the learning acquired from each stage of the development.

The approach allows the team to determine the feasibility of the product early enough and for outright feedback from the prospective users and customers.

3.5.3 Agile Process Models

The Agile software development process shows a clear departure from the traditional classical approach to software development. It is a movement initiated with the goal of developing a faster, cheaper, and better solution to overcome the problems in traditional approach (Dyba and Dingsoyr, 2008). According to Dyba, (2000) the movement was initiated to overcome the traditionalist view that tends to emphasise a rigid engineering approach to the design process. The "traditionalist" believes that through comprehensive planning based on the knowledge of the planner, the planning process could be made efficient without considering the variability in the environment (Boehm, 2002). In contrast to this, the Agile process model sets to overcome the variability in the process by depending on people rather than on techniques alone. The unique feature of the Agile process is that it is developed around the customer and users (Jailty, 2014). Ericksson *et al.*, (2005 p89) gave a vivid definition of agility in relations to software development: "agility means to strip away as much of the heaviness commonly associated with the traditional software-development methodologies, as possible to promote quick response to changing environments, changes in user requirements and accelerated project deadline and the like". Some of these Agile methodologies include Scrum , Extreme programming etc.

3.5.3.1 Scrum

Scrum is an Agile process model methodology used in software development. It is meant to overcome the uncertainty associate with software design (Schwaber and Beedle, 2002). Unlike the traditional classical process models, it incorporates the social value (human) element in the development process. The approach is used in in the development of products with tight timeline and changing business requirements (Pressman, 2005). It entails two key processes; the *backlog stage* and *sprint stage*. The *backlog* refers to the activities to be undertaken by the team while the *sprint* refers to the work that is already at hand to be done by the team and it occurs in phases. Koskela and Howell, (2002) perceived that the theory behind Scrum approach is based on management-as-organising, language action perspective and theory of flow and value. The LPS is also based on the above theories.

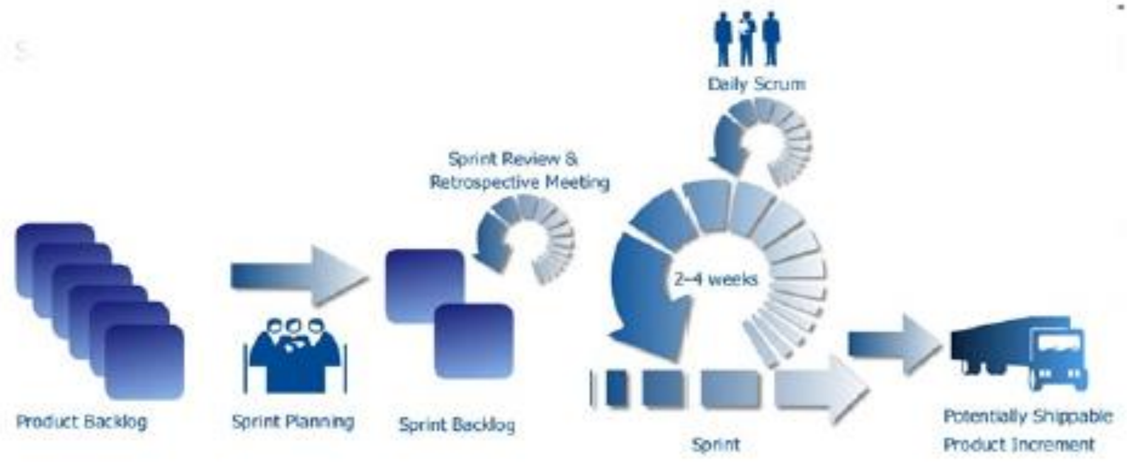

Figure 3.4: The Scrum Process

Source: Schwaber and Beedle, 2002

The approach allows the team to self-organise work collaboratively in the software development process. Rising and Janoff, (2000) stated that in the s*print* process, the project team makes promises on tasks they are confident could be done within the chosen sprint as shown in Figure 3.4. The sprint period could be likened to the production planning stage in the LPS, where the last planners are expected to make reliable process (Pasquire *et al.*, 2015, Ballard, 2000; Ballard, 1994). Also, at this stage, the plans are made visible with input from other stakeholders on the project. Specifically, at the end of the sprint, a more feasible and realistic programme is developed. The backlog (that is the task to be done) is usually reviewed and reasons for non-achievement of the backlog are identified and acted upon.

Other processes associated with Scrum include; daily and monthly Scrum meetings, absence of work breakdown structure, identification of impediment at daily Scrum meeting, and viewing teams as direct customers to each other. This approach is a total deviation from the traditional doctrine of project management where all programmes of work must be centralised before being dispatched to the work phase. Koskela and Howell, (2002) offered a theoretical insight on the success of Scrum as a project management approach.

3.6 Comparing the CPM, RCM, Collaborative Planning and the LPS

With the examination of the CPM in construction, RCM in UP, collaborative planning model in UP, and the Agile model in software development, these are now compared with the LPS in Table 3.3. The focus of the collaborative planning model in UP is on the full engagement of all the stakeholders in the decision making process. Some of these principles were demonstrated in the Scrum process in the Agile methodology and in the LPS. For instance, the development of tasks in Scrum is decentralised to allow all stakeholders, including the customer to make input so as to arrive at a realistic estimate.

Rising and Jannof, (2000) confirmed that at the end of the sprint process, more realistic estimate in terms of durations are arrived at as a result of input from all the stakeholders on the project. Furthermore, in software development using Scrum methodology, teams are direct customers to each other including the client (Koskela and Howell, 2002). Also, in the collaborative planning model in UP and in the LPS, all the stakeholders in the planning process are viewed as the primary client and customer. This is contrary to the CPM and RCM approaches that tend to view only the project financiers and the planning authority as the primary client or customer.

However, collaborative planning and RCM (in UP) and CPM (in construction) differ from the Scrum method (in software design) and LPS in the nature and structure of planning. While the nature of planning in UP and CPM is strategic or management planning, it is operational planning in Scrum and the LPS.This suggests that the collaborative planning model and CPM approaches alone, cannot be used to manage short term planning on a construction project.

A closer look at Table 3.2 also shows similarities between the agile methods such as Scrum and the LPS. For instance, the LPS supports the idea of stakeholders' engagement and involvement in a collaborative manner in phase planning, and Weekly Work Planning (WWP) meeting among others as practiced in the sprint.

Furthermore, the publication of the Percentage Planned Complete (PPC) and Reason for Non-Completion (RNC) in the LPS for team learning and improvement are similar to the visual progress monitoring approach used in Scrum. Though similarities exist between Scrum and the LPS; however, Scrum is less developed as it cannot be used in managing complex projects (Dyba and Dingsoyr, 2008).

In addition to this, its application is still limited to the design stage because of the industry it operates in. The LPS is not only applicable to complex projects, it is also used in design, construction, ship building, and mining among others (Daniel *et al.*, 2015). Also, there are empirical evidences that the LPS has been implemented in 16 countries that cut across all the continents of the world with good output (Daniel *et al.*, 2015). This show that the LPS is and still remains the most advanced production planning and control for construction project management.

Table 3.2: Comparing CPM, RCM, Collaborative Planning in UP, Agile process model and the Last Planner System

Fundamental Processes	CPM (Construction)	RCM (Urban Planning)	Collaborative Planning in (Urban Planning)	Agile process model (software design)	Last Planner System
Level of planning	Comprehensive, disciplined plan with long term focus	Detail and comprehensive plan Long term	Long term, but in consultation with stakeholders and flexible	Continuous control of requirement and short term focus	"Only plan in detail as nearer the task" with a short term plan focus (Phase scheduling, WWP). Note: The Phase Scheduling is usually developed from the master programme.
Communication	Consultation absent	Consultation absent	Consultation	Consultation	Consultation
Review	Review after task completion	Review absent	Review before decisions are made	Review process embedded in the development process (Sprint reviews)	Review embedded in the production planning process (PPC measurement, RCN)
Management style	Command and control	Command and control from planner and planning authority	Leadership and collaboration with the stakeholders	Leadership and collaboration	Collaboration and empowerment of "last planner"
Knowledge management	Explicit	Explicit	Tacit	Tacit	Tacit
Focus	Rigid and process focused	Rigid approach	Flexible and community focused	Flexible and human focused	Understand the presence of variability in production and human focused
Feedback	Only management gives feedback	Only management gives feedback	Everyone gives and get feedback	Everyone gives and gets feedback	Everyone gives and gets feedback
Primary Client	Project sponsor or owner	City planning commission and decision makers.	All stakeholders in the community	Intended customers and the software designer	All the stakeholders on the project
Nature of plan	Strategic planning	Management planning	Management planning	Operational planning	Operational planning
Basis of Planned Task Legitimacy	Technical expertise in the const. planning	Technical expertise in Urban planning	Endorsement of all stakeholders in the community	Input and agreement with customers and designers	Input and agreement with the 'last planners'

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3.7 Development of Collaboration in Planning in other Fields: Implication for Construction Project Management

3.7.1 Implication for Construction Project Management Practice

These developments (changes) in the field of UP and in software development in the approach towards planning should serve as a great learning point for construction project management practice. For instance, the RCM that previously formed the basis of planning decisions in UP has been established to form the basis of planning practice in the construction industry as seen in the CPM. However, with the realisation of the negative impact of the RCM approach to planning decisions, the urban and regional planning profession opted out of the RCM approach to advocacy planning model and collaborative planning model (Morton, 2009; Stiftel, 2000; Mazziotti, 1971). This suggests that the RCM that views planning as a scientific discipline and claims that the knowledge needed for planning is with the expert planner alone, is an illusion that needs to be avoided.

In view of this, construction management practice should also move from the current practice where planning decision is left with the construction planner or the planning engineer alone. Although, Hayek, (1945) made this assertion many decades ago, that the knowledge needed for planning is not in the hand of a single individual, but rather dispersed among people. This reality is yet to be fully accepted in construction project management practice. Leaving the planning decision to the expert planner alone, means the planned duration will largely be based on guess work. Johansen and Greenwood, (1999) observed that relying on the knowledge of the planner alone to decide on activity duration is always a guess work, which contributes to the high level of uncertainty in construction planning. It can be argued that the failure of construction project management with regard to planning is due to its focus on rigid planning techniques than on adopting planning processes that are more collaborative and efficient. According to Faniran, (1994a) and Cohenca *et al.*, (1989) even with the emergence of various planning techniques, construction planning has not been able to improve the efficiency of construction project management practice.

The change experienced in UP and software development with regard to improved planning practice could be attributed to the inclusion of people and process into the planning and decision making system, rather than rigidly focusing on planning techniques alone. For instance, Faniran *et al.*, (1997) suggested that construction project management should improve the efficiency of the industry by focusing on improving the construction planning process instead of holding on to rigid planning techniques alone. Furthermore, the incorporation of human elements in UP (collaborative planning model) and software development (Agile process models) contributed immensely to the development of collaborative approaches in the fields.

The importance of the human element (social) as opposed to the technical element in construction project management has been emphasised (Ballard, 2000; Brasen *et al.*, 2003). This approach was demonstrated in the planning and allocation of space in UP, in software development and the LPS. For example, in the Scrum approach, the client and all the other stakeholders in the software development process are fully involved and seen as direct customers to each other. This improves the level of conversation and commitment to the task, thus improving the quality of the final product (Jannof and Rising, 2000). As seen in this approach, the focus is not on a single individual in the team, but rather the teams are self-organised to deliver the task. This implies that construction project management should create the environment that could empower all stakeholders to make a contribution, especially in the construction planning process.

The collaborative approach to planning has the potential to empower teams to communicate and make a useful contribution to the planning process (Pasquire *et al.*, 2015; Mossman, 2014; Daniel *et al.,* 2014; Ballard, 200). The need to adopt this approach in construction planning is now more crucial considering the uncertainty associated with construction planning (Faniran *et al.,* 1997; Johansen, 1995).

Gonzalez, (2008) observed that the failure of construction planning does not only contribute to poor construction management decisions, but also the failure in construction project management practice. Considering the fact that the variability and uncertainty are inescapable in construction planning and in a project environment in general, the goal therefore should not just be on how to stop change by focusing on rigid and long term plans. Rather, the goal should be on how to handle the inevitable changes that could occur over the life of the projects. This can be done by focusing on short term plans and planning in detail as close to the task as used in software development and the LPS (Highsmith and Cockburn, 2001; Ballard, 2000). Construction project management practice must come to term with the current realities in the project environment in order to improve practice.

3.7.2 Implication for Construction Project Management Theory

The evaluation of the development of collaboration in planning in other fields has implications for construction project management theory. This is crucial as various construction management scientists would argue that there is no uniform theory guiding the construction management practice (Koskela, 2000; Harris, 1998; Halpin, 1993). For instance, Halpin, (1993) opine that if there is any theory for construction management, such theory is still in hiding. Also, Koskela, (2000) acknowledged the fact that there is no defined theory guiding construction management practice. He, however showed that the current practice in construction project management is based on the theory of production that emerged from economics. Koskela therefore postulated that the concept of Transformation, Flow, and Value (TFV) be adopted as the fundamental theory to build construction project management upon (Koskela, 1992).

In reality, the current practice of construction project management is only limited to the '*transformation view'*. The *transformation view* entails the conversion of input into output. The RCM used in UP in the planning process could be said to be based on the *transformation view* theory. So also is the Waterfall process model used in software development and the traditional approach to planning in construction which is based on CPM. This is so, since the tenet of the *transformation view* is on how tasks would be executed effectively following a defined or structured process without considering the influence of external phenomena. Koskela, (2011) argued that the focus of the *transformation view* is on task management. As good as this may look, it lacks the capacity to manage variability and meet customer requirement. This would mean that the application of *transformation view* alone in construction project management and planning lacks the capacity to mitigate variability in the construction process.

However, Koskela, (1999) proposed that the inclusion of *the flow* and *value view*s in construction project management will no doubt help in overcoming the current deficiency associated with the *transformation view*. The concept of *flow* and *value* generation from customer perspective has been in production for decades (Shewhart, 1931; Gilbreths, 1992); but construction project management is yet to fully embrace this reality. The development of collaboration in planning in these fields of knowledge has shown that the incorporation of the concept of *flow* and *value* to the *transformation view* could support better collaboration in construction management process (Highsmith and Cockburn, 2001; Stiftel, 2000). For example, the move from the waterfall process model (transformation only view) in software development to the use of Scrum and Extreme programming (Agile process model based) is due to the inclusion of the *flow* and *value* generation theory concept.

Koskela and Howell, (2002) argued that the decision making process that supports value generation should be decentralised and all the stakeholders in the development process should be given a clear say. They suggest that project planning and management should be viewed as management-as-organising and management-as-planning rather than as management-as-planning alone as enshrined in the *transformation view*. This shows the level of improvement achievable in construction project management practice when built on sound theories; such as the inclusion of the *flow* and *value* theory in construction project management. The successful application of this in software development implies its application in construction project management is realistic and could be beneficial.

More importantly, this theoretical concept of transformation and flow is now also applied in the LPS developed by Ballard and Howell in 1992 for the construction industry (Daniel *et al.,* 2015; Ballard and Howell, 1998), with significant impacts in manging project production in construction. Koskela, (2000) argued that the application of sound theory to construction project management practice will improve performance while its absence will support poor performance. This suggests that more focus should be given to theory in construction management to inform better practice.

However, Seymour *et al.,* (1997) observed that researches in construction project management tend to pay less attention to interpretivism approach that is rigorous enough to develop sound theory.

3.8 Chapter Summary

This chapter examined the concept of collaboration and the development of collaboration in design, planning, and execution of work in different knowledge areas in a bid to contribute to construction project management theory and practice. The review indicates that the desire for collaboration and CW is on the increase in almost every sector including construction. However, the current practice within the construction industry where construction stakeholders tend to seek their individualistic goal even when they claim to be using some form of CW cannot support genuine collaboration in the industry. The chapter shows that without genuine CW built on relational principles, collaboration in planning cannot be achieved.

The review indicates that planning is an important function in construction project management. However, the current approach to planning in construction tends to focus more on planning techniques and pays less attention to the planning process and the uncertainty and variability inherent in the project environment. The current planning approach separates ‘project planning’ from ‘project control’ which hinders project stakeholders from collaborating effectively in the planning process. Thus, the chapter identified the need for the adoption of collaborative approaches to improve construction planning.

The review established that the rational or technical approach to planning is not germane to the construction industry alone. Rather, it seems to exist in various disciplines as seen in the RCM used in UP and in the waterfall process model used in software development. This suggests that the construction industry should not only be criticised for its current practice, but should also be supported to move up from its present position that has less apparatus to support collaboration in planning and in the execution of work.

However, the paradigm shift from the rational approach to planning in UP and in the software development to a more collaborative approach should be of a great significance to construction project management. The successful adoption of collaborative approaches in these knowledge areas shows that the construction industry could also move from its current technical approach to a more social approach that encourages collaboration. This entails focusing on system thinking rather than the current functional 'activity to activity' thinking that dominates the industry.

The review shows that the application of the current theory of project planning, that is 'management-as-planning' (the *Transformation* view) alone, lacks the capacity to develop collaborative relationship among project stakeholders. To overcome this, project planning and management should include the concept of management-as-organising that supports the '*Flow'* and '*Value'* view for a smooth running of the production system. The Last planner System of production control as described briefly in this chapter and fully in Chapter Four is the most advanced methodology that supports the production and flow view in managing construction projects. It also embraces the social elements used in the development of the collaborative planning model used in UP and software development. The LPS is now discussed extensively in Chapter Four.

CHAPTER FOUR: PRODUCTION PLANNING AND CONTROL IN CONSTRUCTION BASED ON THE LAST PLANNER SYSTEM

4.1 Introduction

Chapter three examined the development of collaboration in planning in other knowledge areas and suggested the adoption of the Last Planner System (LPS) in construction because of its capacity to manage production in construction. This chapter examines the LPS of production control in detail, as a production planning and control (PP&C) methodology in construction with focus on its evolution and practical implementation in construction. The first section examines the evolution of PP&C in management science, manufacturing, lean production and in the Toyota Production System (TPS). The eventual application of lean production to construction projects through the seminal work of Koskela is presented. This chapter highlights the development of PP&C in construction with focus on the LPS and its supporting components. The chapter also presents the theories that explain the effectiveness of the implementation of the LPS in construction.

The chapter highlights the practical implementation of the LPS in construction projects through a comprehensive and systematic review of the International Group for lean Construction (IGLC) papers on LPS implementations. It further identifies LPS implementation drivers, success factors, benefits, challenges, trends in implementations and its impact on construction process improvement. It also reports, the current developments in LPS. This chapter does not only set the foundation for the empirical exploration of the PP&C practice based on the LPS in the UK, it also contributes to the creation of Last Planner System Path Clearing Approach presented in Chapter Eight.

4.2 Production Planning and Control

4.2.1 Production Planning: The Search in Management Science

The concept of production planning became popular in the manufacturing industry and management science after World War II. According to Koenisberg and Mckay, (2010) production planning and control are among the topics addressed in management science since the end of the World War II. It seeks to know what, why, how, and who of the production system, while also analysing the production system for continuous improvement. The concept of production planning and control in management science dates back to the work of scientific management theorist Frederick Taylor, where he emphasised the need for production planning and production control in the manufacturing process in order to eliminate waste and improve productivity (Taylor, 1939). Grimsley, (2014) asserted that the improvement achieved from the adoption of Taylor's approach in the production process not only benefits the employer, but also the employees and the society in general. This shows the benefit of production planning and control to stakeholders was wide in the manufacturing industry at its earliest stage. However, prior to these theories, Herrman, (2006) observed that the focus of planning in the manufacturing industry at the end of the 1800's was to optimise the efficiency of the plant and machines and not the production system.

However, this approach changed in the manufacturing industry at the beginning of the 1890 due to complexity in the manufacturing process, giving rise to the concept of formal scheduling or production planning (Herrman, 2006). Fredrick Taylor formally put forward the concept of production planning in manufacturing at the end of World War I to overcome these associated complexities in the production system (Taylor, 1934; 1911). This suggests that the concept of production planning emerged as a result of the complexity and uncertainty associated with the production system in the manufacturing industry.

4.2.2 Production Planning: The Search in Lean Production

Lean production has its origin in the Toyota production System (TPS) developed by Engr. Taaichi Ohno for Toyota in Japan after World War II. Various authors have described extensively the evolution of lean production and the TPS in the manufacturing industry (Shah and Ward, 2007; Holweg, 2007; Womack and Jones, 2003; Ohno, 1998). It is worth noting that lean production philosophy is also applicable in other sectors such as the construction industry (Koskela, 2000). The goal of lean production is to add value and eliminate waste from the product right from design through to the manufacturing or production stage. However, Shah and Ward, (2007) cautioned that lean production should not only be viewed as waste elimination, continuous improvement, JIT, pull planning, and quality management among others, rather it should be viewed as a multifaceted concept that spans across philosophical characteristics that cannot be easily defined. This implies that lean production is not just a singular concept, but an integrated approach used in delivering products with much value.

Before the emergence of lean production in manufacturing, mass production was the common approach used in production (Womack *et al.*, 1990). The weakness of this approach is obvious from the lack of synergy or collaboration from the employee working on the production line since labour is divided.

According to Dilworth, (1992); Murdick *et al.*, (1990) production planning does not only produce the overall plan for production, it also gives the details and exact number of units that needs to be produced per hour, day or week. This approach is termed, production schedule in lean production (Schniederjans, 1992). Again, this illustrates the level of detail achievable in production planning in a controlled environment. It can therefore be said that production planning shows the minutest detail of all the processes in the production process, indicates the interrelationship of activities in the production line and emphasises the place of the human element in developing a reliable plan.

4.2.3 Application of Lean Production Philosophy in Construction

Lean construction (LC) principles are based on the Toyota Production System (TPS) principles. This may be due to the similarities that exist between manufacturing and the construction industry. For instance, McCrary *et al.*, (2006) Howell, (1999) and Koskela, (1997) argued that both industries create products with the aim of meeting their client requirements and they both look forward to earning profits. However, the view of likening the manufacturing industry to the construction industry projects is not accepted by all. For example, Gann, (1996) opined that construction products are usually large and immobile; this implies that construction products are created at the point of consumption unlike manufacturing where materials are fully produced in the factory before sending it to the market. Although, Salem *et al.,* (2006), agreed that there are clear differences between the manufacturing and the construction industry; he conceded that both operations involve ‘production’ and ‘services’ with the aim of meeting customer demands and requirements. Tommelein *et al*., (1999) argued that both the manufacturing industry and the construction industry can be seen as production systems that use processing points and hand over partially completed work to the next person on the production line. Furthermore, the one-off nature of construction products makes it unique and different from the manufacturing industry (McCrary *et al.,* 2006; Salem *et al.,* 2005).

However, Koskela, (1997) asserted this is not only akin to the construction industry, as it also exists in product development in the manufacturing industry. He therefore suggested that the problem associated with the one off nature of construction product could be reduced through modular construction and standardisation in controlled environments. This implies that the lean production philosophy is applicable to construction and is now termed as lean construction. It is worth to note that the present approach used in delivering construction projects will not readily support lean production philosophy in construction due to some peculiarities of construction. In view of this, Koskela, (1997) underscored the need for change in attitude and adoption of methods and techniques that could drive a new system.

Lean construction is the application of lean thinking in the design and production of construction facilities through systematic elimination of waste, thus improving value for construction stakeholders (Womack and Jones, 2003; Howell, 1999; Koskela, 1992). The aim is to minimise waste from the construction process and to challenge construction practitioners to move towards continuous improvement, thus delivering value to customers (Koskela, 2000; Pasquire and Conally, 2002).

4.2.4 Criticism of Lean Construction

Lean production philosophy has been criticised as a mere collection of tools that could only be used for one-off improvement in an operation (William *et al.,* 1995; Berggren, 1990). Green, (2002); Lewis, (2000); Green, (1999); Pheng and Tan, (1998) critiqued that the application of lean production principles supports unpleasant practices such as repression of worker's rights as practiced in Japan, and lack of due consideration for the social, moral and political significance of the process. The critics are of the view that if this is what lean production is associated with in the manufacturing industry; it is not worth bringing it to the construction industry. This could be due to the view that the construction industry is imitating the manufacturing industry, but not in a controlled environment.

According to Ballard and Koskela, (2011) lean construction only attempts to abstract and adapt lean production principles that address the deficiencies in the construction industry. The full application of lean production principles into the construction industry following the initial of work of Koskela, (1992) has received wide criticism from construction management researchers such as in Green, (1999; 2000; 2002); Green and May, (2005), and Winch, (2005; 2006; 2010) among others.

For instance, Green, (1999) argued that lean construction advocates such as Koskela, Ballard, and Howell base their conclusion on the potentials of lean production principles in construction on one-sided literature of lean production while ignoring the critical view regarding human cost in lean production method such as stress, accident, long working hours etc. But in response to Green, Howell and Ballard, (1999) argued that lean production is a new approach of organising the production system to make work more efficient. They further stated that the application of lean principles results in better working condition for workers than the craft and mass production regime. In fact, there are empirical evidences that the application of lean construction principles reduce health and safety issues on site and improves the wellbeing of workers (Fernandez-Solis *et al.*, 2012).

Additionally, Winch (2010) critiqued that LC is limited to site construction and production of standard products, separates design from making, and is a form of bureaucracy which is opposed to professionalism. However, Ballard and Koskela (2011) provided convincing rebuttal to all the criticisms of Winch. For example, Koskela and Ballard, (2011) argued that LC is not only applicable to the site construction as misrepresented in Winch, (2010), but also used in target costing. This is backed up by Ballard and Paul, (2004) that reported the first successful application of lean construction approach in target costing and other publications on its successful implementations such as in Do *et al*., (2014a); Zimina, Ballard and Pasquire, (2012); and Ballard, (2006). This shows that LC is not applicable to site construction only. Koskela and Ballard concluded that Winch's critique could be due to the complexities associated in understanding the LC concept which they attributed to the low number of lean construction publications in the mainstream journals.

It is no surprise that lean construction researchers have taken up this challenge, with publications in mainstream journals is on the increase in recent times. These, coupled with empirical evidences of the impacts of the application and the increase in the number of LC techniques used in construction (LCI, 2015; Daniel *et al.,* 2015; Fernandez-Silos *et al.,* 2012; McGraw Hill, 2013) could have contributed to the reduction in the criticism of LC in recent time. For instance, a recent research indicates that the Last Planner System; a lean construction techniques has been implemented in 16 countries that cut across the major continents of the world (Daniel *et al.*, 2015). This shows the application of LC techniques could be beneficial, with increasing acceptance.

4.2.5 Lean Philosophy in Production Planning and Control in Construction

Construction projects are considered to be complex and characterised with uncertainties arising from both the process and the delivery mechanism (Barlow, 2000). Planning and control have been considered to be an important management function and used extensively in construction management. However, the current approach used in managing construction projects separates project "planning" from "control" which contributes to the uncertainties in the construction project environment (Ballard and Howell, 2003). Ballard and Howell, (1998) observed that construction project management lacks a defined theory for "production control", thus all attention seems to be shifted to "project control". Project control focuses on analysing 'the effects' which contributed to non-achievement of tasks as planned (Hamzeh *et al.*, 2015; Fiallo and Revelo, 2002; Ballard, 1994).

However, in production planning and control (PP&C) "planning" and "control" are seen as an integrated process (Daniel *et al.,* 2016; Ballard and Howell, 2004). This makes the planned construction programme more predictable and reliable, thus leading to reduction in lead time in the construction phase. The Last Planner System (LPS) has been identified to be among the most developed lean construction technique that effectively support project production control in construction (Khanh and Kim, 2015; Papke and Dove, 2013; Ballard and Howell, 2004). It is a production planning and control methodology developed for managing the production process in construction (Hamzeh *et al.,* 2015a; Papke and Dove, 2013; Ballard, 2000). LPS plays a central role in improving workflow reliability and predictability of planned construction activities at the work phase because of its capacity to shield projects from workflow uncertainty (Khanh and Kim, 2015; Khanh and Kim, 2014; Ballard and Howell, 2003; Ballard and Howell, 1998).

4.2.6 Evaluating Production Planning and Control in construction

The need for production planning in construction cannot be overstated due to much variability in the construction process. The argument that construction should be viewed as a production system as presented by Ballard, Howell, and Koskela has indeed brought a paradigm shift in the construction industry (Ballard, 2000; Koskela, 1992; Ballard and Howell, 1997). Previous studies confirm that construction planning can become reliable and predictable when work is planned using production planning and control processes (Ballard, 2000; Howell and Ballard, 1997). This shows the benefit of production planning in construction. However, it is worth noting that a system could deviate unknowingly if it lacks proper mechanism for evaluating it.

Bernardes and Formoso, (2002) suggested a method for evaluating production planning and control practices in construction based on the Last Planner System methodology. The PP&C principles were identified from numerous studies on LPS implementation in construction usually termed as Planning Best Practice (PBP) index (Sterzi *et al.,* 2007; Bernades and Formoso, 2002). The identified practices have been used to examine the implementation of PP&C in relation to the LPS on construction projects including 12 projects in Israel (Priven and Sacks, 2015); 6 case study projects in Brazil (Bernardes and Formoso 2002) and in observing 5 projects in Brazil (Sterzi *et al.,* 2007). They argued that identifying the basic practices through an evaluation process could provide a basis to initiate the process and practice that could support improvement in the LPS implementation.

4.3 The Last Planner System of Production Control

4.3.1 The Last Planner System: An Overview

The Last Planner System (LPS) was developed by Ballard and Howell in the 1990's following a research in the industrial construction sector (Daniel *et al.,* 2015; Ballard and Howell, 1988). The LPS focuses on reducing workflow uncertainty identified as a missing component in the traditional project management kit (Baldwin and Bordoli, 2014; Ballard and Howell, 2003; Koskela, 1999). This missing component has been identified by lean construction researchers as a contributory factor to the poor performance of construction projects (Ballard and Howell, 2004; Howell and Ballard, 1998). The LPS is an integrated and comprehensive approach that intends planned construction activities are predictable and reliable at the implementation stage on a construction site (Forbes and Ahmed, 2011; Mossman, 2014; Chee *et al.,* 2009). It is worth noting that its application is not limited to the construction stage alone, as it is also effective at the design stage and in decommissioning.

LPS supports the creation of a platform for stakeholders on the project to plan together in order to reduce uncertainty and improve the quality of the construction programme. According to Howell and Ballard, (1994) the level of uncertainty in the traditional project management approach is at a high level and most times is due to the manner in which tasks are planned. The LPS is designed to address this shortfall in the traditional project management approach. Koskela and Howell (2002) argued that the traditional project management approach is obsolete and has failed to address the many problems confronting the construction industry, but it is still being used.

Unlike the traditional approach of project management that focuses only on activities on the programme; the LPS in addition to this manages relationships, conversations, and commitments, and ensures construction planning decisions are agreed collaboratively among the stakeholders at the lowest level of the project (Gonzelez *et al.,* 2015; Hamzeh *et al.,* 2015; Mossman, 2014; Ballard, 2000). The influence of the LPS in managing the production process in construction has been posteriorly rationalised through theories relating to decision-making and uncertainty in the production process (Ballard *et al*., 2009). These theories and principles include:

- Transformation, Flow, and Value theory (Koskela, 1992; Koskela and Ballard, 2006)

- The Language/action perspectives (Macomber and Howell, 2003; Flores, 1982) and
- Hayek's, (1945) comment about the way knowledge needed for planning is dispersed among individuals.

More importantly, the underlying theories of the LPS revolve around planning, execution, and control. According to Baldwin and Bordoli, (2014); Ballard and Howell (2003), LPS focuses on planning and production control as opposed to directing and adjusting resources in the traditional project management approach (thermostat model). There are 5 key principles in the LPS (Ballard *et al.*, 2009), and these are;

- ensure tasks are planned in increasing detail the closer the task execution approaches
- ensure tasks are planned with those who are to execute them
- identify constraints on the planned task to be removed by the team beforehand
- ensure promises made are secure and reliable, and
- continuously learn from failures that occur when executing tasks to prevent future reoccurrence.

Ballard (2000, p. G-14) stated that "the Last Planner(s) is the person or group that make assignments to direct workers". Last Planners are actively involved in developing the programme for the work and ensuring the work is made ready before sending it to the work phase (Alsehaimi *et al.*, 2014; Mossman, 2014, Ballard, 2000). The duties of the Last Planners are therefore to ensure that work is broken down, structured and planned efficiently to create flow in the construction process and to ensure such work is executed at the optimal level (Lindhard and Wandahl, 2013; Ballard, 2000).

4.3.2 [3]Components of the Last Planner System

The Last Planner System implementation comprises of 5 key processes as shown in Figure 4.1 and subsequently discussed. These progressive processes yield significant benefits especially in developing a collaborative relationship. However, lack of full implementation has adverse effects on both the upstream and downstream flow of

[3] Part of this section has been published in Pasquire, Daniel and Dickens, (2015a)

construction activities (Mcconaughy and Shirkey 2013, Mossman, 2014). Unfortunately, many construction organisations are yet to pay full attention to flow in their implementation effort and continue to focus on optimising tasks (transformation).

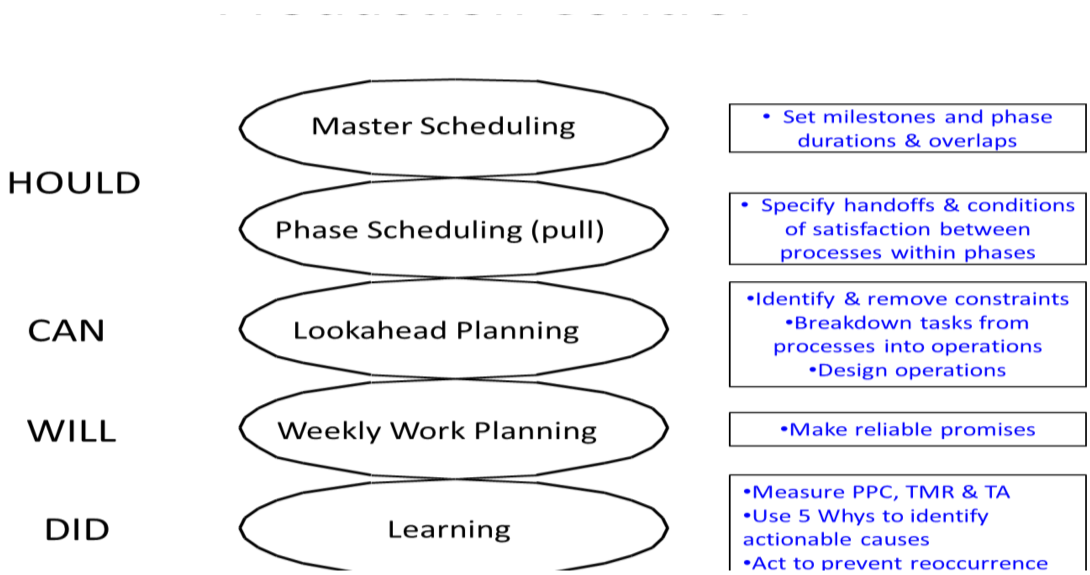

Figure 4.1: The Last Planner System of Production Control Model

Source: Ballard (2011)

4.3.2.1 The Master Plan or Milestone Planning

The Master Plan or milestone planning captures the entire tasks to be executed throughout the project and at the same time shows the length of time required for each activity to be completed. It identifies the project milestones and initiates the means for achieving them (Forbes and Ahmed, 2011; Zimina and Pasquire, 2012; Ballard *et al.,* 2007). This is usually referred to as the contract programme and presented on a Gantt chart or in Primavera. It forms the basis for the development of the collaborative programme or phase planning. The purpose of the Master Plan therefore, is to show the target (milestone) for accomplishing a given task, and to use such information to steer the project delivery through the collaborative programming or phase planning meetings (Ballard, 2000). The master programme shows how the enire project can be achieved.

4.3.2.2 Phase Planning or Collaborative Programming

Phase planning or Collaborative programming is a process used in developing a reliable construction programme from the master or contract programme by direct involvement of the subcontractors, contractors, suppliers, designers and other stakeholders including the client on the project. It builds strongly on the concept of "next customer" to understand the interfaces in the process. It is prepared early in the project planning through logical arguments used to agree how one activity ends and the next starts - called handing off (Mossman, 2014; Anderson *et al.,* 2011; Ballard, 2000). The phase planning is usually developed from the master programme through series of dialogues and input from subcontractors, suppliers, specialist contractors, designers and others who are party to the project (Baldwin and Bordoli, 2014, Mossman, 2014; Hans *et al.,* 2006). This increases transparency and builds trust within the project team and is essential in developing a common understanding (the eighth flow) of all aspects of the project (Pasquire, 2012).

However, this approach is considered to be non-existent in the traditional approach of project planning which is characterised by a lack of trust and little collaboration in agreeing procedures for delivering the project (Zaghloul and Hartman, 2003; Austin and Baldwin, 2002). Ballard and Howell (1998) argued that the non-existence of collaborative programming in developing construction tasks and activities is among the major causes of construction project failures. Other terms used for collaborative programming in the construction industry include*: Detail planning; Detail programming to completion; Phase Scheduling; Collaborative programming, Pull planning* and *High level programming* among others. It is worth noting that this process is commonly called collaborative programming by practitioners in the UK, while phase scheduling is the common name used for it in Lean Construction Institute literature (LCI, 2015; Ballard, 2000; Ballard and Howell, 2004).

In practice, the approach not only leads to a reduction in construction programme, but also enables the team to develop a common understanding of the tasks (Pasquire, 2012). Hans *et al.,* (2006), Anderson *et al.,* (2011), asserted that collaborative programming of construction activities reduces incidences of change in orders, delays, rework, non-value adding activities, and litigation at the construction phase. Furthermore, Hans *et al.,* (2006); Ballard and Howell, (2004); Ballard and Howell, (1998) stressed that in collaborative programming, planning activities and tasks must be done in detail and collaboratively with the team. This will make the construction programme transparent, reliable, and predictable.

Process of Phase Planning

Adequate collaborative programming of construction activities adds value to the entire project delivery process (Mossman, 2014). This is because the client requirements are most times clearly defined and the supply chain proposals are constantly deliberated on to arrive at best optimal solution. Ballard and Howell, (2004) identified eleven key processes in developing a Phase Scheduling or collaborative programming which must be done collaboratively by those required to do the work.

1. Define the work to be included in the phase
2. Determine the completion date for the phase
3. Use team planning notes to develop network of activities
4. Apply duration to each activities
5. Re-examine logic to shorten the duration
6. Determine the earliest start date for the task
7. Decide on activities to buffer by asking
    a. Which activity duration are most fragile
    b. Rank order the fragile activities by degree of uncertainties
    c. Allocate available time to the most fragile activities.
8. Remember the contingency is meant to be spent
9. Check to be sure the teams are comfortable with available buffers, if not re-plan or shift milestones
10. If there is time in excess, accelerate the schedule or use it to predict on-time completion
11. Reverse unallocated time in a general contingency buffer for the phase.

This approach provides opportunity for the subcontractors and the suppliers to participate meaningfully in developing the overall programme for the project, thus gaining their commitment.According to Ballard and Howell, (2004) the process is used in producing a plan that is mostly based on team approach and uses reverse phase scheduling.

4.3.2.3 Look-Ahead Planning

The look-ahead planning is a medium term plan for project activities and is developed from the collaborative programme. Usually, tasks that will occur within three to six weeks in the look-ahead window will be screened for constraints in all eight flows including information, permissions, resources, space etc. The project team members then identify every constraint for the proposed assignments for action in the make-ready process (see below). In doing this, the problems that could affect the task negatively will be identified so they can be removed before the commencement of the task, thus eliminating delays and waste from the production process (Zimina and Pasquire, 2012; Porwal, 2010; Ballard, 1997).

However, in the traditional way of managing projects, the look-ahead plan (master programme) only provides advance notice of the start date of an activity and does not consider work flow sequence, matching work flow with capacity, or maintaining a backlog of workable activities (Ballard *et al.,* 2009). In implementing the LPS, the purpose of the look-ahead planning is: (1) to create workflow between activities in the project (2) to ensure that the available labour and resource matches the work (3) to ensure prerequisite tasks are completed as planned (4) to group works that are closely related together for easy execution and (5) to identify tasks that need to be planned together. In this way, constraints to all eight flows are properly recognised to enable effective "make-ready" and eliminate the waste of making do (Koskela 2004).

4.3.2.4 Make-Ready Process

The make-ready process is used to eradicate the constraints to planned activities identified in the look-ahead programme before they pass into production on site. The make-ready process focuses on matching the available resources for work with the present realities on the construction site, so as to ensure production can proceed at an optimum level (Ballard, 2000, Ballard and Howell, 1998). Daniel *et al.,* (2014b); Ballard, (2000) observed that the make-ready process helps in controlling the production system on site. Baldwin and Bordoli, (2014); Ballard, (2000) observed that most scheduled activities in the traditional approach to planning are not achieved as planned because they are not "made-ready" before the commencement of the task on site. The implication of this for the production system is that the expected work flow will be elusive. Lindhard and Wandahl, (2012) and Koskela, (2000) affirmed that the lack of flow and the failure in removing constraints from the construction process generates numerous non-value adding activities in the construction phase.

The goal of the make-ready process is to ensure that only sound activities move into the backlog of sound assignments for use in the Weekly Work Plan (Mossman, 2014; Lindhard and Wandahl; 2012, Ballard, 2000). This ensures that only sound works enter the production phase on site. The make-ready process is undertaken collaboratively so that agreement can be reached on what "Can Be Done" – which makes it consider all eight flows. The eight flows are the people required to do the work, the information required for the work, the equipment needed to execute the work, the material for the work, prerequisite assignment that need to completed, creating safe external conditions, safe place for work and developing a common understanding (Koskela,2000; Pasquire, 2012). For an activity to be "made-ready" for the next work phase, it is expedient these conditions are clearly satisfied.

The impact of the make-ready process is felt across the entire production system. The make-ready process improves construction planning reliability even on complex projects by using systematic approaches (Jang and Kim, 2008; Ballard and Howell, 1998,). However, Lindhard and Wandahl, (2012) cautioned that the project planner must be meticulous in identifying all the necessary preconditions in order to make a sound activity, else the entire process could be interrupted.

4.3.2.5 Weekly Work Plan (WWP)

Weekly Work Plan is done to review tasks planned in the previous week in order to plan for the week ahead collaboratively with the team. During the WWP, only activities that meet the specified criteria and that have been collaboratively developed from the make-ready process are allowed into production. The criteria require that work must be 1. well defined (detailed task breakdown), 2. sound (can be done), 3. sequenced (interdependencies assessed) and 4. properly sized (load matches capacity) (Ballard, 2000).

Here, the Last Planners that are responsible for doing the work make promises (commitments) on what "Will Be Done". The reliability and predictability of the construction programme is a function of the soundness of works or assignments sent into the WWP and the commitment of the work force to do them. This approach requires stakeholders on the project to report the position of the previous week's planned tasks. Only a "Yes" or "No" answer is given to indicate if the planned tasks were achieved or not, whilst also recording the reasons for non-completion. In recording the reason for non-completion (RNC), 99% completion is a "No" answer.

The RNC enables the team to identify the root causes for the failure. This in turn enables the team take necessary actions to address the identified reasons for future learning (Mossman, 2014; Ballard, 2000) and for error proofing future activities to prevent reoccurrence. In practice, the WWP meeting enables each subcontractor or team leader on site to propose the production plan for the week ahead after successfully reviewing the previous week's work plan. This not only enables the team to understand the interdependencies of tasks (next customer), but also requires the team to only promise what they are sure they ***will*** do, and not what they might or will try to do (Ballard, 2000).

Daily Coordination

It is part of part the WWP (Ballard, 2015). It is a daily conversation that occurs on the day of production with the Last Planners either at the start of work or at the end of work to assess the progress of the planned tasks for the day and review the next day's production. Through this meeting, "bad" news is delivered early which considerably helps in taking mitigating actions to address problems early and accordingly (Mossman, 2014). The daily coordination meeting could be weekly during the design stage and daily at the construction stage. The approach is used to maintain the entire production system thus ensuring the designed or intended output is achieved at the end of the production process. It is worth noting that the 'daily coordination meeting' is commonly referred to as 'daily stand up meeting' among construction practitioners in the UK (Daniel *et al.,* 2016).

Measurement and Learning

Mossman, (2014) observed that production evaluation and measurement in the LPS context enables the team to maintain commitment to the overall goal of the project. This addresses the client's needs while also making the supply chain aware of what is required of them. However, to achieve and maintain the commitment requires cultural shift, especially when LPS is not included in the contract. The key metrics measured in the LPS implementation are; the Percentage Plan Complete (PPC), Reliability Index using metrics from Tasks Made Ready (TMR), and Tasks Anticipated (TA) (Hamzeh *et al.,* 2015; Ballard, 2000). TA is a metric used to measure the performance of the look-ahead planning process for tasks due to be performed in two to three weeks.

The TMR is the ratio of the tasks that has its constraints removed within two weeks ahead of execution in relation to all the tasks anticipated in the look-ahead window (Hamzeh *et al.,* 2015a; Ballard and Howell 2003; Ballard, 1997). Hamzeh *et al.,* (2015) observed that TA supports in-process performance measurement, however, it is less used or done when compare with PPC measurement on projects that claim to use the LPS in managing the production process. PPC is used to measure the completed work against the actual work promised to give an indication of productivity. RNC can be presented statistically to provide visibility of the frequency and distribution of the factors inhibiting production.

$$(PPC) = \frac{Total\ Number\ of\ Activities\ Completed}{Total\ Number\ of\ Activities\ Promised} \times 100\%$$

In practice, PPC measurement, and recording of RNC not only encourage learning but also provide a clear indication of productivity (Kalsaas, 2012; Liu and Ballard, 2008). This has been confirmed in Liu and Ballard, (2008) where their study reveals a strong correlation between PPC and productivity. Ballard, (2000) asserted that the uniqueness of LPS metric measurement is the learning loop which is embedded in the system as shown in Figure 4.2. This is contrary to the 'push' approach used in traditional project management which hinders learning.

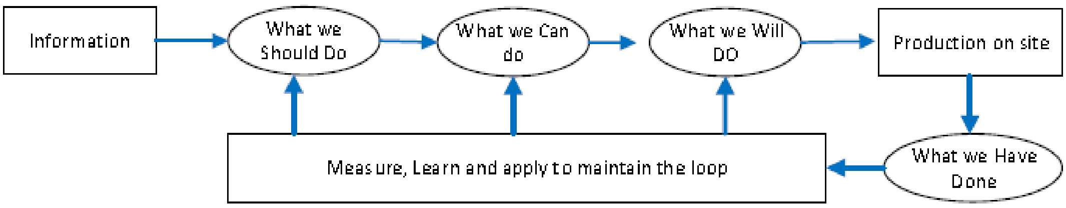

Figure 4.2: The learning loop in the Last Planner System

Adapted after: Ballard, (2000)

When PPC and RNC are considered together in this way, learning is coupled with action at the moment, as opposed to at the end of the project. Kalsaas (2012) and Ballard, (2000) observed that learning is a key element of the Last Planner System which will further lead to higher productivity of the project team. The measurement and evaluation process allows the team to have a more transparent and realistic approach to work as it gives the team opportunity to evaluate the past and purposively propose the next week's task (Ballard, 2000).

4.3.2.6 First Run Studies

A First Run Study (FRS) is an approach used to aid understanding of the construction process before actual production or execution on site. It is used in the redesign of activities that are considered to be critical in the production process which may also be repetitive in nature, for instance, a prototype building (Ballard and Howell, 1998). However, Mossman, (2014) argued that FRS is not limited to repetitive tasks alone, but on all activities that are critical to the success of the project in terms of time, quality, cost, and safety. In the UK, this process is commonly called Mock-up or Prototype among others. The process encourages continuous improvement and allows standard works to be developed and constraints to be identified. Hackett and Pasquire, (2014) identified Virtual First Run Studies (VFRS) as a form of "Proof of production" based on collaboration and discussion in advance of the physical First Run .

According to Salem *et al.,* (2005) FRS is an approach that encourages continuous improvement which entails productivity studies, understanding work method and redesigning the different action in the production process collaboratively by the team. In practice, FRS is based on the Plan-Act-Check-Do cycle (Shewart and Deming, 1939). This allows the team, through collaborative conversations to brainstorm, explore opportunities, and identify the best approach to deliver the product more efficiently before the actual production. This approach enables the team to understand the construction process and what is required of them at each stage beforehand. In addition, it helps in driving out non-value adding activities and maintaining quality of the finished product.

The LPS implementation processes as discussed enables all stakeholders on the project to develop a collaborative relationship during the planning and execution of tasks on site. In fact, Daniel *et al.,*(2014b) and Mossman, (2014) described the LPS implementation process as a set of social conversations that enables the team to build trust and commitment, thus making the construction programme more predictable and reliable. Various theories have been used to explain the working of the LPS in managing project production system as discussed in the next section (Ballard *et al.,* 2009; Macomber and Howell, 2003; Koskela, 1992).

4.4 Theories used in Explaining the Last Planner System

The LPS practice revolves around planning, execution, and control. Koskela and Ballard, (2006); Macomber *et al.,* (2005); Macomber and Howell, (2003) Koskela and Howell, (2002) analyse the theories that support the practice of the LPS in construction. Table 4.1 presents construction project management practices and the theories that explain them in relation to the LPS approach.

Table 4.1: Underlying Theories of the Last Planner System

Subject of Theory	**Practice**	**Theories**	**Further supportive literature**
Project		Transformation Flow	Koskela, (1992)
Management	Planning	Management-as-planning Management-as-organising	Hayek,(1945) Johnston and Brennan, (1996)
	Execution	Language/action perspective	Flores, (1982); Winograd and Flores, (1986)
	Control	Scientific experimentation model	Shewhart and Deming (1939)

Adapted from: Koskela and Ballard, (2006)

4.4.1 Transformation and Flow Theory in the Last Planner System

Koskela developed the *Transformation Flow* and *Valu*e(TFV) theory mostly referred to as TFV theory (Koskela, 1992). It has been observed that the current approach used in managing construction project tends to support only the *transformation view*. The transformation view focuses on the conversion of input into output with less regard to what happens in the project environment (Koskela and Howell, 2002). In this approach, it is assumed that the tasks are independent and that requirement for the execution of tasks can be captured completely at the outset of the project (Ballard and Howell, 2004; Koskela and Howell, 2002). However, such view is false and counterproductive due to the uncertainty and variability inherent in the construction environment.

In view of this, Koskela and Howell, (2002) proposed that the Flow and Value concept should be added to the Transformation concept on which the current theory of project management is conceptualised. The understanding and usefulness of the flow concept has been demonstrated in the LPS (Bertelsen *et al.*, 2007; Koskela and Howell, 2002). The LPS uses the flow concept to identify and ensure task preconditions are satisfied before sending them to the work phase. It ensures that the seven plus one conditions for smooth workflow are fulfilled (Pasquire *et al.*, 2015;

Bertelsen *et al.*, 2007). This implies that the flow theory recognises the complexity and uncertainty inherent in the construction production environment, while the transformation view does not. Koskela, (2000) observed that the limited view on the production system in construction is one of the major issues facing construction.

4.4.2 Management-as-Planning and Management-as-Organising Theory in the LPS

The management-as-planning (MAP) theory dominates the current approach used in construction planning. The theory advocates that project consists of two parts; "the managerial part" (the planner who does the planning) and 'the effector part" (field workers) who are responsible for translating the plan into action (Johnston and Brennan, 1996). Koskela and Howell, (2002) observed that the management-as-planning theory advocates for plan centralisation, revision of plan and then implementation. This implies that in this approach, field workers are not involved in the planning at the beginning although they could be during revision. To overcome this, the management-as-organising (MAO) view is presented (Johnston and Brennan, 1996; Johnston, 1995). In this approach, it is believed that each sub-unit in the system has the capacity to plan, sense and act, thus, the planning decision should not be left with "the managerial part" alone. In construction, this approach supports the inclusion of the supply chain in the planning process as demonstrated in the LPS.

The MAO theory also aligns with the position of Hayek (1945) on social planning where he argued that the knowledge needed for planning is dispersed among the people doing the work. Apparently, this view supports and further shows the need for the planner to involve subcontractors, foremen, and site engineers in developing the construction programme. This will not only provide an opportunity for the people doing the work to do the plan, but will also lead to the development of a more realistic and predictable plan which the LPS supports (Koskela and Ballard, 2006; Koskela and Howell, 2002).

4.4.3 Language/Action Perspective Theory in the Last Planner System

In the conventional project management approach, the nature of communication that occurs at the *execution* stage on site is one-way, and is characterised by lack of commitment. As compelling as this may seem, it is contrary to the nature of conversations that occur in the LPS; which is usually in two ways. The work of

Flores (1982) on *language/action perspective (LAP)* which centred around five conversations; coordination of action, assessment, discourse, trust between workers and mood explains the nature of conversations that occur in the LPS (Flores, 1982; Winograd and Flores, 1986). The LAP theory as applied in the LPS has been evaluated in Macomber and Howell, (2003), and its practical application in construction was demonstrated in Viana *et al.*, (2011).

According to Macomber and Howell, (2003) LAP supports conversations that could lead to the development of a reliable promise as encouraged in the LPS approach of managing production in construction. Viana *et al.,* (2011) confirmed from an empirical study that LAP supports mutual commitment from project stakeholders. This is opposed to the dispatch model in conventional project management which believes that tasks can always be sent to the work phase as soon as the start date is due without conversation and commitment from those doing the work (Koskela and Howell, 2002).

4.4.4 Scientific Experimental Model

It has been argued that the "model" of *control* used in the construction industry is based on project control rather than production control (Koskela, 2002, Ballard and Howell, 1998). This approach of managing construction is known as the "thermostat model". It emphasises conformity of tasks to plan, not minding the overall effect of changes on the production system. However, the *scientific experimental model* of production control as advocated by Shewart and Deming (1939) identified the cause of nonconformities to plan and suggested the means to act on them, rather than pushing the system to conform to the predefined goal. The *scientific experimentation model* is the approach used in the LPS. It provides opportunity for the production system to be evaluated at regular intervals through some metric such as measuring the PPC; this also encourages learning (Liu and Ballard, 2008; Koskela and Ballard, 2006). In addition, the *transformation* and *flow* theories play roles in the LPS at both the execution and control stages, and specifically, during the short term planning (Koskela and Howell 2002; Ballard, 2000; Koskela, 1999). The LPS achieves this by ensuring that planning and execution are fully integrated. These theoretical conjectures are used to comprehend the current understanding and application of PP&C principles based on the LPS in the UK construction industry.

Amundson, (1998) opined that the use of theory as a lens has the potential to create an understanding and better development of situational awareness of the problem under investigation. According to Koskela and Howell (2000), theory enables us to understand behaviours in the social world thereby contributing to knowledge. This study deems it important to use the theoretical lens as it will enable it to critically screen current practices on LPS logically and coherently. In reality, this could lead to the development of new theories, and confirmation or improvement of existing theories or practice. Amundson, (1998) asserted that using theories as lens could guide a study in screening out unwanted practices while identifying new practices, thus developing more understanding on the research problem. However, the theory that explains the practice of the LPS in construction is not limited to those described above.

4.5 Last Planner System Implementation and Developments- Review of IGLC papers

4.5.1 Overview of the Review

The aim of this review section is to enable the study to understand the extent of application of the Last Planner® System in construction from previous studies. Thus, a systematic review of the International Group for Lean Construction (IGLC) conference papers on LPS implementation reported between 1993 and 2014 and other publications elsewhere is carried out.

This review not only serve as a solid foundation to the current study which is exploring the practice of LPS in construction projects, it also enables the study to compare the reported practices elsewhere with the practices observed in the UK construction industry. It also supports the LPS-PCA developed in this study. [4]The systematic review identifies the trend in the LPS implementation, LPS implementation drivers, its success factors, benefits and the reported challenges.

[4] Part of this review has been published in Daniel, Pasquire and Dickens, (2015a) Exploring the implementation of the Last Planner® System through IGLC community: twenty one years of experience

4.5.2 Review Framework

The framework for the review is based on the approach recommended for content analysis by Berg and Lune (2011) and Robson (2002) as shown in Figure 4.3. Berg and Lune (2011) asserted that content analysis is applicable in any field of human communication such as written documents, audio and video information, and it has been used in various fields for research, including construction management (Jacob, 2010). Content analysis is used in research to achieve the following: (1) identify cultural trend in a group, institution or society (2) show trend in communication contents (3) identify response to communication (4) identify propaganda in information content and (5) show focus in communication by group, institution or society (Weber, 1985). Again, this shows that the choice of content analysis for this study is not only appropriate, but also robust.

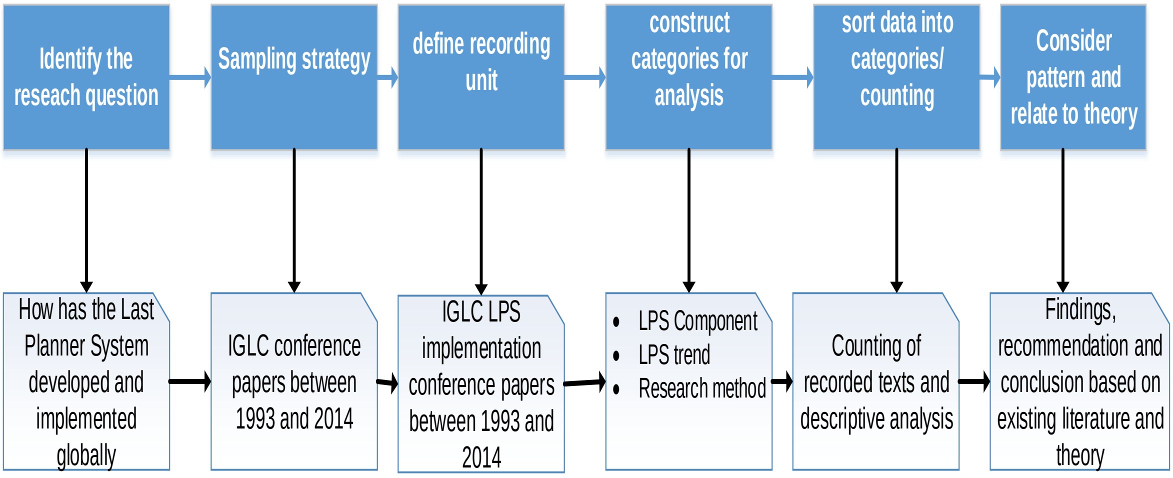

Figure 4.3: The review framework

(Adapted after Berg and Lune (2011) and Robson (2002))

The sample was arrived at through reading on the topic, abstracts of various sections and using keyword searches. These include publications from the production planning and control section; the case study and implementation section among others. Keyword searches such as Last Planner System and case study were made on the database in each publication year. This approach was used to avoid omission of papers on LPS implementation. Based on this, a total of 57 publications from 16 countries that reported LPS implementation were retrieved from www.iglc.net as shown in Table 4.2. Of these, 42 reports contained implementation on sites, 4 on design, while 11 show no actual implementation. The 42 studies that reported LPS implementation on construction sites were analysed. The selected papers were read thrice, with a focus on obtaining information on the stated objectives. The table also shows the list of the papers retrieved.

Table 4.2: IGLC Papers on LPS Implementation between 1993 and 2014 Retrieved

S/NO	Year of publication	Author(s)
1	**1993**	Ballard
2	**1994**	Howell
3		Ballard
4		Ballard
5	**1996**	Ballard *et al.*
6	**1997**	Ballard
7	**1998**	Junior *et al.*
8		Conte
9		Miles
10	**1999**	Mendez and Heineck
12	**2002**	Ballard *et al.*
13		Fiallo and Revelo
14		Soares *et al.*
15		Alarcon *et al.*
16		Conte
17	**2003**	Johansen and Porter
18		Mastroianni and Abdelhamid
19	**2005**	Kim and Jang
20		Alarcon *et al.*
21		Bortolazza *et al.*
22	**2006**	Kim and Jang
23		Knapp *et al.*
24		Lim *et al.*
25	**2007**	Kim *et al.*
26		Ansell *et al.*

27		Kemmer *et al.*
28	**2008**	Aslesen and Bertelsen
29		Hamzeh *et al.*
30	**2009**	Kalsaas *et al.*
31		Alsehaimi *et al.*
32		Hamzeh *et al.*
33		Olano *et al.*
34		Ballard *et al.*
35		Liu and Ballard
36	**2010***	Skinnarland and Yndesdal
37	**2011**	Viana *et al.*
38		Rosas *et al.*
39		Hamzeh
40		Aves and Britt
41	**2012**	Samudio and Alves
42		Kerosuo *et al.*
43		Hamzeh *et al.*
44		Skinnarland
45		Porwal *et al.*
46		Adamu and Howell
47	**2013**	Drysdale
48		Barbosa *et al.*
49		MCconaughy and Shirkey
50		Fauchier and Alves
51		Aihaikwo *et al.*
52		Zegarra *et al.*
53		Fuemana, and Puolitaival
54		Cerver-Romeno *et al.*
55		Kalsaas
56	**2014**	Kalsaas *et al.*
57		Fundi and Drevland

Source: Author's review of IGLC paper on LPS implementation

(*link not working as at the time of the review)

4.5.3 Last Planner System Implementation across Countries

Table 4.3 presents a glossary view of the LPS implementation in construction across the globe. The study reveals that the uptake of the LPS is not limited to North America alone, as implementation has been reported in almost all the continents of the world. This shows the universal applicability of the LPS; overcoming language and geographical barriers.

However, it is worth noting that cultural barriers such as attitude to work could influence the LPS implementation (Johansen and Porter, 2003). To be specific, Johansen and Porter (2004) revealed from their study that cultural and structural issues are among the barriers to LPS implementation in the UK construction industry.

Table 4.3: Last Planner System Implementation across Countries

Country	**Number of cases**
USA	15
Brazil	10
Norway	5
Venezuela	5
UK	4
Chile	4
Korea	3
Nigeria	2
Finland	2
Lebanon	1
Peru	1
Mexico	1
Ecuador	1
India	1
Saudi Arabia	1
New Zealand	1
Total	**57**

Source: Author's review of IGLC paper on LPS implementation

4.5.4 Major Components of Last Planner System Implemented

As shown in Figure 4.4, measuring PPC, Weekly Work Planning (WWP) meeting, and recording reasons for non-completion (RNC) are among the commonly implemented components of the LPS in the IGLC papers reviewed. This finding aligns with recent empirical findings such as Dave *et al.*, (2015) where they observed that WWP was the most commonly implemented LPS element from the evaluation of five projects and a detailed case study. Daniel *et al.*, (2015) also observed that phase planning/collaborative programming, PPC measurement, and WWP meetings were the most fully implemented LPS elements from their evaluation of 15 construction projects in the UK. The frequent reporting of the measurement of PPC in the studies reviewed seems to show PPC measurement is among the early indicators of LPS implementation in construction.

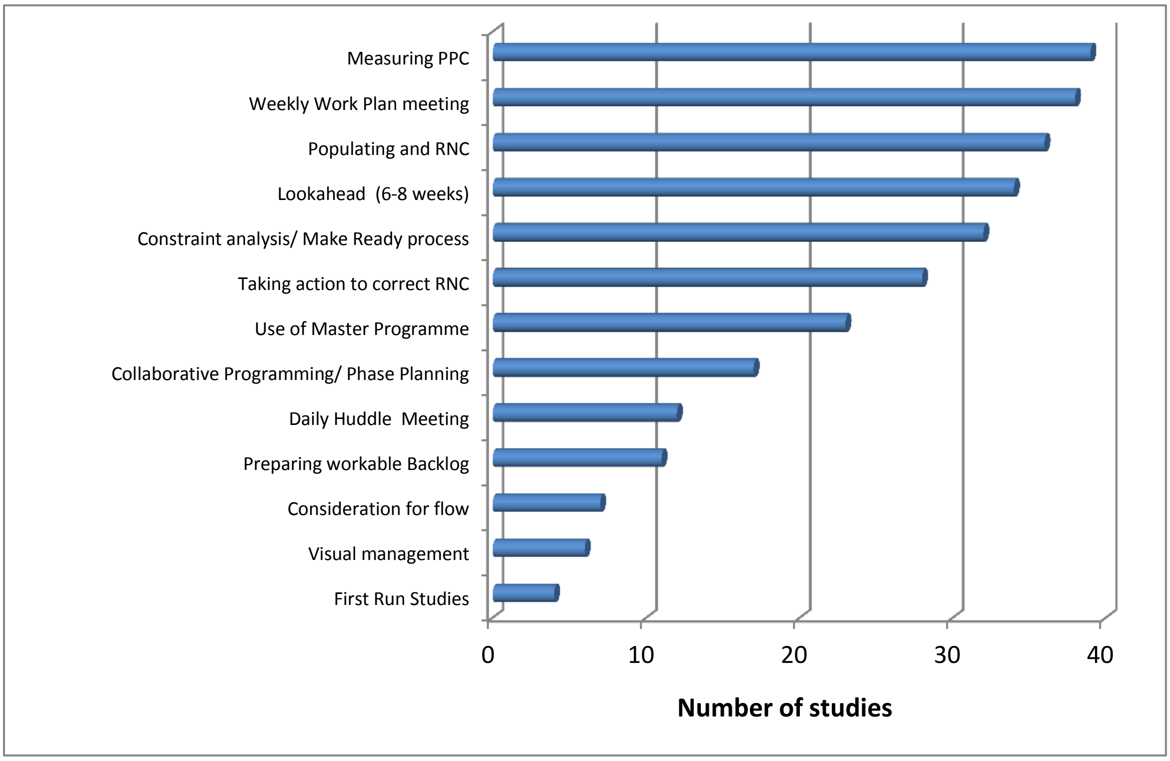

Figure 4.4: Components of LPS reported in the review

Source: Author's review of IGLC paper on LPS implementation

Ballard (2000) asserted that PPC measurement supports continuous improvement as it allows the team to learn from the reasons for non-completion. These are collected at the WWP meetings which is part of the PPC measurement process. This implies that the PPC measurement does not only show plan reliability, but also other project performance indicators such as productivity (Liu and Ballard, 2008).

4.5.5 Trends in the Implementation of LPS Components

The review of the IGLC papers indicates that the LPS elements implemented were not consistent across all the years. This could be due to the evolution of the LPS over this time. For instance, phase scheduling/collaborative programming became prominent after 2000. This could be due to the publication of a white paper by LCI in 2000 to back its use (Ballard, 2000). Furthermore, the review reveals a progressive increase in the use of most of the elements in recent years, as shown in Figure 4.5, with few exceptions such as workable backlog and FRS. This confirms that the implementation LPS's elements is growing (LCI, 2015).

However, the extent of the implementation of these reported elements (i.e. in terms of partial or full implementation) still remains an issue to contend as recent empirical studies have shown some of these elements are not fully implemented as claimed.

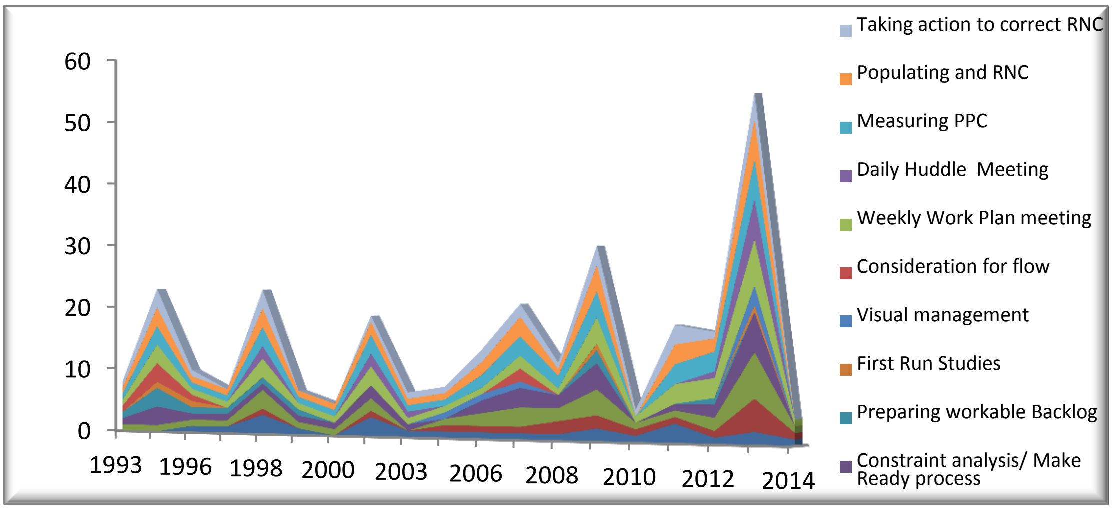

Figure 4.5: Trend in LPS Elements Implemented across the Years

Source: Author's review of IGLC paper on LPS implementation

4.5.6 Last Planner System Implementation Success Factors

Hamzeh and Bergstrom (2010) identified harnessing the support of the project owner, training and retraining of workers, developing a clear vision, having internal champions, and mapping the current planning process as factors that contribute to the success of LPS implementation in construction. Similarly, Ballard *et al.*, (2007) identified LPS implementation success factors from their implementations experience in seven construction organisations. The factors include; provision of training at the project and field level, developing lean champions, top management commitment, use of contracts that favour collaboration, use of demonstration projects, collaborative involvement of all the stakeholders, use of long term alliance and team building exercises.

Furthermore, a comprehensive and systematic review of LPS implementation case studies published by the IGLC between 1993 and 2014 carried out in this study reveals about 15 LPS success factors as presented in Figure 4.6.

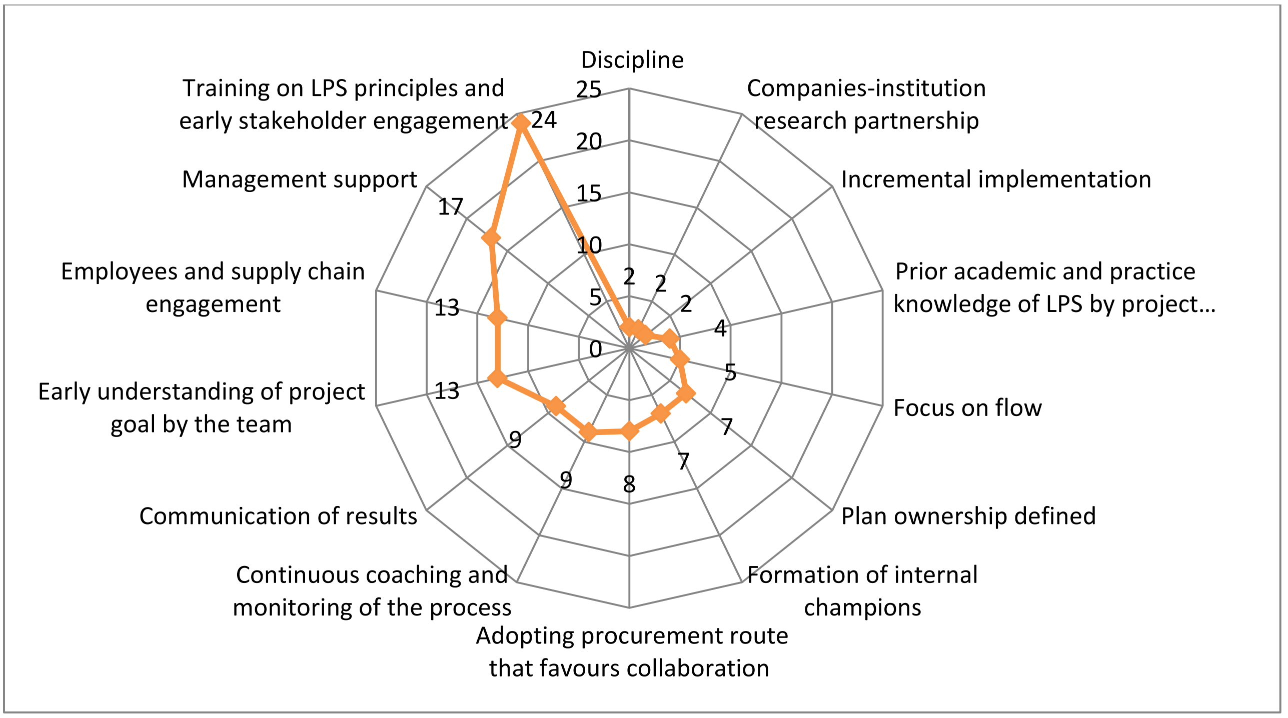

Figure 4.6: Last Planner System implementation success factors in construction

Source: Author systematic review of IGLC papers on LPS implementation

The review reveals training, management support, and early involvement of stakeholders are among the most emphasised LPS success factors for LPS implementation in construction. This finding is further confirmed by the studies of Hamzeh, (2011) and Ballard *et al.*, (2007). This does not imply that other factors are not crucial, as all the above mentioned factors are needed for the successful implementation of the LPS in construction. However, the emphasis on the factors by these studies could be due to their capacity to support the success of the other identified factors.

4.5.7 Last Planner System Implementation Drivers

Ballard *et al.,* (2007) identified the following drivers for the implementation of LC techniques in construction; (1) Owner and client demand, (2) internal demand for a better way of working (3) desire to reduce stress on project managers (3) desire to reduce variation and waste and (5) desire to improve communication with project team. Additionally, Ogunbiyi, (2014) identified drivers such as the need to meet customer or client expectation, gaining a competitive edge, and the desire for continuous improvement.

This suggests that the drivers for implementing LC techniques such as LPS could be viewed from two perspectives; external drivers and internal drivers. For example, the demand from the owner or client for LPS implementation is externally motivated. While factors such as the desire for LPS implementation for better way of working for enhanced performance, the desire to improve communication between project teams, and desire for continuous improvement could be viewed as internal drivers, since they can be initiated by supply chain organisations. This shows that the driver for LPS implementation is not from client alone, but it could also come from the contractor's quest for continuous process improvement.

4.5.8 The Impact and Benefits Last Planner System on Construction Process Improvement

Lean construction (LC) researchers have observed that the implementation of LC techniques support construction process improvement (Adamu and Howell, 2012; Ballard, 2000). In recent times, the implementation of the LPS in construction is on the increase, this could be due to its benefits (LCI, 2015; Daniel *et al.,* 2015). Mossman, (2014) asserted that the LPS helps in creating overriding improvement in project programme predictions, productivity, reduces project time and site accidents, increases profit, while giving due consideration to employee satisfaction. Fernandez-Solis *et al.,* (2012) also identified 9 major benefits of implementing LPS in construction from the review 26 case studies projects where the LPS was implemented. The LPS benefits identified from the study are; increased work flow reliability, improved supply chain integration, reduced project delivery or production time, improved communication among project participants, less firefighting or fewer day-to-day problems, improvement in quality of work practice at construction site, enhancement of managerial practices in construction projects, knowledge expansion and learning among project teams and reduced stress levels on construction sites. Their study was only based on selected case study projects where the LPS was implemented between 2000 and 2009.

Also a review of IGLC papers in this thesis identifies 13 benefits of LPS implementation as shown in Figure 4.7. The figure reveals that LPS implementation supports the development of reliable and predictable programme, improves workflow, and develops common understanding of the project goal among others.

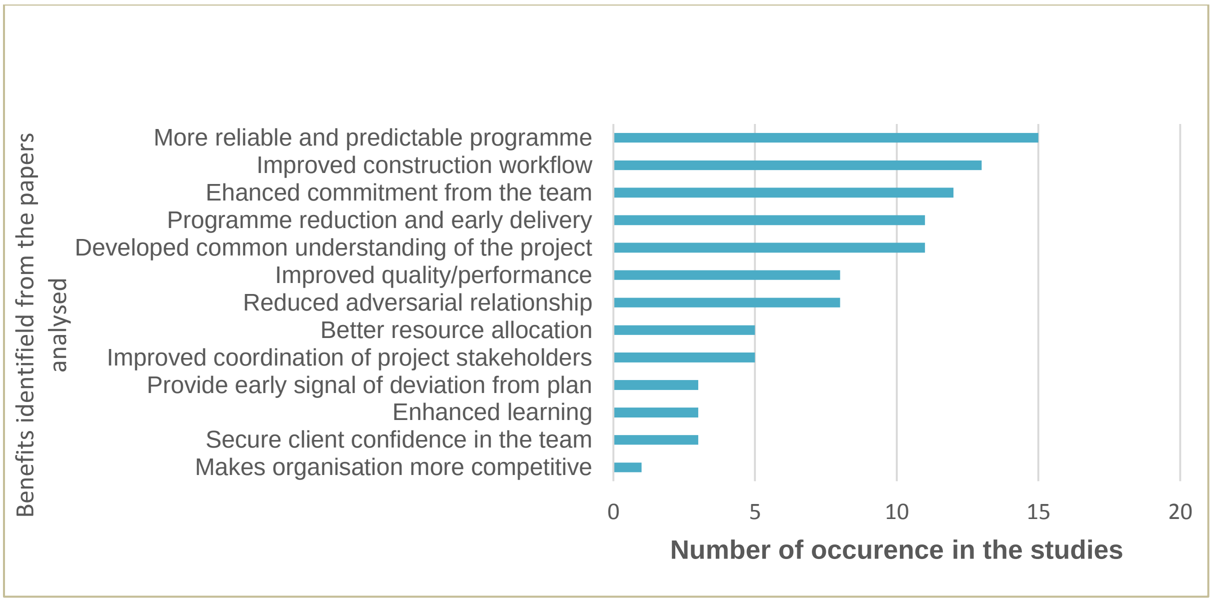

Figure 4.7: LPS Implementation Benefits in Construction

Source: Author's review of IGLC paper on LPS implementation

This shows that LPS implementation in construction has the potential to maintain stable workflow. According to Ballard, (2000) the goal of the LPS is to stabilise the production process. However, workflow reliability in the construction industry is still very low in the traditional approach of project management (Ballard, 1999).

4.5.9 LPS Implementation Challenges in Construction

Researchers in LC have attempted to underscore the implementation challenges of LPS in construction (Ballard, *et al.*, 2007; Hamzeh, 2009; Porwal,*et al.*, 2010; Fernandez-Solis *et al.*, 2014). For example, Porwal *et al.*, (2010) identified 12 major challenges associated with LPS implementation as observed from previous studies between 2002 and 2009. The study revealed that lack of training and resistance to change are among the commonly reported challenges in the studies presented. Furthermore, in a related study, Fernandez-Silos *et al.*, (2012) identified 13 specific LPS implementation challenges from the review of 26 case studies. The topmost implementation challenges from the review were resistance to change, lack of commitment to LPS, lack of training and experience, and lack of management support among others.

It is worth noting that some of the LPS implementation challenges identified in Porwal *et al.,* (2010) were also identified in Fernandez-Solis *et al.*, (2012). This shows that the implementation challenges identified by Porwal *et al.,* (2010) are valid and more needs to be done to overcome them.

Hamzeh, (2009) also classified the LPS implementation challenges into local factors and general factors. The local factors relate to the project related challenges while the general factors are those relating to the organisation implementing the LPS. This implies likely strategies for overcoming LPS implementation should take due consideration for these classifications. According to Liker, (2004) in implementing lean, the organisation must be willing to change and the people (workers) must be ready to accept the new approach for the needed change to happen.

Figure 4.8 indicates recent findings on LPS implementation challenges in construction from a systematic and comprehensive review of IGLC papers conducted in this research. The findings in this present study presented in Figure 4.8 and those from previous studies such as Fernandez-Solis *et al.,* (2012) and Porwal, (2010) show the need for training to improve on LPS implementation. Liker in his book *The Toyota Way* highlighted the need for training in its 9th principle (Liker, 2004). The principle states that *"Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others"*. Training as emphasised here is not just in having mere technical knowledge of the LPS process, but rather, a mind-set change training, which could further help in overcoming some of the other identified challenges.

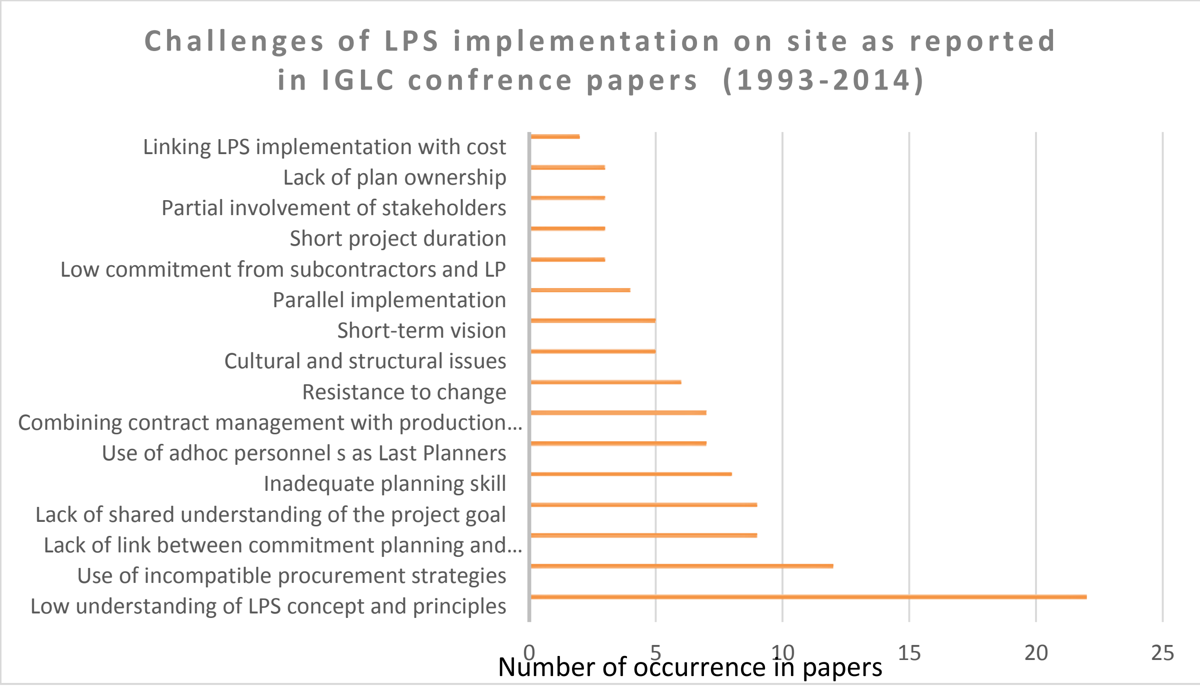

Figure 4.8: Last Planner Implementation Challenges in Construction

Source: Author's review of IGLC paper on LPS implementation

This shows that any organisation seeking to deploy the system across its business must be committed to training at all levels. According to Fernandez-Solis *et al.*, (2012) developing human capital within the organisation will enable the organisation to implement LPS effectively. Loosemore *et al.*, (2003) also argued that the best investment to improve the construction industry should be in human resource development. However, as crucial as training is to LPS implementation, it is initially an additional cost to the organisation even though it can be offset by improved performance.

4.5.10 Past and Current Developments in the Last Planner System

Figure 4.9 shows the timeline of the developments in the LPS. According to Glenn Ballard, one of the inventors of the Last Planner System (LPS), an earlier study on *Crew Planning* in the 1980s was a precursor to its development (Ballard, 2015a). At that time, Glenn was the Productivity Improvement Manager for Brown & Root's Construction in the US. Some key LPS principles such as '*make ready*' and '*shielding workers from bad assignments*' were practiced then.

While this and other studies contributed to the emergence of the LPS, it took another 10 years before the "Last Planner System" formally emerged as a system for managing production in construction (Ballard, 2015a; Daniel *et al.*, 2015; Ballard, 1993). It shows that Glenn Ballard and Gregory Howell's consulting work in the industrial construction sector led directly to the development of the LPS in the early 1990s (Daniel *et al.*, 2015; Ballard and Howell, 1998). The timeline reveals that the LPS did not emerge from the Toyota Production System, rather, it is an approach developed by construction practitioners specifically for the construction industry. The initial principles of the LPS were to: (1) improve workflow and (2) improve plan reliability and predictability (Ballard, 2000; Ballard and Howell, 1998). These principles have not changed but the list of LPS principles have been supplemented over time with on-going research and development.

The history of the LPS would be incomplete without mentioning its early marriage with Lauri Koskela's seminal work in 1992 on the application of production principles in construction (Ballard, 1993; Koskela, 1993). This union created the field now known as *'Lean Construction'* and led to the formation of the International Group Lean Construction in 1993 with its inaugural conference held in Espoo, Finland (Ballard, 1993). The term "Last Planner" was first mentioned at this conference and published in the Proceedings (Ballard, 1993). Early experimentations and implementations of the LPS on construction projects occurred between 1993 and 1994, with a full implementation of the system carried out on a major refinery project in Venezuela between 1995 and 1996 (Ballard and Howell, 1998; Ballard, 1993).

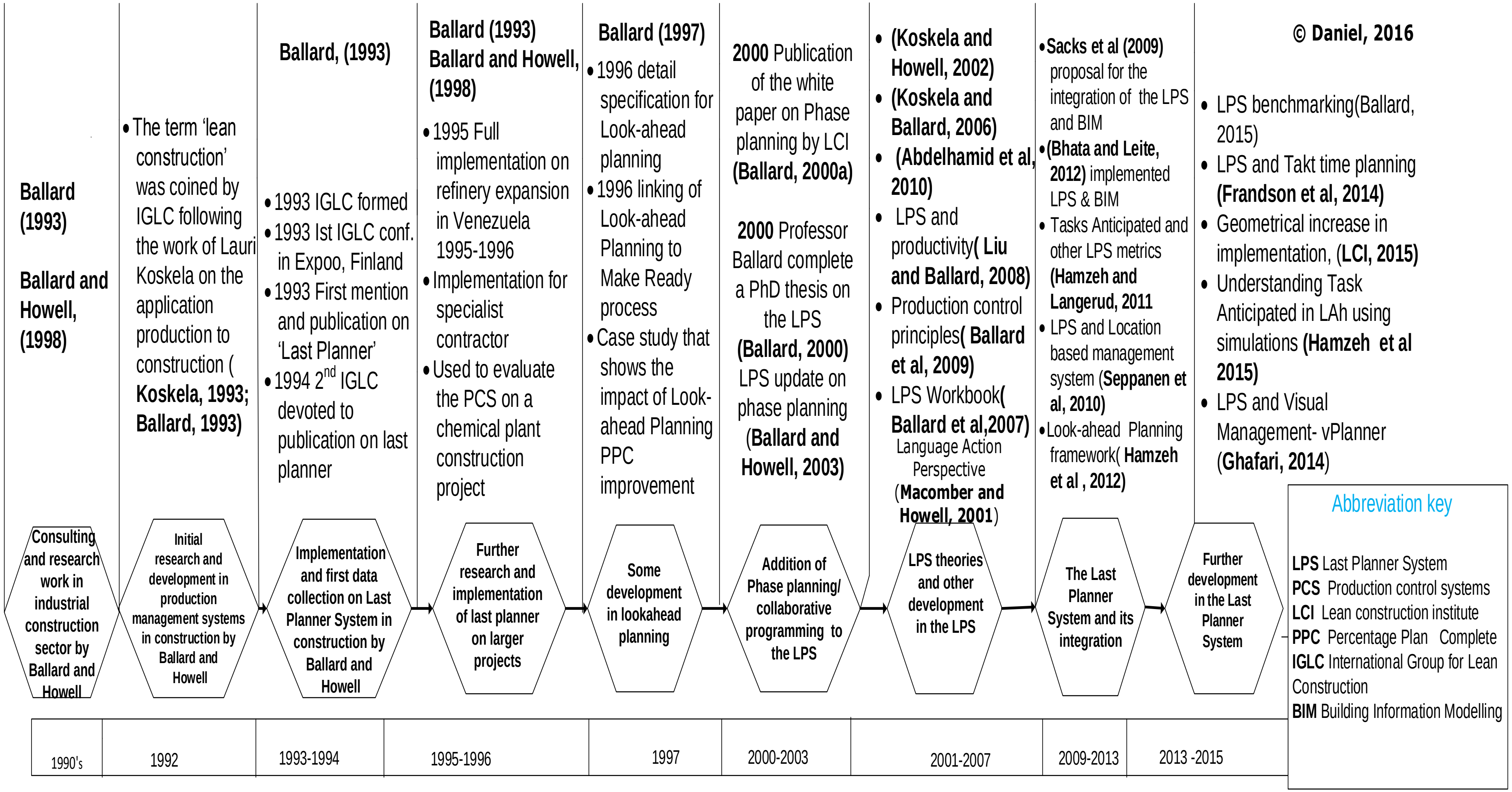

Figure 4.9: Timeline highlighting major developments in the Last Planner System

How it has Developed

Figure 4.9 reveals that various developments have occurred over time. For instance, in 1996, the link between look-ahead planning, the make-ready process, and the impacts of look-ahead planning in improving the PPC was first discovered and incorporated into the LPS. In terms of research, the most influential publication is Glenn Ballard's PhD thesis "Last Planner System of Production Control" published in 2000. A recent Google scholar search showed 909 citations of this work (Google scholar, 2016), the most cited publication on the LPS to date. Ballard's thesis has informed research into the LPS in both industry practice and academic activity. It is a core part of the Lean Construction education for undergraduates, Masters students, and PhD scholars around the world.

The figure also shows how theory can be used to underpin the system and explain how it works. Some of the studies that exemplify this include: the work of Lauri Koskela on the TFV (Transformation Flow Value) model of production (Koskela 2000), language action perspective (Macomber and Howell 2003), and the development of production control principles (Ballard *et al.,* 2009) to mention a few. The LPS has also been integrated with other systems such as Building Information Modelling (BIM), Location Based Management System, Takt Time planning and visual management. Several commercial software products have also been developed based on the LPS.

In terms of implementation, there has been an exponential increase in LPS implementation (LCI, 2016) in the construction industry with written evidence of LPS implementation in 16 countries and in all the major continents of the world (Daniel *et al.,* 2015). Currently, Glenn Ballard is creating a LPS benchmark with inputs from both industry practitioners and academics around the world (Ballard, 2015). The goal of the benchmark is to: list the current best practices of the LPS, provide Q&A to common questions on the LPS, give organisations the ability to measure their implementation of the LPS relative to the ideal state, and standardise the language used by the industry when referring to different components of the LPS.

4.6 Summary of Chapter

This chapter examined the evolution of production planning and control in management science, lean production and its eventual application in construction as demonstrated in the LPS of production control. The review indicates that the concept of production planning and control (PP&C) dates back to the work of a scientific management theorist, Frederick Taylor, and this idea was formally put forward after the World I with the aim of improving efficiency in the production line. The chapter showed that this approach is used extensively in the manufacturing industry as demonstrated in the lean production approach used in the Toyota production System. However, the application of lean production principles into construction was based on the seminal work of Koskela in 1992, which is not without criticism.

The chapter established that the LPS is a PP&C methodology for managing project production in construction, a system developed by Ballard and Howell from research in the industrial construction sector. The chapter reveals that the LPS supports the development of collaborative relationship among construction stakeholders through the key components when implemented holistically. It also shows that the success of the LPS in construction has been explained with robust theories. This is opposed to the theory, if any, on which the traditional project management is built on. The chapter demonstrates that the LPS has developed in terms of its level of implementation, theory development, and is now used as a vehicle to improve construction management practice in different parts of the world.

The chapter established that despite the initial criticism of the application of lean techniques in construction, the implementations of the LPS (a lean technique) in managing production in construction is on the increase. The review indicates that it has been implemented across 16 countries which cut across the major continents of the world. The review shows that the LPS is not static, but has evolved greatly in managing production in construction as demonstrated in its successful integration with other emerging concepts such as BIM, and vplanner.

Also, the trend in the implementation of its elements, progress in research, and building practice on sound theory among others attest to its development. The chapter reveals the drivers, benefits and the challenges for implementing the LPS in construction from the review of IGLC conference papers on LPS implementation between 1993 and 2014. This chapter presents a global perspective on LPS implementations in the construction industry and its influence on construction process improvement. The LPS has shown its potential to improve construction projects' cost, schedule, productivity, and safety.

Many researchers from around the world are actively conducting research on the LPS and new findings are continuously integrated into the LPS. Currently, the LPS is being benchmarked with input from across the world, the participants are drawn from both industry and academia. The intention for this is to reflect on the initial framework and to correlate that with current practice in the industry in order to strengthen its application and influence.

CHAPTER FIVE: RESEARCH METHODOLOGY AND DESIGN

5.1 Introduction

The previous three chapters (2, 3 and 4) presented the depth of literature covered in this study, and have thus been used as the basis to consider how the research should be carried out. This chapter presents a detailed account on the research methodology and design used in capturing the evidence used in answering the objectives proposed in chapter one. The chapter critically examines the philosophical assumptions and the research paradigm adopted for the study. It further justifies the chosen paradigm used in the study. In the chapter, the research strategy and methods were critically examined, and justification for the choice of mixed research method is presented. The chapter also presents the overall research design and discusses the five major stages involved in the study in detail. The measures taken to ensure that the data collected were valid and reliable are also examined in the chapter. Sections 5.3 and 5.4 centre on the research philosophy and paradigm, while sections 5.6 and 5.7 present the research strategy and justification for the methods. Furthermore, section 5.8 provides a detailed account of the six major phases of the research, while sections 5.9 and 5.10 discuss the quality of the research and the chapter summary respectively.

5.2 Understanding Research Methodology and Methods

It has been observed that the success of every research lies on the appropriateness of the research methodology and methods used in the investigation. However, as important as they are, some researchers misuse these terms which further affect its application in the study. Henn *et al.,* (2006) observed that it is vital to understand the difference between research methodology and research methods from the onset as it will help in designing the research process. Fellows and Liu (2008) defined “research methodology as procedures of logical thought process that applies to scientific investigations while research method refers to the specific techniques that are available which are actually used in conducting the research”. Collis and Hussey (2003) also concluded that research methodology is the sum of the approaches and perspectives used in the research process that focuses on stating the reason for data collection, what data need to be collected, where to collect the data, how to collect the data and how these data will be analysed, while research methods are the specific tools used in collecting and analysing the data.

Dainty (2008) argued that the success of a social science research is not just in selecting the methods but rather on the philosophical assumptions considered in selecting the methods. Furthermore Henn *et al.*, (2006) asserted that research philosophy influences the choice of research strategy and methodology.

5.3 Research Philosophy

It is vital to clarify the issue of research philosophical position as this is very crucial in determining the right methodology and methods to be used in carrying out an investigation. The two major schools of thought on research philosophy are epistemology and ontology (Saunders *et al.*, 2012; Bryman, 2012; Henn *et al.*, 2006), and they are housed in the outer layer as shown in Figure 5.1. In Figure 5.1, the outer layer (research philosophy) is the shell shielding the entire research process.

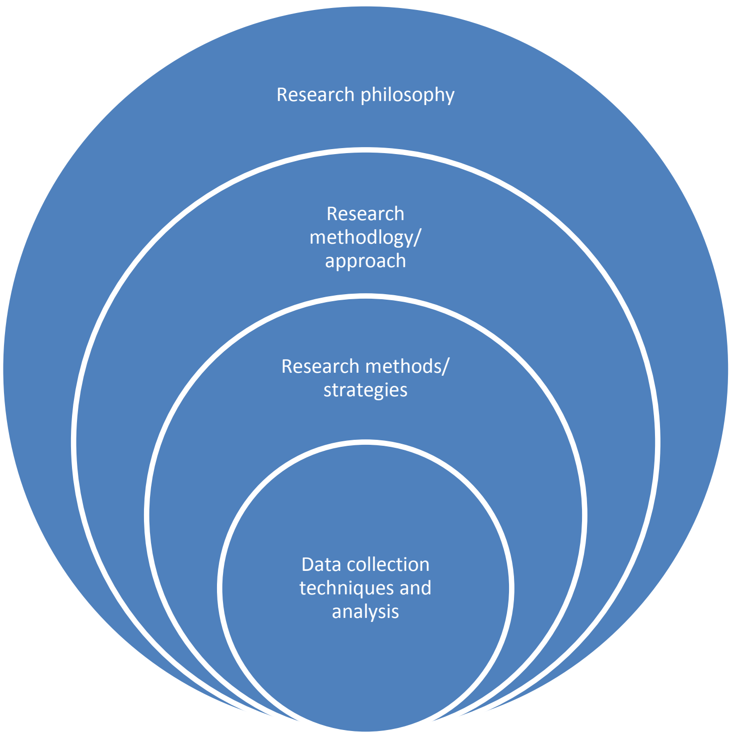

Figure 5.1: The relationship between research philosophy and methods

Source: Adapted from Sanders *et al.*, (2012) The implication of this is that without proper positioning or establishment of the of the research philosophy, i.e. the outermost layer, the remaining layers in the research framework cannot be accessed or achieved. According to Saunders *et al.*,(2012) and Henn *et al.*, (2006), research philosophy determines the acceptable knowledge and the processes to undertake in order to answer the research question. However, Johnson and Clark (2006) cautioned that the focus of the researcher should not be only on ensuring that the study is philosophically informed; but should be able to reflect on the chosen philosophy and as well justify why the alternate philosophy is not chosen. Thus, the two research philosophical positions are considered.

5.3.1 Ontology

Every research has its own ontology. Ontology is concerned with the assumptions and claims the researcher made about knowledge that exists out there, with focus on the form in which the knowledge exists, the different parts that make up the knowledge and how they interact (Saunders *et al.*, 2012; Blaikie, 2007). Creswell, (2013) and Ritchie and Lowis (2003) submitted that ontology is concerned with understanding the social world and its characteristics. The goal of ontology is to identify the knowledge that exists out there and how they can be presented. Different ontological positions have been identified in the literature. Easterby-Smith *et al.*, (2012) identified four positions which include; realism, internal realism, relativism and nominalism while Ritchie and Lowis (2003) identified three major positions which are; realism, materialism and idealism.

According to Easterby-Smith *et al.*, (2012) and Richie and Lowis (2003), realism is the belief on the existence of only one truth and on external reality of the world which is independent of people's view or belief. Relativism on the other hand is a belief that truth should not be validated on the basis of the process used in ascertaining it and that there are many truths while the nominalism position argues that there is nothing called reality; and that all realities are created by human actions (Easterby-Smith *et al.*, 2012). Contrary to these is the materialism view which believes in reality; though the reality here is limited to physical characteristics that can be touched.

Other authors broadly classified ontological positions into two which are; objectivism and constructivism (Saunders *et al.*, 2012; Grix, 2002; Crotty, 1998).

Objectivism and constructivism are also expressed in epistemology which further shows the link between ontology and epistemology. The ontological position of this study is a combination of constructivism and objectivism as presented and justified in subsequent sections. The discussion in this section has shown that ontological consideration is vital for every research as it will guide the researcher to know the nature of reality that exists in the world before commencing the investigation on how to know that reality i.e. epistemology.

5.3.2 Epistemology

To a social scientist, epistemology is concerned with the theory of knowledge with special focus on the process used in gaining the knowledge about social reality (Grix, 2002). The word is derived from two Greek words i.e. *episteme* (knowledge) and *logos* (reason). Its focus is on what should be considered as an acceptable knowledge in a given field of study (Saunders *et al.*, 2012; Bryman, 2012; Henn, 2006). These suggest that epistemology aims at investigating the kind of knowledge produced, how the knowledge was developed and the conditions to use in differentiating valid knowledge from invalid knowledge (Blaikie, 2007). It is worth to state that every study must identify and take a specific epistemological position throughout the research process. Two contrasting epistemological positions have been identified; though they are presented under different names, they have the same meaning. For instance, while Crotty (1998) named the two epistemological positions as objectivism and constructivism; Grix (2002) viewed them as positivism and interpretivism.

Objectivists and positivists believe that social reality can only be known and understood via the application of natural science methods. While constructionists and interpretivists believe that in order to understand the social reality, there is need to study the actors that are involved in the process, this implies that social realities are created by the actors (Saunders *et al.*, 2012). From the above discussion, it is obvious that choosing or taking a particular epistemological position will influence the methodology that will be used in the investigation. This implies that different methodologies could be used to study even similar phenomena if the epistemological positions are different. The epistemological position of this study is a combination of both interpretivism and positivism. The justification for this is presented in subsequent section

5.3.3 The Relationship between Ontology, Epistemology, Methodology, and Research Methods

As earlier stated, every research has its ontological and epistemological positions or assumptions. Grix (2002) asserted that ontology and epistemology are the fundamentals of every genuine research as they play a major role in deciding the research methodology and methods. However, many have failed to understand the relationship that exists between these key terms, which leads to muddling up of the research process. This is clearly discussed here to prevent the author from making similar mistakes. For instance, it has been observed that ontology is usually confused with epistemology while methodology is usually confused with methods (Grix, 2002; Blaxter, 2010). The consequence of these confusions is the omission of the logical sequence that exists between each concept. Figure 5.2 shows the relationship between each concept and the logical sequence.

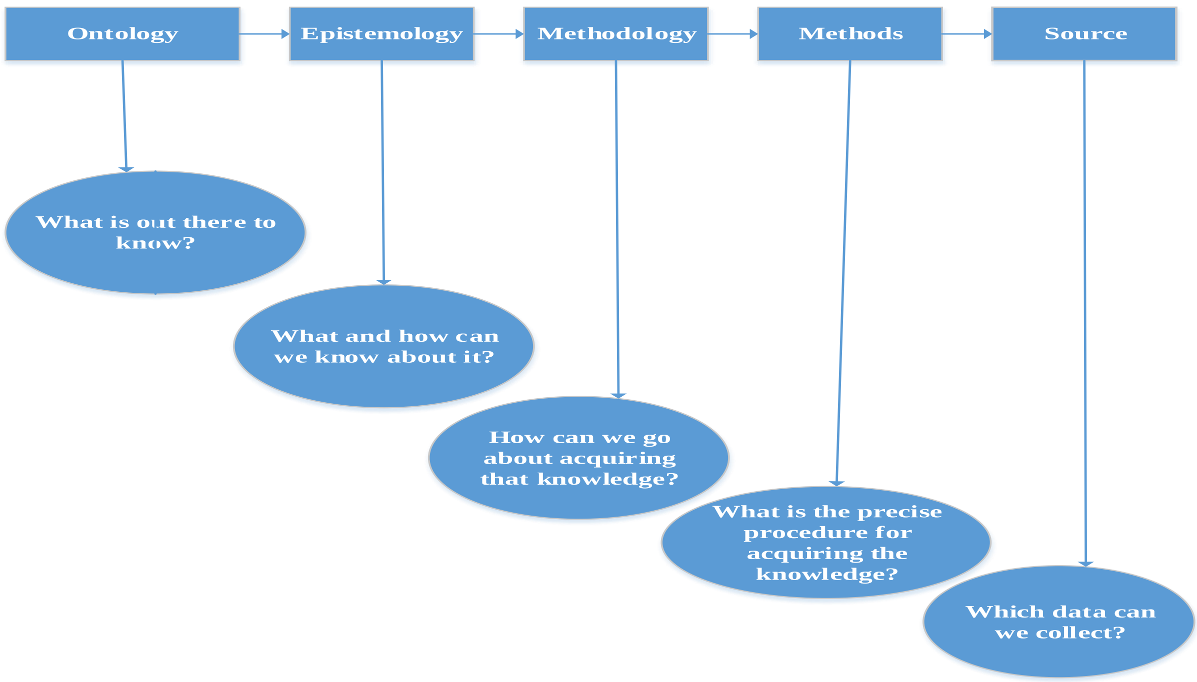

Figure 5.2: The Logic of Research building block

Source: Adapted from Hay (2002)

As shown above, these logic needs to be maintained in developing the research process. According to Grix (2002), the implication of this interrelationship is that research cannot just commence at any point in the diagram. This further emphasises the need to allow an ontological and epistemological position to shape the research process and not the research methods. It is obvious that choosing a research method before developing the research question is against the logic presented in Figure 5.2 as it will eventually lead to research question and method misfit (Saunders *et al.,* 2012; Grix, 2002). The ontology and epistemology in the research building block presented in Figure 5.3 formed the basis of the research paradigm.

5.4 Research Paradigms

According to Henn *et al.,* (2006 P10), paradigm "is a set of assumptions about how the issue of concern to researcher should be studied". It is a means of evaluating social phenomena with a view to determining the approach to be used in conducting the investigation and how the phenomena can be explained (Saunders *et al.,* 2012; Bryman, 2012; Fellows and Liu, 2008). Research paradigm has been classified into three, these include; positivism, interpretivism and mixed approach) (Saunders *et al.*, 2012; Bryman, 2012; Fellow and Liu, 2008, Smith, 2006).

5.4.1 Positivism

The dominance of positivism and interpretivism in construction management research has been widely acknowledged in the literature (Dainty, 2008; Neville, 2007; Love *et al.*, 2002). Positivism is based on the assumptions that there is an objective reality that must be studied, touched, and known in the physical world (Lincoln, 1994). It focuses on identifying, measuring, and evaluating problems in order to establish any available causal relationship (Henn, 2006; Neville, 2007). The proponents argued that social science research should be viewed and investigated like any other natural science research by adopting the empirical methodologies in the natural sciences (Berg, 2007; Collin and Hussey, 2003). Guba and Lincoln (2005) noted that the approach allows the researcher to investigate the problem without influencing it. The commonly used research method or strategy with positivistic view is quantitative research method or strategy. The research methods used in positivistic approach are survey, experimental survey, longitudinal survey, and cross-sectional survey.

5.4.2 Interpretivism

Interpretivism is based on research paradigm that is contrary to the positivistic view on knowledge. The interpretivist believes that research in social science cannot be conducted as in natural science research, since human behaviour and phenomena which social research is associated with cannot be easily measured as applicable in the natural sciences (Collin and Hussey, 2003). The proponents argued that social science research involves people, institutions, settings, and organisations which are fundamentally unique from the natural science research, thus a unique approach that gives consideration to human behaviour should be adopted in conducting a social science research (Bryman, 2012). It focuses on understanding human behaviour and phenomena from the participant's point of view which is contrary to the positivistic approach that tends to explain behaviour from the researcher's perspective (Bryman, 2012; Neville, 2007).

This suggests that the approach allows participants to make meaning out of the world around them. Neville, (2007) argued that people have the ability to influence the event around them in order to improve their condition, thus research methods that examine and investigate problems or trend of events from the participants' perceptive should be adopted. According to Bryman (2008 Pp, 16), "social reality has a meaning for human beings and therefore human action is meaningful". This implies that the need for adopting philosophical viewpoints that allow human action to come into play in the research process (especially in social science research) cannot be underestimated.

The commonly used research strategy with interpretivistic views is the qualitative research strategy. Qualitative strategy incorporates the following research methods; case study, action research, ethnography, participative enquiry, feminist perspectives and ground theory. Table 5.1 indicates the key differences between positivist and interpretivist research philosophies.

From the foregoing, interpretivist point of view tends to support the goal of this study which seeks to know how the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK from a production planning and control perspective aligns with the advocated principles and theories of the Last Planner System (LPS) in a social setting (UK). But no decision could be made here without the examination of other paradigms.

Table 5.1: Comparing Positivist and Interpretivist Research Philosophies

Positivist	**Interpretivist**
Knowledge is based on phenomena that is directly observable	Knowledge is based on understanding, interpretations and meanings that are not directly observable
The social world should be researched using the principles of natural science	The social world should be studied in its natural state, using participants observation and in-depth interviews
An explanation is achieved through the formation of causal laws	Explanation is achieved through description of social meanings/reasons
It uses deductive method with emphasis on hypothesis testing	It is based on inductive method in which theory is generated from data
Methods imply researcher/ respondent detachment in the objective collection of data	Methods imply insider approach, researcher/ respondent closeness in joint collection of subjective data
Analysis is based on statistical testing of given theories	Analysis is based on verbal, action and situation description from which theories evolve
There is stress on reliability and generalisation	There is no stress on generalisation
Research methods: survey, experimental studies, longitudinal studies and cross sectional studies	Research methods: case study, action research, participant observations, participative enquiry etc.

Sources: (Bryman, 2012; Sanders *et al.*, 2012; Henn *et al.*, 2006)

5.4.3 The Chosen Paradigm and the Rationale

Having critically examined the various research paradigms in the preceding sections, it is now germane for this study to take its own philosophical stance which should be capable of driving the study to achieve its ultimate goal. The importance of taking a philosophical stance and its role in shaping the research process has been emphasised by numerous authors (Saunders *et al.*, 2012; Lipscomb, 2011; Dainty, 2008; Fellow and Liu, 2008; Henn, 2006; Grix, 2002). Johnson and Duberly (2000) suggested that researchers should take philosophical stances that match the researcher's profile, the nature of the study and with the potential of assisting to understand and address the concerns of the study. As discussed in sections 5.4.1 to 5.4.3, the most utilised research paradigm in social science research and by extension construction management are positivism and interpretivism. All of these and some of the justification for their use in this study have been discussed in section 5.4.1.

Furthermore, interpretivism paradigm is more aligned with research methodologies that enable the researcher to develop an understanding of problem when there is limited knowledge on the subject under investigation. It also allows the views, positions, concerns and the meaning ascribed to the problem by the participants to be known and not limited to that obtained from the literature (Fellow and Liu, 2008; Cole, 2006). All these align with the aim of the study earlier described.

However, the study also seeks to objectively identify the impact of production planning and control practice based on the LPS on construction process improvement (CPI). It is to also objectively evaluate and validate the Last Planner System Path Clearing Approach (LPS-PCA) developed to support construction stakeholders in the implementation of the LPS in construction, which requires research methodology associated with positivism. Based on this understanding, the chosen paradigm in this study is a mixture of interpretivism and positivism (Saunders *et al.*, 2012; Henn *et al.*, 2006), as it enabled the study to achieve the study aim and objectives.

The effective combination of interpretivism and positivism in conducting construction management research has been widely reported in the literature (Dainty, 2008; Fellow and Liu, 2008). Dainty (2008) asserted that positivism (quantitative) and interpretivism (qualitative) research both have their root in ontology and epistemology, thus they can be combined.

5.5 Research Strategy

Naoum (2013 pp.39) defined research strategy as “the way in which research objectives can be questioned” while Bryman (2008 pp.22) referred to it as “the general orientation for conducting social science research”. Both authors identified quantitative and qualitative approaches or the combination of both as the main research strategy. These research strategies will be critically examined in the next section to further help in positioning the study.

5.5.1 Quantitative Approach

Quantitative research is based on positivist research paradigm as outlined in Table 5.1. It emphasises the need for data quantification and establishment of causal relationships between variables (Dainty, 2008; Bryman, 2012). Henn *et al.*, (2006) observed that with the quantitative approach, there is pre-conceptualisation with regard to research question, research design and the likely findings. This implies that when the research design is highly structured, the methods should be reliable. The research design also aims at generating large scale statistical information in order to generalise the findings. Although the approach allows large data collection for generalisation and reproduction of findings, the highly structured research design poses a great limitation to such findings as there could be various ways to explain why a particular event occurs. Quantitative approach tends to be objective in focus, while also trying to establish a trend in a study; it is concerned with answering questions such as, what? how much? and how many? (Naoum, 2013; Bouma, 2000). Basically, sample survey and experiment are the methods used in quantitative approach. The aim of this study is not to test theory, hypothesis or make any form of generalisations, however, quantitative method such as survey will be adopted on a lower scale at some points in the study for evaluation and validation purposes.

5.5.2 Qualitative Approach

Qualitative research approach is based on interpretivist paradigm as outlined in Table 5.1. Qualitative research can be defined as "an approach to inquiry that begins with assumptions, worldviews, possible theoretical lens, and the study of research problems exploring the meaning individuals or groups ascribe to social or human problems" (Creswell, 2007 pp.50). Unlike the quantitative approach, it emphasises the use of words in the collection and analysis of data rather than measurement and quantification. This will enable the study to closely explore the problem and develop solution. It seeks to know why, what, how or where of an event and the likely meaning ascribed to such event by the participants in that setting (Fellow and Liu, 2008); which aligns with the aim of this study.

It is worth noting that this strategy has been criticised for lack of objectivity and that the data are not large enough to generalise findings. In this study, effort was made to improve this, as the study used multiple approaches in collecting data and triangulating methods. According to Berg (2007), the essence of research is not just to assemble data, rather, it is to adopt a logical and systematic process that helps in answering the research question. Thus, qualitative research seeks to answer the research question by investigating the social settings and individuals in the settings (Berg, 2007; Henn, 2006). In this study, the social setting is the UK construction industry and the people inhibiting it are the construction industry professionals and organisations.

Qualitative strategy is considered appropriate for this study based on its attributes identified by Naoum (2013); Bryman (2012); Fellow and Liu (2008); Henn *et al.*, (2006); which align with the aim and objectives of the study. Firstly, it allows the study to be conducted in a real life social setting in order to understand the current phenomenon investigated, and this is in line with aim of the study. Furthermore, qualitative research can be conducted under different methods such as interviews, case study, action research, ethnography (participant observations), and participative enquiry (Henn *et al.*, 2006; Bryman, 2012). Table 5.2 clearly outlines the major differences between quantitative and qualitative strategy.

Table 5.2: Differences between Quantitative and Qualitative Strategies

Features	Quantitative strategy	Qualitative strategy
Aim and objectives	Measurement of views and opinions	To gain full insight into the research problem
	The goal is to establish cause and effect	Focus on describing the problem and process
	Focus on data quantification and generalisation of findings	Focus on understanding the research problem and the motivations
Hypothesis/ research question	Stated before the commencement of the study	No defined hypothesis before the study
	Investigation is based on theory and it uses deductive approach	Theory is usually developed inductively after the investigation
Study variable	The independent variable is usually controlled and manipulated	Does not focus on any variable, its focus is to investigate the social or natural settings.
Data collection method	Fixed and objective approach. Uses closed and structured questionnaire, experimental methods	Flexible approach. Uses open ended, semi-structured and unstructured interviews, case studies, observations, focus group etc
Research design	Fixed research design, usually developed before the study	No pre-determined research design, it keeps developing as the study progresses
Method of data	Descriptive statistics with	Content analysis and coding of

analysis	focus on numerical values, percentages, mean etc.	themes
Validity and reliability	Uses statistical analysis and data to ascertain and validate data	Use of multiple approach known as "triangulation" helps in validation of information
Study sample	The selected sample should represent the population for the study	Purposive sampling is usually used for the study, sample size is not the focus
External validity	Uses statistical data (size of population) and inference to validate results and generalise findings	The focus here is not to generalise findings, but multiple sources are used in validating and enriching findings
	Focus is on the research design and the data collected	Based on the procedures used in carrying out the investigation
	The research problem is investigated in a simplified and objective manner	The research problem is investigated from all perspectives (holistically)
Strength	Findings can be easily generalised	Multiple sources of data collection help in enriching information
	The selected variables can be easily measured	Detailed information about the problem can be easily obtained
	Data is obtained from large sample, which supports finding generalisations	Participants' opinions and views about the phenomenon can be readily obtained
Weakness	The approach is rigid which could limit the development of theories	Findings cannot be easily generalised due to small sample size. Knowledge generated may not be readily applicable in other settings

Sources: Sanders, 2012; Bryaman, 2008; Creswell, 2007; Henn *et al.*, 2006; Denzin and Lincoln, 2012

Having examined the characteristics of the quantitative and qualitative strategies which further align with the aim and objectives of this study, the combination of both approaches which is commonly termed mixed strategy or approach was chosen for this study. However, within each strategy, specific methods were used.

5.6 Research Method Consideration and Choice of Research Method for the Study

In the introductory section of this chapter, an attempt was made to explain the differences between research methodology and research methods. The relationship that exists between them was further shown in Figure 5.1. However, Fellow and Liu (2008) suggested that in order to determine the appropriate method to adopt, it is necessary to consider the logic that exists between data collection and analysis from using the method. Also, the method should be sufficient enough to achieve the overall research objectives. This suggests that it is paramount to critically examine some available research methods before selecting the appropriate method for the study. In view of this, the following research methods were critically examined because of their relevance to the current study. They include: Design science/Action research, Ethnography, Surveys and Case study.

5.6.1 Ethnography Evaluation

It is a qualitative method used to study groups of people, their culture, and the interactions and practices that occur among them within their social environment or settings (Saunders *et al.,* 2012; Fellow and Liu, 2008). The study occurs through close observation of the participants in their natural setting by the researcher. The empirical data for the study is usually obtained by questioning the participants formerly or informally so as to gain an understanding of the problem (Fellow and Liu, 2008). Henn *et al.,* (2006) suggested that the use of an informal approach in conducting the investigation will enable the researcher to observe and gain understanding of the problem without being viewed by the participant as surveillance. In this approach, the goal of the researcher is to study the participants in the setting so as to understand the problem without causing any form of obstruction to the work being done by the participants.

From the above mentioned, ethnography approach could have been a potential approach to use in exploring how the current understanding and application of CP from delivering construction projects from production planning and control (PP&C) perspective in the UK construction aligns with theory and principles of the LPS. This is because of its ability to interact and observe a specific practice in a given context (Saunders *et al.,* 2012; Fellow and Liu, 2008). However, ethnographic approach is dominated by participant observations over a long period of time which makes it less suitable for this study that has a limited time frame. Again, the focus of the study is not only to observe participants but to also understand the meaning the participants ascribe to the problem under investigation.

5.6.2 Design Science/ Action Research Evaluation

Design science research (DSR) is similar to action research in many areas (Cole *et al.*, 2005). DSR method is a problem solving approach that focuses on providing an innovative solution by identifying problems while also developing and implementing the right approach for addressing the problems (Hevner *et al.*, 2004). The method incorporates exploratory and action research approaches which has been identified as proactive research methods that directly influence real world problems in order to provide practical solutions to such problems in real life (Cole *et al.*, 2005; Berg, 2007). It is commonly used in operation management and information system but it has now diffused into construction management research especially lean construction research (Cole *et al.*, 2005; Hevner *et al.*, 2004; Ahiakwo *et al.*, 2013; Formoso *et al.*, 2012).

Considering the fact that the construction industry is dynamic and at the same time complex, the best approach to initiate change within the industry could be via research methods that encourage learning through associated actions.

DSR relies on existing knowledge including those from literature, practice, and iteration of processes in order to develop an innovative and systematic approach for addressing the identified problem (Hevner *et al.*, 2004). Like in the case of action research, the researcher must be actively involved in identifying, developing, and implementing the solution for the identified problem. The approach reduces the gap that exists between practice and theory in research (Koskela, 2008

Given the proactive and practical nature of action research (AR) and DSR, in addition to the recommendation for its use by lean construction scholars for researches in lean construction (Koskela, 2008), this could be a potential approach for conducting this study which focuses on the application of lean principles in planning.

However, the focus of AR/DSR is on developing and implementing a practical system in an iterative process to address the problem with active involvement of the researcher. This study only created and piloted an approach to support LPS implementation towards the end of the study, which implies there is no intention for iteration of the process, hence AR/DSR is less feasible. Furthermore, as much as the study is not claiming to generalise its finding, it seeks to explore different approaches to present a fairer picture of LPS/CP in the UK construction industry, in order to suggest a means to support the process. This cannot be achieved with AR/DSR alone; hence, the method was discounted. There could be feedback delay from the iteration process which may not be good for this time constrained study.

5.6.3 Surveys Approach Evaluation

Survey method is used to obtain response from a large sample of respondents in a structured format. It is usually based on statistical analysis and uses a deductive approach (Saunders *et al.*, 2012; Henn *et al.*, 2006). The knowledge acquired from the process could be generalised since the approach could be used to reach large number of respondents. It is worth to state that the respondents must be a true representation of the population of the study before such conclusions can be valid. The limitation with this approach is that it does not allow for new perspectives on the subject or phenomenon under investigation to be gained from respondents. This is because the factors to be investigated are already predetermined by the researcher especially in questionnaire survey, thus limiting the view of the respondents (Henn *et al.*, 2006).

Survey data are collected via face to face, telephone interview and postal questionnaire. The type of survey technique used has influence on the quality of data and also on cost (Naoum, 2014; Bryman, 2012). It is worth noting that, survey method is not limited to questionnaire survey as commonly believed. It includes other structured approaches such as structured observations, structured and semi-structured interviews among others (Henn *et al.*, 2006). Although, questionnaire survey is relatively cheap compared with interview survey, interviews generate more quality data.

Considering the exploratory nature of the study, going into the study with a predetermined question such as in questionnaire survey will not support the aim of the study, as this would limit the respondents from sharing their experience on the problem being investigated. Even though some of the interview questions were developed from the literature review, they were open ended questions and flexible. Thus, questionnaire survey was discarded. Also, the focus of the study is not to generalise the findings, and considering the fact that lean construction in general, and LPS in particular is an emerging concept in the construction industry, obtaining representative sample for statistical analysis will be unlikely. For instance, there is no database for lean construction practitioners in the UK construction industry.

However, structured survey was used to evaluate and validate the LPS-PCA developed in this study and also in the assessment of the impact of the LPS implementation on construction process improvement. This was done to obtain objective data on these objectives.

5.6.4 Interviews

Interview is a common approach used in data collection in social science research. There are different types of interviews; open-ended, semi-structured and unstructured interviews. Interviews could be conducted face-to-face, via telephone conversations, use of online medium such as Skype, computer mode supported interview, and e-mail correspondence among others (Bryman, 2012; Sanders *et al.*, 2012; Creswell, 2007). However, Bryman (2012) and Yin (2014) observed that semi-structured interview is the most used approach in qualitative research. Bryman (2012) observed that semi-structured interview is commonly used because it promotes standardisation in the asking and recording of responses to the interview questions. The goal of using semi-structured interview is to be able to aggregate the responses of the interviewees. However, unlike questionnaire survey where the respondents are restricted by the rigid nature of the questions, the semi-structured interview process is flexible. This enables respondents to bring out in-depth information based on their experience.

Naoum (2013) pointed out that in a semi-structured interview process, the interviewer has a great deal of freedom to probe the respondents on specific areas for further insight, which further enriches the quality of the data collected. Thus, semi-structured interview was used in the study. But it has been claimed that the attribute of the interviewers could influence the responses of the interviewees in a semi-structured interview (Naoum, 2013; Bryman, 2012). Bryman (2012) argued that there is no clear evidence to support such claims. This implies that interview has its own strengths and limitations. Table 5.3 presents the strengths and limitations of interviews as summarised in Recker (2008 pp109) and Robson (2002 pp.269-290). However, effort was made by the researcher to minimise the limitations associated with interview in the study. This was achieved by ensuring invitation letters/e-mails were sent out to the interviewees ahead of time. In the mail, the purpose of the study was made known to the research participants. This process builds trust between the researcher and the interviewees.

Table 5.3: Strengths and Weaknesses of the Interview Approach

S/NO	Strength of interviews	Some limitations with interviews
1	Can be used for thematic and issue analysis	Time consuming in terms of actual interview and corresponding analysis
2	Useful for small samples	Training of interviewers and the need for interpersonal skills
3	Allows subjects to speak for themselves	Usually needs to be transcribed
4	Allows teasing out of underlying issues	Potential lack of precision
5	Enabling gathering of rich and deep knowledge	Need for rigorous thematic analysis
6	Can serve as foundation for extending the study	Potential lack of trust
7	Formally tests the emergence of patterns and relationships	

Source: (Recker, 2008; Robson, 2002)

Also, interviews can be used in different qualitative methods, such as action research, ethnography, grounded theory, and case studies among others. However, the nature of the study usually determines the type of interview to be used. Table 5.4 presents interview types in relation to the focus of the study.

Table 5.4: Interview Type in Relation to the Nature of the Study

Type	Exploratory study	Descriptive study	Explanatory study
Structured		More frequent	Less frequent
Semi-structured	Less frequent		More frequent
Unstructured	More frequent		

Source: Sanders *et al.*, 2012, pp377

Sanders *et al.*, (2012) observed that two or more of these interview approaches could be used in a single study with each building on each other to enrich the data. This informed the use of semi-structured interview in the exploratory phase of this study and structured interview in the descriptive phase.

[5]Specifically, exploratory interviews was used since the study examined the current understanding and application of PP&C based on the LPS in the UK construction industry, by exploring the social settings (the UK construction industry sector) and the individuals in it (the UK construction practitioners). Creswell (2013) observed that exploratory interviews are appropriate when a study seeks to know the meaning people ascribe to an event and not the meaning from literature alone; which aligns with the aim of this study.

Additionally, the interview approach was considered appropriate as it has been identified as an effective means of learning about a phenomenon in a particular setting. It has been observed that no research method "can provide the detailed understanding that comes from directly observing people and listening to what they have to say at the scene" (Taylor and Bogdan, 1984, p. 79). Thus, interview and observation were used in the second, third and fourth stages of this research.

5.6.5 Case Study

Yin (2009 Pp.18) defined case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". This suggests that the case study method is used to explore research problems or phenomena in a real life situation or context. According to Eisenhardt and Graebner, (2007); Amaratunga *et al.*, (2002), the case study approach allows the researcher to gain deeper understanding of the research problem or the phenomenon in relation to context in which the study is being conducted. Saunders *et al.*, (2012) asserted that unlike in the survey approach, the boundaries within which the phenomenon is being studied in case study is not restricted by any variable. Yin (2014) suggested three conditions that should inform the choice of the case study method; (1) when the study seeks to answer research questions such as "how" or "why" (2) when the goal of the study is not to have full control over the phenomenon being investigated and (3) when the goal of the study is to focus on real life situations in a given context. All these align with the research questions this study answered;

[5] Part of this have been published in Daniel *et al.,* 2015c

How does the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK align with the advocated principles and theories of the Last Planner System (LPS)?

How can construction stakeholders be supported for rapid and successful implementation of the Last Planner System?

Yin (2014) observed that the case study approach is appropriate when a study seeks to know the how or why of an event. For instance, the goal of this study is to understand how PP&C as currently practiced in the UK construction industry aligned with the LPS and how to support construction organisation for rapid and successful implementation of LPS. Also, the case study approach could entail investigating a single case or multiple cases, which is usually determined by the overall aim of the study or how the case study has been designed. The techniques used in collecting data include but are not limited to interviews, semi-structured interview, observation, exploring documents, and audio visual materials. As shown in Table 5.5, each technique has its own weaknesses and strengths (Yin, 2014).

To overcome these weaknesses, the study combined these techniques to supplement the weaknesses. The key advantage of adopting multiple case studies is that it allows the researcher to gain a better understanding of little known problems or phenomena in a particular context using data from various sources known as "triangulation" (Yin, 2014; Leedy and Ormrod, 2001). Since this research aimed at developing a better understanding of the phenomenon under investigation in order to develop a holistic support, the multiple case study approach was adopted. This also supports triangulation. The triangulation approach has been identified as a mechanism that adds rigour to case study research method (Yin, 2014). The approach could also be used to develop a new theory, confirm an existing theory or in modifying it when necessary based on findings from the study.

Table 5.5: Strengths and Weaknesses of Sources of Evidence in Case Study

Source of evidence	Strength	Weakness
Documentation	• Stable – can be reviewed repeatedly • Unobtrusive - not constructed as a result of the case study • Exact - contain exacts names, reference, and details of events	• Retrievability - can be difficult to find • Biased selectivity (Collection is incomplete) • Reporting bias • Access - may be deliberately

		withheld
Interviews	• Target –focuses on the case study • Insightful- provides perceived causal inferences and explanation	• Bias due to articulated questions • Response bias • Inaccuracy due to bias • Reflexivity - interviewee gives what interviewer wants to hear
Direct and participants observation	• Reality –covers event in real time • Contextual cover • Insightful into interpersonal behaviour	• Time consuming • Selectivity - broad coverage difficult • Reflexivity - event may proceed differently because it is being observed • Bias due to participant-observer manipulation of event

Source: Yin, 2014

The case study method has been criticised for lack of rigour and defined procedure for carrying out the investigation. However, Yin (2014) argued that the issue of lack of rigour can be overcome when different techniques are used in collecting data, as adopted in this study.

Accordingly, in this study, multiple methods were used in collecting data as discussed in section 5.6.6. The case study method has been used extensively in understanding and addressing real life situations in social sciences, business, information system, and construction management among others. This could be due to its potential to enable the researcher to develop an understanding of the problem contextually, unlike the experimental method that tends to divorce the context when collecting data. All the above highlighted points informed the choice of case study method in this research.

5.6.6 Rationales for Choosing Mixed Method

The choice of mixed method for this study is mainly informed by the mixed research paradigm chosen for the study, which has been justified in section 5.4.4. As earlier stated, research paradigm influences research strategy or methodology. Mixed approach refers to the incorporation of both quantitative and qualitative approach in the research process. The use of mixed approach in construction management research has been widely reported in literature (Dainty, 2008; Fellow and Liu, 2008). Bryman (2012); Greene (1989) stated that the purpose of using mixed approach in research could be for triangulation, facilitation, sequential research development, credibility, to compliment, gain fresh perspectives, expansion i.e. adding breadth to scope, enhancement etc.

For this study, the essence of using mixed approach is not limited to but includes triangulation, to complement, gain fresh perspectives, sequential development of the research and ‘expansion’ adding breadth to scope. To be specific, the study used triangulation as it combined techniques such as exploratory interviews, structured snapshot observations, and multiple case study, which enriches the quality of the data obtained. Multiple sources (triangulation) were used in order to validate the data, and to ensure the LPS-PCA developed to support LPS implementation in this study is holistic.

Also, the sequential development of the research and adding breadth to scope approach was adopted. For instance, the structured snapshot observations on LPS practice questions was developed based on the findings from the first exploratory interviews and the initial literature review in phases 2 and 1 of this study respectively. This demonstrated adding breadth to scope. Also, the findings from the exploratory interviews and the snapshot observations informed the choice the three case studies conducted in the study. Henn *et al.,* (2006) observed that the combination of methods in research does not only appear in the gain from the individual method’s strengths when combined, but also stands to remedy the drawbacks that are inherent with the use of a singular method.

Furthermore, while the exploratory interview enabled the study to obtain detailed information on the current understanding and application of PP&C based on the LPS, the snapshot observation presents some objective view on current practices. The case study also reveals further information on the current practice and the nature of support to be provided for successful implementation. It has been acknowledged that combining two or more research approaches in a single study could be problematic due to time constraints, money, the required resources and most especially the different philosophical thoughts that underpins each method (Fellow and Liu, 2008; Henn *et al.,* 2006). However, Henn *et al.,* (2006) argued that the adoption of different research methods makes the research findings more credible as the approach adds more breadth and depth to the study.

In addition, Dainty (2008) further observed that quantitative and qualitative approaches both have their root in ontology and epistemology, thus they can be combined. The mixed method approach selected forms the basis of the overall research design.

5.7 Research Design and Phases

The preceding sections of this chapter examined the research philosophical positions, the methodology, methods, and justification for their choice in this study. This section fully examines the research design and processes involved in the study. The importance of research design cannot be overemphasised in any research endeavour. Yin (2014, pp28) defined research design as "the logical sequence that connects the empirical data to a study's initial research questions and, ultimately to its conclusions". Research design enables the researcher to reflect on how the data for the study will be collected, analysed and how meanings can be made to the data.

Similarly, Sauder *et al.*, (2012) asserted that research design is very crucial to the success of a research as it usually helps the researcher to present clear objectives for the study from the research questions, propose how data will be collected and analysed, give consideration for ethical issues and likely limitation to the study. It is worth stressing here that research design is not just a mere plan of work to be carried out by the researcher. According to Yin (2014), the essence of the research design is to enable the study to avoid the circumstance in which findings or evidence(s) from the study do not really address the original research question(s). Figure 5.3 presents the overall research design for this study and the processes involved. As shown Figure 5.3, the study comprised three key phases. The First stage highlighted in green is mainly the literature review. The literature review supported the development of the research question. The second stage highlighted in grey is the data collection phase. The final phase, which is highlighted in red, represented the creation and validation of the LPS-PCA. These three key phases are further divided into six specific stages.

The key stages of the study include:

1. Literature review
2. Semi-structured interviews
3. Structured snapshot observations

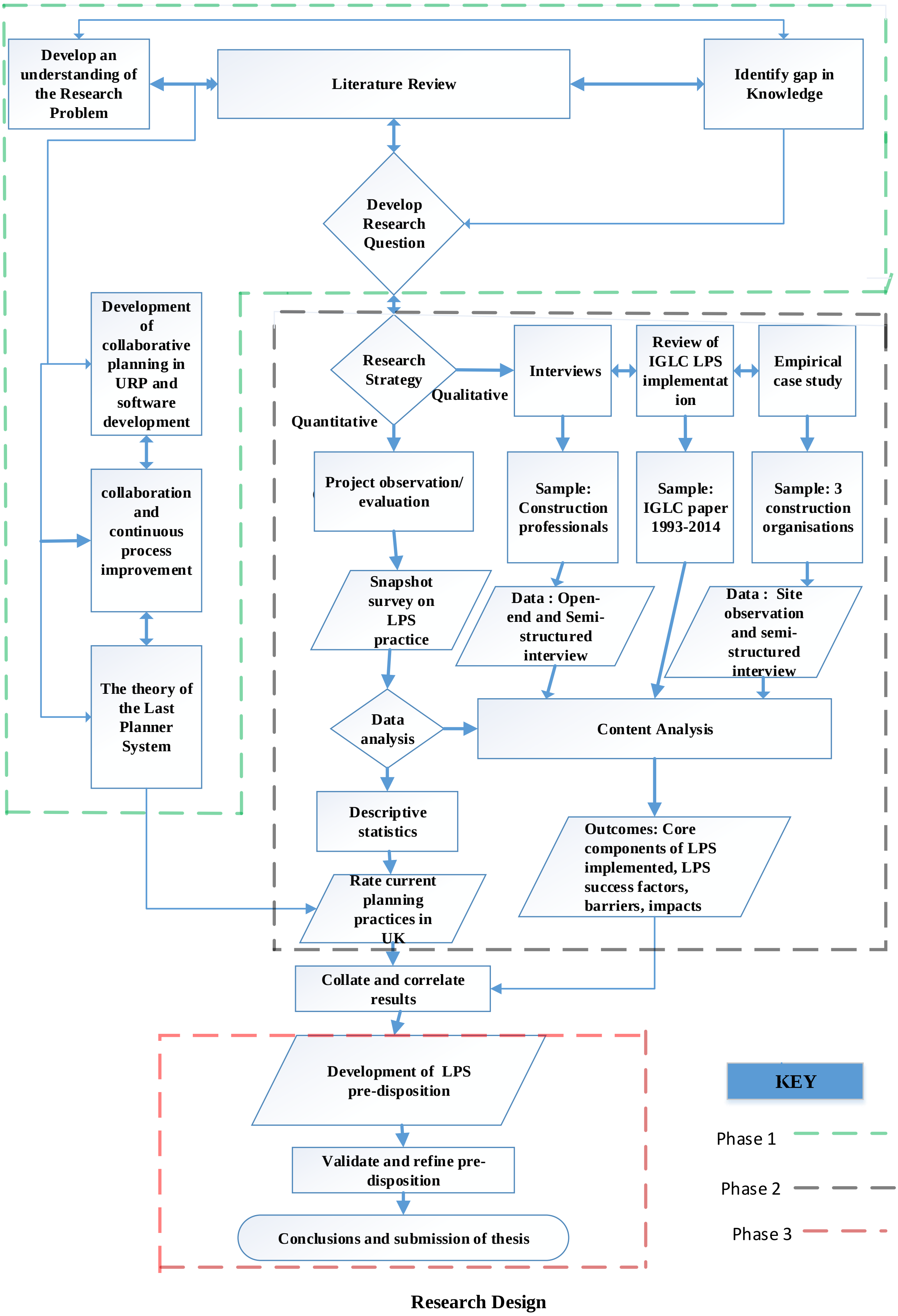

Figure 5.3: Research Design and Process

4. Multiple case studies
5. Development of Last Planner System Path Clearing Approach(LPS-PCA) and evaluation, validation and piloting of LPS-PCA.

Table 5.6 shows how each phase of the study linked with the objectives set out in Chapter One. It is worth to state that all the objectives are interlinked.

Table 5.6: Relationship between the Research Objectives and Phases of the Study

Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6
Phase 1	Phase 1	Phase 1			
			Phase 2		
			Phase 3		
				Phase 4	
					Phase 1 to 5

5.7.1 Stage 1: Literature Review

Literature review plays a vital role in a research process. Literature review has been defined as the “the selection of available documents (both published and unpublished) on the topic, which contains information, ideas, data and evidence written from a particular standpoint to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed” (Hart, 1998, pp13). Bryman (2012) observed that the essence of conducting a literature review is to understand what has been done in the area, the theories, and methods used in researching the area, and unanswered questions in the area among others. This will further position the researcher well to identify the importance of the present research and in framing the argument for the study accordingly. This implies that the literature review guides against researchers doing what others have already done.

Similarly, Naoum (2013) and Fisher (2007) observed that literature review enables the researcher to build on existing knowledge and expand the scope of the present study. Literature review played a major role in this study, ranging from the research question to the aim and objectives. For instance, the knowledge gap and the research question were partly identified from the literature as presented in Chapter One. Also, objectives 2, 3 and 4 were solely achieved via literature, while all the objectives were supported by the literature review as shown Table 5.6. Figure 5.4 shows the flow of the literature review chapters.

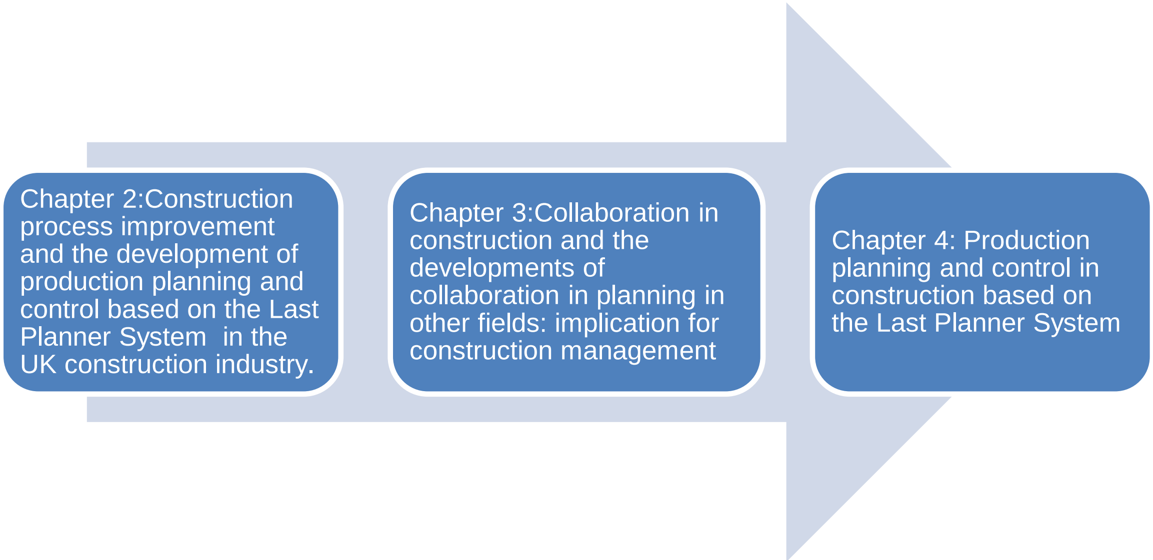

Figure 5.4: Literature Review Chapter Flowchart

The study reviewed the development of PP&C based on the LPS and the need for CPI in the UK. This included the review of the construction industry reports and the Lean Construction Improvement Programme (CLIP) demonstration projects. The development of collaboration in planning in the UK and other field of knowledge specifically in urban planning (UP) and software developments were reviewed. Also, the current theoretical understanding and application of production planning and control in the construction industry with focus on the LPS was considered. Furthermore, a comprehensive literature review on the LPS case study implementations as reported by the International Group for Lean Construction (IGLC) between 1993 and 2014 was done. This particular review enabled the study to compare the current practice of PP&C in the UK with the LPS and also in development of LPS-PCA.

In achieving this, a robust literature survey protocol that selects publications based on source, time frame and its relationship to the study was developed. Publications and collections from databases such as Emerald, Elsevier, Construction industry Institute, the International Group for Lean Group for Lean Construction (IGLC), Construction Economic and Management Journals, Journals of construction engineering and management, and Lean Construction Journals among others were examined. These databases were chosen because they house peer reviewed publications on lean construction and construction project management. The review was restricted to only published and peer reviewed materials. However, other materials that were considered important and not published were reviewed. This was done to ensure that important information in the study area was not neglected.

The search also extended to other academic and scholarly publications, database searches, journals, technical reports, conference proceedings, case study reports, text books, Nottingham Trent University (NTU) database, google scholar, and Scopus among others. For instance, publications that were not available on the NTU database were sourced through inter library loan. Each literature review chapter commenced with an introduction, the arguments, and the summary of the chapter which highlighted the conclusions from the arguments in the chapter. The literature was constantly updated throughout the research process and all the materials used in the review were referenced.

5.7.2 Stage 2: Semi-structured Interviews

Sanders *et al.,* (2012) observed that semi-structured interview is appropriate when undertaking an exploratory study and when the goal of the study is to understand the meaning ascribed to the subject investigated, which aligned with the focus of this study. From the initial literature review and knowledge gaps identified in phase 1 of this study, an exploratory semi-structured interview was designed (see Appendix 1 for a sample copy). The aim of the exploratory interview was to investigate the current understanding and applications of PP&C principles in the UK construction industry through in-depth interviews with construction industry practitioners. This empirical investigation became essential as a result of the knowledge gap caused by the dearth of study that empirically explored the application of production planning and control practice based on the LPS across the major sector of the UK construction industry.

More importantly, since the study aimed to develop an approach to support stakeholders (client, main contractors, and subcontractors) in the implementation of LPS in the construction industry, in-depth interviews with these major practitioners was considered essential to ascertain the current situation. The interview process consisted of 6 key processes as presented in Figure 5.5, each process was carefully examined.

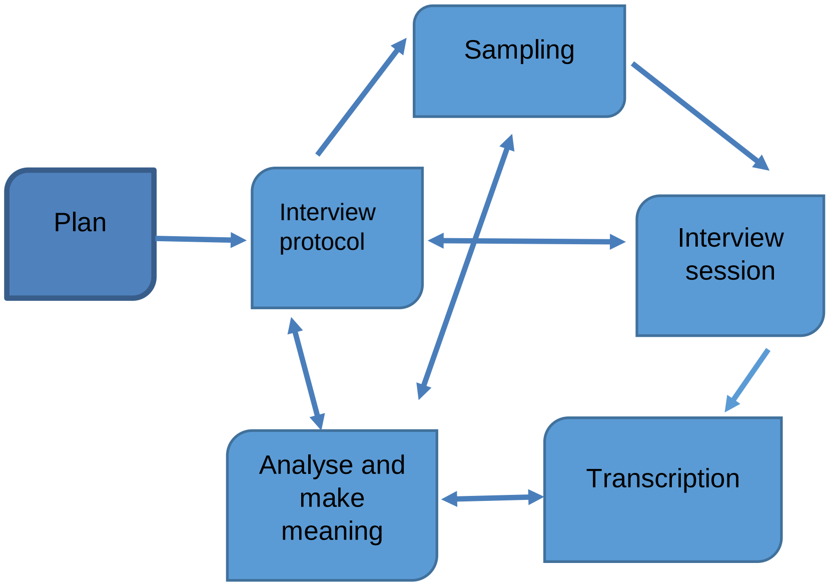

Figure 5.5: Interview Process

5.7.2.1 Interview Plan

The interview plan entailed a critical consideration of the overall data collection and analysis process to ensure that the research question could be answered sufficiently at the end of the process. This includes the drawing up of the interview process as presented in Figure 5.5. The double arrow heads in Figure 5.5 indicate the feedback loop that was observed throughout the interview stage. Also, at this stage, the researcher further reviewed the study aim and objectives to ensure that the above developed process will support the achievement of the aim and objectives of the study.

Also, all the needed skills, resources, and training required for conducting the research were identified by the researcher and the supervisory team. Subsequently, the researcher acquired and sought the appropriate support needed for conducting the research from within and outside the institution. For instance at this time, approval was sought from the college ethical committee (see Appendix 2 for a copy of the ethical approval letter).

5.7.2.2 Interview Protocol

The importance of developing interview protocol in an interview process cannot be overemphasised. Naoum (2013) observed that developing a robust interview protocol increases the confidence of the respondents in the interview process, which further supports the quality of the responses received from the respondents. In developing the interview protocol, the ten criteria for successful interview suggested by Kvale (1996) were adopted. These include; knowledge of the research focus, giving clear purpose of the interview, making question simple and easy, being gentle and patient with respondents among others.

Also, the need for ethical consideration as suggested by Bryman (2012) was not neglected. In doing this, ethical approval was sought and given from the college ethical committee with full description of the proposed study, (see Appendix 2 for the approval letter). Following the ethical approval from the ethical committee, the invitation/consent letter to participate in the research interview was designed, (see Appendix 3 for a copy of the letter). A copy of the invitation letter to participate in the interview was sent to each of the respondents and the arrangement for interviews was made following a formal response indicating their interest to participate in the study. This is essential as it assured the respondents of the confidentiality of their responses.

The interview protocol also included the development of the semi-structured interview guide. Figure 5.6 presents the protocol used in developing the interview questions. The interview questions were formulated based on the research question and the specific objectives, which was internally validated by the researcher's Director of Studies, a Professor of Lean Project Management and the supervisor, a senior lecturer in the school of Architecture Design and the Built Environment at Nottingham Trent University. Subsequently, the interview guide was piloted with 3 PhD research students at NTU and 1 business improvement manager working for a contracting organisation. As shown in Figure 5.6, the development of the interview questions was an iterative process as indicated by the double head arrow. This was done to improve the quality of the questions and invariably the quality of data collected.

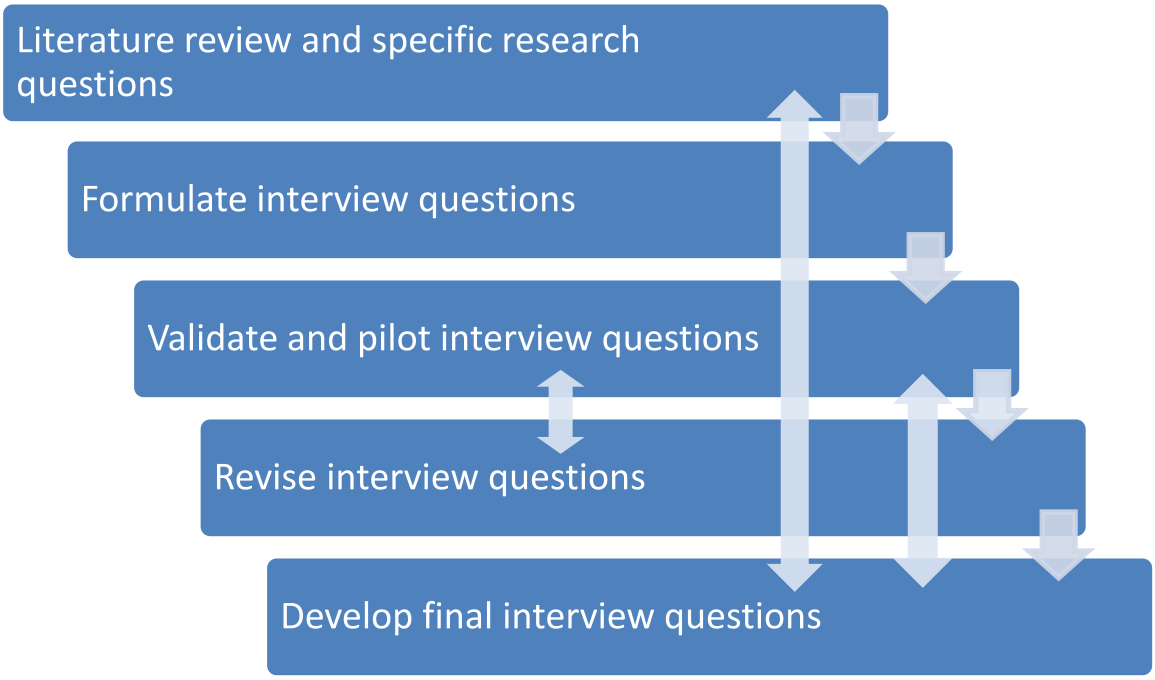

Figure 5.6: Interview Questions Development Protocol

This was done to enable the researcher understand the flow in the questions, ensure clarity of the questions to the respondents, and the likely duration of the interview among other things. Following the feedback from the pilot interview, the interview guide was revised and the final version developed. The interview instrument consisted of 6 sections. The first section focused on the background of the respondents, section 2 focused on the current views and practice of LPS and CP, section 3 investigated the current drivers for implementing LPS and CP. Section 4 investigated the success factors for implementing LPS and CP, while sections 5 and 6 investigated the current benefits and barriers (See Appendix 1 for a sample of the interview guide). The questions were open ended to allow the respondents to express their thought on the phenomenon under investigation, to reduce bias and to improve the richness of the findings. However, the questions were structured to keep the respondents on track.

5.7.2.3 Sampling

Sampling is the process of selecting the population for the study. Sanders *et al.*, (2012) pointed out that selecting the right sample determines largely if the research question would be sufficiently answered. Bryman (2012) identified two main sampling principles in research; probability and non-probability sampling principles. While probability principle is commonly associated with quantitative methods, the non-probability principle is associated with qualitative methods. According to Sanders *et al.,* (2012), non-probability sampling approach is appropriate when statistical inference and sample representation of the population is not a must in a study. Thus, non-probability principles are the adopted in the study. Sanders *et al.,* (2012) identified the following non-probability sampling techniques; quota, purposive, snowballing, self-selection and convenience sampling.

Quota sampling techniques are associated with a large population as in the case of some surveys. Bryman (2012) argued that quota sampling is more of probability sampling than non-probability. In purposive sampling, sample cases/participants are selected by the researcher such that the population sampled are relevant in answering the research question (Bryman, 2012). Purposive sampling is used extensively in exploratory qualitative research to obtain balanced information. On the other hand, Sanders *et al.,* (2012) observed that the snowballing approach is used when it is difficult to identify the members of the proposed population for the study from the onset. This would require the identified population to suggest other members who could also participate in the study. It could entail referring the researchers to similar case projects elsewhere.

While convenience sampling technique is concerned with using the available population to the researcher by chance, self-selection focuses on individuals who agree to be selected to participate in the study without consideration if they have met the criteria for participating in the study. This implies that quota, convenience sampling, and self-selection sampling may not fully support the aim of this study, thus purposive sampling and snowballing were used in the research. These approaches would enable the researcher to only include those who qualify to participate in the study. For example, in order to present a holistic view on the current practice of PP&C based on the LPS in the UK construction industry, purposive sampling was used in selecting the key stakeholders interviewed. They include lean construction consultants, main contractors, clients, and subcontractors in the UK construction industry. The criteria used in selecting the respondents include:

1. Having over 3 years' experience in the UK construction industry
2. Having one year and above experience in the use of PP&C principles based on the LPS in the UK and
3. Awareness on current deployment of lean construction principles in the UK.

This was done to ensure that only those who have good knowledge on the use of PP&C based on the LPS in the UK construction industry were included in the interview. This was achieved by utilising the researcher's Director of Studies who is a Professor in Lean Project Management and a Director and Trustee of Lean Construction Institute UK, while the researcher's second supervisor has over 20 years work experience in senior management position in the UK construction industry. Their extensive network in the UK construction industry was used in contacting the interviewees.

The initial respondents purposively sampled and accessed were small. This is due to the absence of a database for lean construction practitioners in the UK. Thus snowballing approach was subsequently used. This implied that the initial contacts would further recommend other lean construction consultants, main contractors, clients, and subcontractors that are adopting PP&C practice based on the LPS on their projects in the UK to the researcher. Although, the sample size for the interview was not predetermined, the data collection continued to the point of saturation, that is, where additional data provides little or no new information (Sanders *et al.*, 2012).

Thirty in-depth interviews were conducted over a period of 18 months comprising 18 main contractors, 2 clients, 4 lean construction consultants, and 6 subcontractors. Respondents interviewed all had over 3 years' experience in the use of PP&C principles based on the LPS and were drawn from building construction, highways infrastructures and rail sectors. The respondents occupied various posts such as lean improvement managers, project director, director, principal planning engineers, planners, project managers, lean improvement directors, and business improvement manager among others.

5.7.2.4 Conducting the Interview

Kvale (1996) suggested ten criteria that support quality interview. These include (1) the researcher being knowledgeable in the research area, (2) making the purpose of the interview known to the respondents, (3) openness and flexible to the interviewees, and (5) relating your questions to what has been previously said by the interviewee (6) Be patient with the interviewee (7) Be ready to challenge what the interviewee has said (8) use questions and prompt question to steer the process (9) respond to what is important to the interviewee (10) Provide summary on what has been said. These criteria were adhered to in conducting the interviews. Also, the consideration of ethical issues and maintaining a balance between the interviewer and the interviewee was done in the process (Bryman, 2012). The researcher observed all of these in conducting the interview. In doing this, the researcher sent out an email to each of the respondents describing the aim of the research with the consent form attached (see Appendix 3 for a copy). A Sample of the interview guide was sent to respondents who accepted to participate in the study a week ahead of the interview day. This was to enable the respondents familiarise with the subject of the interview so as to prepare well ahead of time. The interviews were conducted in an environment neutral and familiar to the respondents, for instance, the majority of the interviews were done face-to face in the respondent's project site office or office. Although, the cost implication to the researcher is high, as he had to travel to those locations, it improved the richness of the data collected as the researcher was able to probe further through reading the eye contact and body language of the respondent on interesting points.

However, due to time constraints and distance, some respondents preferred to be interviewed via skype and phone. In all, 26 respondents were interviewed face-to-face, 3 via Skype and 1 via telephone. The duration of the interviews varied from one respondent to another, but was between 60 and 90 minutes. The average time spent in each interview session is 70 minutes, thus a total of 2,170 minutes was used in conducting the interviews.

Having received the consent of the respondents, each of the interview session was recorded on *Recordium (a digital recording application)*, the researcher also took hand written notes during the interview session. These were to ensure all information was captured in real time. At the end of each interview, the researcher allowed the respondent to say what was on their mind in relation to the study aim. It was observed that this part of the interview session brought in new and rich insight to the study. For example, one of the interviewees said *"I never thought I have all this stuff in me and I have given it out, can I have a copy of the result of your study please?* [**Operation Director**]. The researcher promised to send the outcome of the study to respondents who requested for it.

5.7.2.5 Interview Transcription

According to Bryman (2012) recording and transcribing interview helps to correct natural limitation in our memories and the likelihood of omitting what the respondent might have said during the interview. It also, allows for repeated evaluation of respondents' responses. Hence, all the 2,170 minute interview sessions were transcribed and word processed since they were audio recorded. Considering the fact that it takes 5 to 6 hours to transcribe a 1 hour interview, the researcher ensured that each interview session was immediately transcribed after the interview session. This helped in easing the work at the data analysis stage.

All the interviews were transcribed verbatim (word for word) in the exploratory stage and in the case study (see Appendix 4 for a sample of the interview transcript). However, parts of the recordings that were not clear to the researcher were denoted with question marks such as this (?????) to avoid guesswork. Bryman (2012) observed that this approach increases the confidence of the reader in the research process. The study ensured that each direct quote from the interview was placed in open and close quotes ("   "). This was done to ensure that no part of the interviewee's response is paraphrased, which could be misleading to the readers.

5.7.2.6 Analysis of Interview

It has been observed that there is no rigid approach for analysing qualitative data as common with quantitative research, as most times the data type and the creativity of the researcher prevails (Berg and Lune, 2014; Henn *et al.*, 2006). Content analysis and coding of themes is the common approach used in analysing qualitative data (Bryman, 2012; Sanders *et al.,* 2012; Berg, 2007). In this study, the analysis focused on understanding the trend emerging from the transcribed interviews while also conceptualising this with the existing knowledge identified in the literature.

The transcribed interviews were grouped into data sets and analysed via content analysis and coding process. The three coding approaches used in qualitative data analysis were utilised. These include; axial coding, open coding and selective coding. While open coding entails close examination of data, breaking down of data into little chunks, comparing the data, making meaning out of data and data categorization, axial coding focuses on transforming the data and establishing relationship between them (Bryman, 2012). On the other hand, selective coding helps in validating the identified relationships. The qualitative data analysis process suggested in Berg and Lune (2014) and Sanders *et al.*, (2012) and as presented in Figure 5.7 was used in the analysis of the transcribed data. The arrow shows the kind of iteration that occurred in the data analysis process. This was done to ensure that no likely themes and subthemes for the study were omitted in the data analysis process.

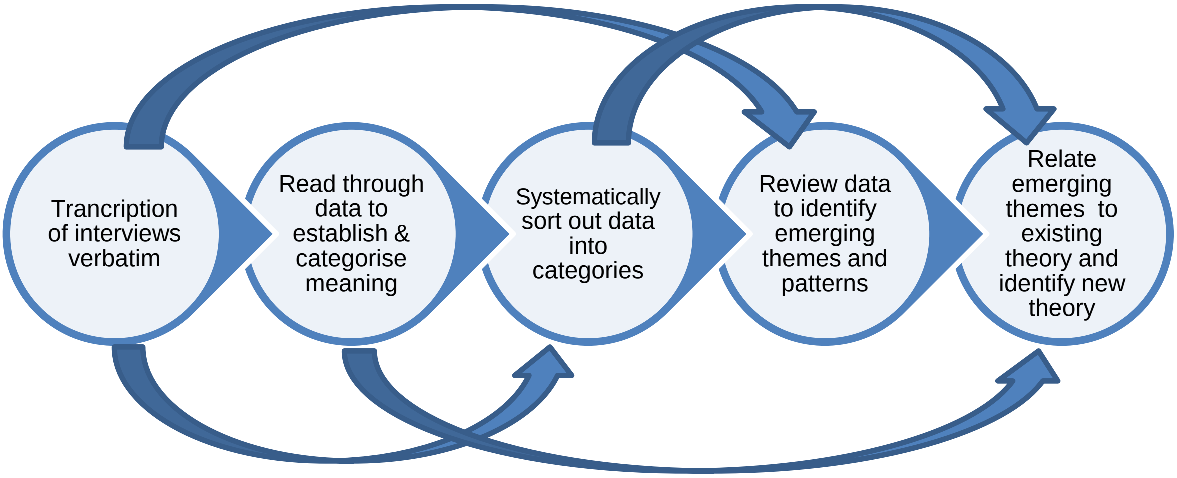

Figure 5.7: Interview Data Analysis Process used in the Study

Also, the study considered the use of the qualitative software; [6]'*Nvivo'* to analyse the interview data given its potentials in managing large data sets (Bryman, 2012). However, following a closer examination of the nature of the interview questions, the stage of study, and the size of data collected, manual analysis was considered appropriate at this stage of the study. Specifically, since this was the first stage of interviews in this exploratory study, the researcher believed that analysing the data entirely via a manual means offered the researcher more opportunity to interact with the data.

This implied that the researcher was actively involved in organising the data and making sense out of it. Henn *et al.*, (2006) argued that in analysing qualitative data, computer should be viewed only as a tool to help in storing data, since sense making out of the data rests with the researcher. Also, considering the fact that the data is not so large, the manual approach was deemed suitable. However, '*Nvivo'* was still used in analysing the qualitative data from the multiple case study in the fourth phase of the study.

[6] Software that supports in the analysis of qualitative data

The analysis of the interviews commenced with coding. [7]The code and themes for the study were developed based on (A) the interview questions and (B) emerging themes recognised from the transcribed interview. As earlier explained, the analysis used both inductive and abductive approaches; this implied that there was a continuous cross evaluation of the current practice of LPS and CP observed in the UK with principles of the LPS (Dubois and Gadde, 2002). While an inductive approach entails making meaning from the analysis to generate theory, a deductive approach uses predetermined theory to explain the data obtained (Sporrong and Kadefors, 2014; Dubois and Gadde, 2002). An abductive approach on the other hand is the third form of inference that seeks the simplest explanation for observations. Sober (2001) described abductive reasoning as the "inference to the best explanation". This approach was adopted as it allowed the study to gain new theoretical insight through the empirical data and the established theoretical model of the LPS (Sporrong and Kadefors, 2014; Dubois and Gadde, 2002).

Codes were used to identify all the interviewees involved in the study. Code such as MC01, CO01, CL01 and SC01 were used, where MC= main contractor, CO= consultants, CL= clients, and SC= subcontractors while 01 indicate the numbering. Through this, the researcher was able to capture the responses of all the interviewees. In doing the analysis, the qualitative data analysis protocol in Figure 5.8 was systematically adhered to. The emerging themes from the analysis were explored to identify relationship with existing theories of the LPS and detect new emerging themes. The findings from the analysis, the emerging themes, grouping, and categorisation of meanings among others are presented and discussed in Chapter 6 of this thesis. Each finding is critically discussed in Chapter Six in light of the existing literature and in relation to the objectives of the research.

5.7.3 Stage 3: Structured Observation

Following the second stage of the study (the exploratory interviews), a structured observation was conducted on projects on the current practice of CP for delivering construction projects from the PP&C perspective in the UK. *Structured observation* also known as *systematic observation* is a structured approach used to record behaviour or practice (Bryman, 2012). The aim of the structured observation is to

[7] Part of this has been published in Daniel *et al*, 2016 The relationship between of LPS and CP in the UK

enable the study to aggregate the current practice of CP for delivering construction projects from PP&C in the UK in all aspects of the projects observed. This was done in a systematic manner in relation to the identified production planning and control principles advocated in the LPS, so as to identify the level of implementations on the projects observed and to compare the implementation across sectors.

Structured observation was considered appropriate as the approach allows the study to capture real time information on PP&C in relation to LPS in the UK construction industry. According to Bryman (2012), structured observation identifies behaviour or practice directly, which improves the quality of the data collected rather than relying on information from questionnaire survey. Also, Cooper and Schindler (2008) confirmed that structured observation is used when a study is aimed at answering a research question and it usually provides valid and reliable account of what happened. It could be used as a primary method or to supplement other methods. In this study, the structured observation is used as both. All of these supported the aim of the study at this stage thus, structured observation was used.

5.7.3.1 Observation Schedule

It has been observed that observation schedule influences the reliability and validity of the data obtained through structured observation (Cooper and Schindler, 2008). The researcher adhered to the rules for designing structured observation schedule suggested in Bryman (2012). An observation can be behavioural or non-behavioural observation approach. However, in this study, only the non-behavioural approach was used and it includes (Cooper and Schindler, 2008);

- Record analysis.
- Physical condition analysis.
- Physical process analysis.

In record analysis, the researcher observed past records of PPC charts, PPC calculation sheet, RNC charts, snapshots image of past collaborative or phase planning meetings and Weekly Work Planning meetings. While in the physical conditions analysis the researcher observed the currently displayed PPC chart, RNC chart, collaborative planning /phase planning room, phase planning board or wall with ‘sticky notes’, the duration of the look-ahead plan on the phase planning board and the location of information display board. The last phase of the structured observation was the physical process analysis, here the researcher developed a structured survey guide to capture the PP&C based LPS practice as done on each project (see Appendix 5 for copy on the instrument). The questions were based on a 15 PP&C practices used in examining the degree of implementation of the LPS. This metric is generally called Planning Best Practice (PBP) index. The PBP indexes were identified from LPS implementation on several construction projects (Bernardes and Formoso, 2002; Sterzi *et al.*, 2007; Viana *et al.*, 2010). The identified practices have been used to examine the implementation of production planning and control practice in relation to the LPS on construction projects. For example, it was used to examine 12 projects in Israel (Priven and Sacks, 2015); 6 case study projects in Brazil (Bernardes and Formoso 2002) and in observing 5 projects in Brazil (Sterzi *et al.*, 2007). It has the capacity to reveal LPS implementation efficacy (Sterzi *et al.*, 2007; Bernardes and Formoso, 2002). Also, two other PP&C practices identified from the literature review which the author considered to be crucial were added. In all, 17 PP&C practices were observed across the projects. During the interviews the researcher was able to obtain further clarifications on all the observations made in the record and physical condition analysis which was used in rating the level of implementation on each project.

5.7.3.2 Observation Checklists

The PBP index checklist had three scales; full implementation, partial implementation and no implementation to capture the state of current implementation on the projects sampled. This scale was arrived at from previous academic research on PP&C practices based on the LPS in construction (Bernardes and Formoso, 2002; Sterzi *et al.*, 2007), and has also been used in observing the level of LPS implementations in construction (Priven and Sacks, 2015). As this is a snapshot study, the three point Likert scale was adopted to capture production planning practices on the projects observed and to also reduce response bias. Dolnicar, *et al.*, (2011) and Paulhus (1991) observed from their study that 5-7 point Likert scale suffers from response bias. More importantly, Dolnicar *et al.,* (2011) Jacoby and Matell (1974) concluded from their study that the reliability and validity of the information obtained from an evaluation process has no relationship with number of steps on the Likert scale. However, Bryman (2012) argued that structured observation could lack reliability and validity if the observation schedule is not followed as supposed. To overcome this, the researcher ensured the observation schedule described in section 5.7.3.1 was strictly adhered to on the all the 15 projects observed. Results of the analysis and discussion are presented in Chapter Six of this thesis.

5.7.3.3 Structured Observation Sampling

This study examined the available sampling strategies in section 5.7.2.5. In conducting the structured observations, purposive sampling and snowballing approach was adopted (Bryman, 2012). Purposive sampling was adopted as it enabled the researcher to identify the projects that met the predetermined criteria before selection. For instance, the following criteria must be satisfied before inclusion for observation for PP&C practices based on the LPS:

- The project must be managed with PP&C based on LPS
- The use of PP&C principle on the project must not be less than a year
- The project must be on-going
- The project must be domiciled in the United Kingdom

These criteria were used to ensure only projects that claimed to use LPS principles were observed. According to Bryman (2012), and Cooper and Schindler (2008), for structured observation data to be valid and reliable, the observation criteria must be uniform across the sampling elements. The sample elements were drawn from building, highways infrastructures, and rail projects. The three sectors were chosen as the study aimed at presenting the current PP&C practices across the major sectors in the UK construction industry. Originally, 15 projects were targeted with 5 from each of the sectors.

Although 15 projects were accessed, they were not equally distributed as proposed earlier in the study. This was due to the inability of the researcher to gain access to sufficient rail projects that are using PP&C principles based on the LPS. The actual 15 projects observed comprised; 8 highways infrastructure, 5 building, and 2 rail projects. The building projects observed include; a social housing, and new build for an institution of higher learning among others. The projects were coded with alphabets (A= highway infrastructure project; B= building projects and C= rail projects, while the numeric 01 represents the project numbering).

On each of the projects observed, in addition to record and physical condition analysis, semi-structured interviews were conducted with all those involved with the implementation of PP&C principles based on LPS on the projects. The respondents interviewed include lean improvement managers, principal planning engineers, planners, project managers, site managers, site agents, and excellence manager. Purposive sampling was used in selecting the projects and respondents. This was to ensure that only those with experience in PP&C practices were interviewed and projects where PP&C principles were used were observed.

5.7.3.4 Data Collection and Analysis of Structured Observation

In collecting the data, the researcher personally visited the physical setting (the project site). An average of 5 hours was spent on each of the projects on a day site visit. This afforded the opportunity to collect data on 'record analysis', 'physical condition analysis', and conduct of interviews. A camera was also used to capture parts of the physical setting that are of interest to the study after securing necessary approvals. However, during the site visit, the researcher was only able to have access to the middle line managers such as the planners, site engineers, site managers, site agents among others.

Other project members such as the top managers, subcontractors and supply chain members, foremen etc were not reached. This was due to the day access visit given to the researcher on each of the 15 projects observed, which was not sufficient to have conversation with all the stakeholders concerned with PP&C practice. This was considered as a major limitation of this approach, as there is a high possibility that the responses could be one sided. However, the limitation was overcome in phase 3 of the study.

All the data collected from the projects observed were grouped into data set under the three main schedules used in collecting the data. Data from the record and physical condition analysis were analysed using content analysis. The procedure for conducting content analysis as suggested in Berg and Lune (2014) was adopted. Simple descriptive statistics such as percentages was used in analysing the level of PP&C practices based on the LPS on the projects observed. The result was presented using tables, and charts and discussed in Chapter Six of this thesis.

5.7.4 Stage 4: Multiple Case Study

The justification for the use of case study has been discussed in section 5.6.5 of this thesis. This section presents a detailed account of how the case study was conducted. Figure 5.8 presents the overall case study design.

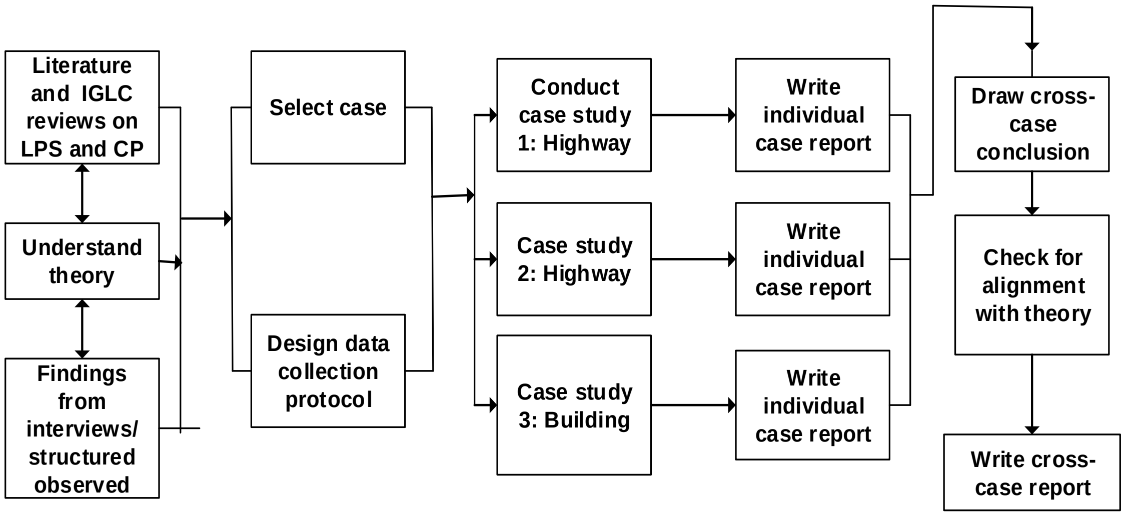

Figure 5.8: Case Study Research Design

The major aims of the case study were;

- To identify the nature of support to provide for effective implementation of the LPS;
- To identify the impact of the current practice of PP&C based on LPS on construction process improvement;
- To examine the influence of procurement route on the implementation of PP&C principles based on the LPS and
- To further validate the findings from the exploratory interviews and snapshot observations on the current practice

To achieve the above objectives, the study needed a detailed consideration and interaction with the physical settings (the project site) which could not be addressed in stages 1-3 of this study. Thus, the case study approach was adopted. Bryman (2012) observed that the case study approach focuses on intensive examination of the physical setting in order to provide empirical evidences of the phenomenon being investigated. The case study also offers the study the opportunity to interact with all the major stakeholders in order to fully understand the support needed for effective implementation of the LPS. It also supports the development of LPS-PCA.

Multiple case studies were considered appropriate at this stage, as they best support the study to holistically achieve the above mentioned objectives. According to Yin (2014), the analytic results from two or more cases are more powerful compared to a single case situation. The subsequent section describes the case study planning, case study selection, data collection protocol, and process among others.

5.7.4.1 Case Study Planning

Planning has been identified as a crucial element to consider in conducting a case study (Yin, 2014). Here, the researcher considered the overall case study research process with due recognitions of the likely issues (weakness and strength of the approach) that could occur in each phase of the case study. In view of this, an extensive literature review in section 5.6.5 of this thesis was devoted to it. In planning the case study, all the likely constraints such as the difficulty in having access to the site, research respondents, and documents, which all have an influence on the overall case study duration were considered. For instance, the negotiation for case study started immediately after the researcher's project approval, which was six months ahead of the proposed case study commencement date as stipulated in the researcher's programme for the study.

The 3 case studies were conducted independently, but simultaneously between January and October 2015. The process was demanding and cost intensive as the researcher had to travel several miles each week since the 3 projects are widely dispersed geographically. However, it paid off as the researcher was able to complete all the case studies as programmed.

5.7.4.2 Case Study Selection

In selecting the cases, various factors associated with case study design as suggested in Yin (2014) and Bryman (2012) were adhered to. It is important that cases are selected carefully to avoid a condition where the evidence obtained is insufficient to answer the research question (Yin, 2014). In view of this, the researcher and the supervisory team selected 3 cases to be studied from the major sectors of the UK construction industry. These case studies were chosen as they would allow the study to also compare practices across the industry. Two of the cases are from the Highways and infrastructure and one from the building sector.

No case was chosen from the rail sector as it has already been observed from the snapshot study in stage 3 that rail projects, share similar characteristics (linear construction) with highway and infrastructure projects. The focus of the study was to develop an approach that could support LPS implementation across the UK construction industry, thus selecting case studies from the major sectors was considered appropriate. This was also to ensure that the cases were sufficient to give a true reflection of the current state of the practice in the UK construction industry. The three cases were selected from the top 100 UK construction companies. Purposive sampling was used in selecting the cases. Bryman (2012) stressed that purposive sampling allows the researcher to select case(s) in order to answer the research question. For instance, the researcher and supervisory had to agree on the criteria for selecting the cases. The criteria used include:

- The project must be managed using PP&C based on LPS principles
- The project must be on-going
- The project must be in the construction sector and domiciled in the UK and
- Must be in a safe zone and accessible to the researcher in terms of the cost of visiting the project site as required for the study

Initially, the researcher sent out invitation letter to construction organisations in the UK construction industry based on background information acquired on them in stages 2 and 3 of this study. Four organisations accepted to participate in the case study. In order to ensure that the criteria above are satisfied, further investigation was done with the respective project managers before signing of the consent form (see Appendix 6 for a copy) and commencing of the study. From the background check, it was observed that in one of the projects, LPS principles were not being used as claimed; rather, the project was only attempting to adopt *work zoning* in a sloppy way. Thus, only the 3 case studies that satisfied the above criteria were studied.

It has been observed that it is essential to maintain a balance in selecting the cases to be investigated, as it helps in strengthening the study results (Yin, 2014; Stake, 1995). The researcher ensured this was observed in selecting the cases. For instance, the two cases selected from the highways and infrastructures were chosen because the researcher desired to maintain a balance in the procurement routes. While one used Design & Build (D&B) procurement route, the other used traditional Design, Bid, and Build (DBB). The choice was made since the study aimed at understanding the influence of procurement routes on the implementation of LPS in construction.

The third case was from the building sector and it used Design & Build procurement. This balance enabled the study to sufficiently compare the practices across projects and sectors. On all the projects studied, the population sample had similar characteristics. The population was broadly classified into four categories; the top managers, the middle managers, subcontractors and the lower managers.

The researcher believed that focusing on all of these categories was necessary as their inputs were essential in developing an approach that supports construction stakeholders in implementing the LPS in construction. Two of the case study projects were located in Yorkshire (one in the North of Yorkshire and the other in the West of Yorkshire). The third case study project was located in the Midlands. All the three case study projects were located in England. The researcher's institution of study is based in England, which offered more opportunity for detailed investigation at a reasonable travelling cost and time. The finding on this is discussed in Chapter Seven.

5.7.4.3 Data Collection Protocol

According to Yin (2014), preparation for data collection is crucial in every case study, as failure in this aspect could thwart all the efforts committed into formulating the research question and the case study in general. In view of this, after selecting the cases a data collection protocol was developed in conjunction with the researcher's supervisory team. Contact was made with a senior manager on each of the projects selected and the researcher discussed the major evidence sourced from the case study. The overall aim of the study was discussed with the senior manager and the formal consent form signed. The evidence sourced by the researcher on each case includes; analysis of documents (past and present), observations, and conduction of interview with top manager, middle managers, subcontractors, and bottom managers. These three sources were used in order to triangulate the findings.

The schedule of site visits (to attend look-ahead planning meetings & weekly production planning meetings) was also agreed with the head of the team on each case study project. This allowed the researcher to visit each of the sites routinely. Furthermore, the researcher informed each of the case study project, representatives of his involvement in other case studies. This was to ensure that there was no clash in fixing the site visits. Additionally, ethical issues were considered at this point, and formal invitation letter was given to all the proposed research participants (see Appendix 3 for a copy of the invitation letter to the interview participants). This was done to reassure the research participants of confidentiality. It has been observed that when research participants are reassured of their confidentiality, the quality of the information given out is improved (Creswell, 2007). Through this, the researcher was able to develop a strong relationship with the research participants and also build their confidence in the study.

5.7.4.4 Data Collection

On each of the case study projects, data were collected from three major sources. This includes; documentary evidence, observations and semi-structured interviews. The three approaches were used in deepening and authenticating the results (Yin, 2014). Although, the data collection from the three sources as shown in Figure 5.9 continued throughout the case study period, each case study actually started with observations and document analysis as soon as the researcher was given access to project.

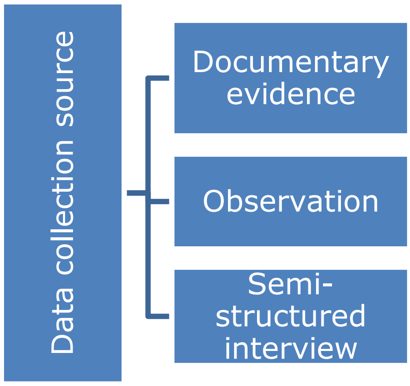

Figure 5.9: Case Study Data Collection Sources

This approach enabled the researcher to seek further clarification on the findings from the observations and documentary evidences during the interviews. Each approach is now discussed in detail in the next section.

A. Documentary Evidence

Documentary evidence has been identified to provide useful information in collecting both primary and secondary data to answer research questions (Sanders *et* *al.*, 2012). In this study, all the documentary evidences sourced were those relating to production planning. This includes documents such as construction programme, Look-ahead plan, weekly work plan sheet, progress reports, published PPC, published RNC, minute of collaborative programming or phase planning meetings, and work make-ready worksheet among others. Bryman (2012) asserted that document evidences are credible and non-reactive since they were not designed specifically for the study. However, Berg and Lune (2014) observed that having access to documents in an organisation could be difficult as some ‘gatekeepers’ (those responsible for granting access to the site) could be reluctant about it.

The researcher built personal relationship with the gatekeeper on each case project and this allowed full access to the necessary documents. Even after the formal completion of the case study, minutes of meetings were still being sent to the researcher as he was put on the project team email list. The documentary evidence obtained in each case study were critically reviewed. Through this, the researcher was able to establish some of the current practices of production planning and control practice on the projects. Snapshots of documents displayed visually on the case project were also taken, others were photocopied, and some sent electronically to the researcher’s email. The result of the document analysis is presented in Chapter Seven of this thesis.

B. Observation

To gain full understanding of the current practices of production planning and control on the projects and to further identify issues associated with the practice, practical observation was considered essential. This approach allowed the researcher to relate the observed practice with the project setting. Bryman (2012) stressed that observation of the social setting where the phenomenon is being investigated allows the researcher to sufficiently map out the link between participant behaviours and the context. In this study, the focus in the observation was production planning and control based on LPS principles.

Specifically, the researcher observed each production planning and review meetings on all the three case study projects. This was considered essential as it enabled the researcher to observe core principles advocated in the LPS while conducting the production planning meeting. Such principles include the nature of conversation (collaborative or non-collaborative) used during production planning meetings, the level of involvement of stakeholders in the projects, the number of stakeholders in each meeting, the process of making reliable promises, how plans are reviewed and recorded, and consideration for the flow of information during planning among others. It is worth to mention here that unlike the third stage of the study, the observation is unstructured. However, the researcher kept an up to date diary of all the observations on each project for cross case analysis and development of themes and reflected on this for further observations.

The observation was unstructured to enable the researcher widen the scope and to allow the themes to emerge naturally. On the project sites, the researcher also observed information display boards, location where PPC and RNC information were displayed and images of some of the observed features of interest were taken. Further information was sought on some of the observed features during the interview.

C Semi-structured Interview

The rationale for the use of semi-structured interview has been justified in the earlier part of this chapter. In developing the semi-structured interview guide, the literature review, findings from the document analysis and observation on each case projects were used. More importantly, the interview questions were such that all the objectives of the case study identified earlier in the section 5.7.4 were sufficiently answered. The semi-structure interview guide consists of five major sections (see Appendix 7 for a copy). As earlier explained, some of the case study questions, in particular sections 2 to 4 were asked to further validate the findings from the exploratory interviews.

However, the semi-structured interviews on the case study were more holistic as major stakeholders on the project were interviewed, thus reducing the level of bias in the overall finding. The respondents interviewed were drawn from top managers, middle managers, subcontractors, and bottom line managers on each case project.

In conducting the interviews, the process used in stage two of this study was adopted. On each of the case study projects the manager charged with the responsibility of managing production planning arranged the interviews for the researcher from the list of desired interviewees designed and made available to him/her by the researcher. Most of the interviews took place before or after the phase planning or collaborative programming meetings. This approach enabled the researcher to maximise his time during each project visit and minimise cost of travelling.

Before the actual date of each interview, the researcher sent out an invitation to interview letter to the interviewee through the production planning manager or facilitator on the project. Also, the personal relationship developed with the interviewees during production planning meetings improved the quality of response received during the interview session. The researcher audio recorded all the interviews with a mobile recording application known as *'Recordium'*.

5.7.4.5 Data Analysis

Evidence for the analysis was obtained from four major sources; documentary analysis, observation, semi-structured interviews and the mini survey. All the data collected were grouped into data set and placed in folders/files for each case study. The interviews were transcribed verbatim and cross checked with findings from documents analysis and observation. All the data obtained were analysed qualitatively, except the closed ended mini-survey that was analysed using simple descriptive statistics. The four sources were fully triangulated to improve the validity of the case study. Each source of evidence was analysed individually and cross analysed to arrive at the converging point of inquiry. Figure 5.10 presents the data analysis process.

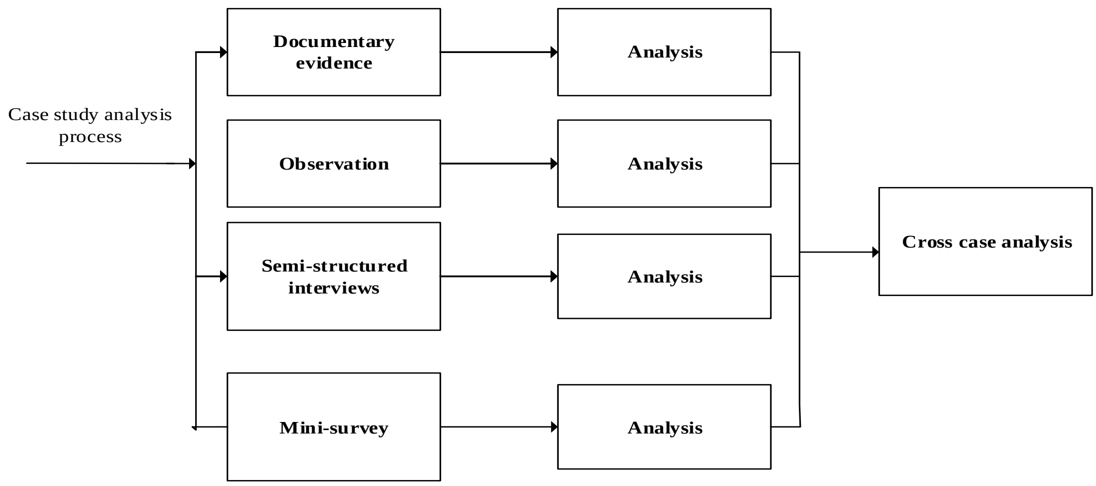

Figure 5.10: Case Study Analysis Process

Yin (2014) observed that triangulating data from multiple sources supports the development of the converging point for research findings and, thus strengthens the validity of the study. In addition to transcribing the interview verbatim, other qualitative data, such as observation, and document analysis were word processed to enable the researcher to make appropriate meaning out of them. This process is time consuming, but it enabled the researcher to maintain flow in interacting with the data and making meaning out of them. The case studies were coded thus; CSP01, CSP02, and CSP03 which referred to case study projects 1, 2, and 3 respectively. The case studies were denoted with these codes for confidentiality purpose. On each case study, senior manager (SM), middle manager (MM), operational managers (OP), and subcontractors (SC) were interviewed. Figure 5.11 shows the distribution of interviewees across the case studies. A total of 28 interviews were conducted from the three case study projects (11 on CSP01, 10 on CSP02, and 7 on CSP03). This was to enable the study to have a holistic view on the current practice and the nature of support to be provided for rapid and successful implementation of the LPS in the UK construction industry.

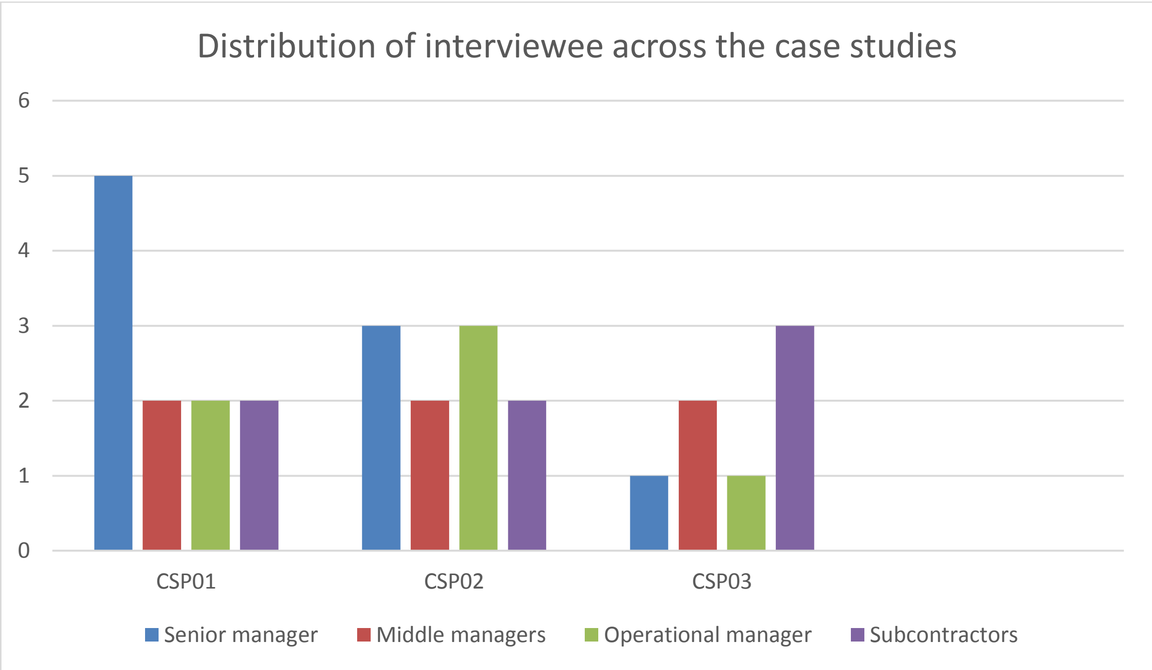

Figure 5.11: Distribution of Interviewees across the Case Studies

Full description of the case studies is presented in Chapter Seven. The interview analysis process described in section 5.7.2.6 was used in analysing the interview results from the case studies. However, in this phase, the process was fully supported by the Computer Aided Qualitative Data AnalysiS (CAQDAS) software known as '*NVivo*'. The software was used due to the large nature of the data. According to Silver and Lewin (2014) and Bryman (2012), '*NVivo*' software does not only manage large data set, but it also supports transparency, replicability and validation of qualitative data. This is made possible as it provides a single platform to systematically organise and interrogate qualitative data from different sources. It also supports the analysis of quantitative data such as survey alongside qualitative data such as interviews among others (Silver *et al.*, 2015). In this study, qualitative data were obtained from three sources; interviews; observation and documents analysis, and different folders were created for them using NVivo version 10 in the internal source folder. A folder was created for the mini-survey here too. This supported the researcher in managing the collected data effectively and efficiently.

The obtained qualitative data were reduced as suggested by Miles and Huberman (1994). The recorded interviews were transcribed verbatim and word processed. The collated data were grouped into data sets and analysed via content analysis and coding process. In doing this, the data was categorised based on qualitative data analysis techniques after Miles and Huberman (1994). The word processed interviews from the three case studies were exported into NVivo 10 for coding of the emerging theme. The code and themes for study were developed based on (A) identified theme from literature (B) the interview questions and (C) emerging themes recognised from the transcribed interview. The concept tree presented in Figure 5.12 was used in capturing the emerging themes and sub-themes before their coding and linking of '*Nodes*' in NVivo 10.

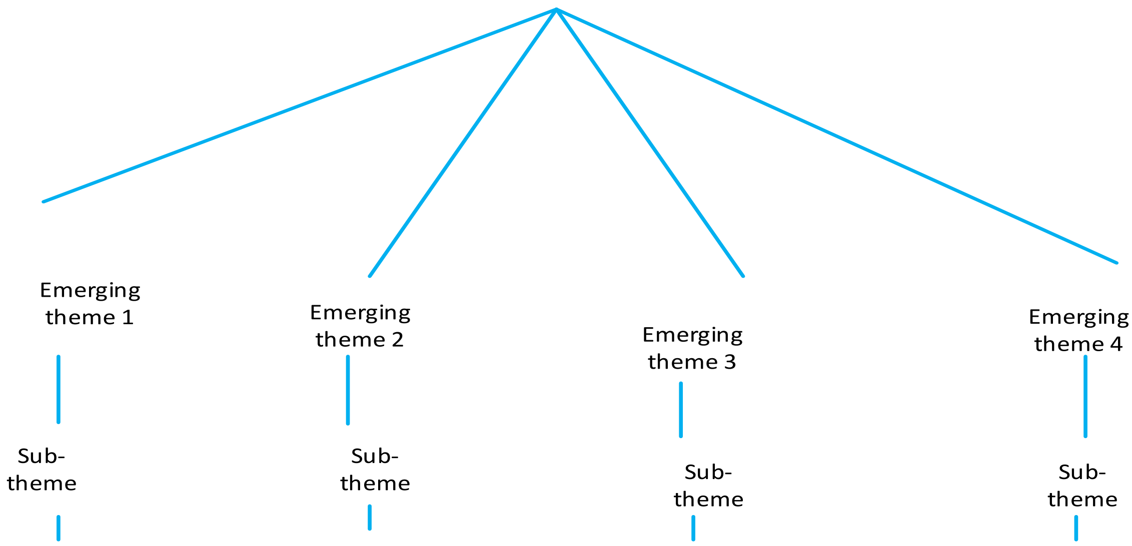

Figure 5.12: Emerging Concept and Theme Tree

Again, this shows that the strategy for analysing the data was developed by the researcher and not the software, thus the richness and quality of the result of the interview were still preserved as a result of the full interaction of the researcher with data in the analysis process. Silver and Woolf (2015) observed that strategies are developed outside the software, while tactics relies on the software tools to analyse the data. The emerging themes and sub-themes were coded and linked with Nodes to enable the researcher capture what the respondents are saying on the emerging themes and cross analysis of the findings. The '*model'* tool in NVivo 10 was used to analyse and graphically present emerging themes and sub-themes. Figure 5.13 shows a sample on emerging themes and sub-themes on procurement practice on CSP01 as exported from NVivo 10 using 'model tool'. The remaining findings are presented and discussed in Chapter Seven.

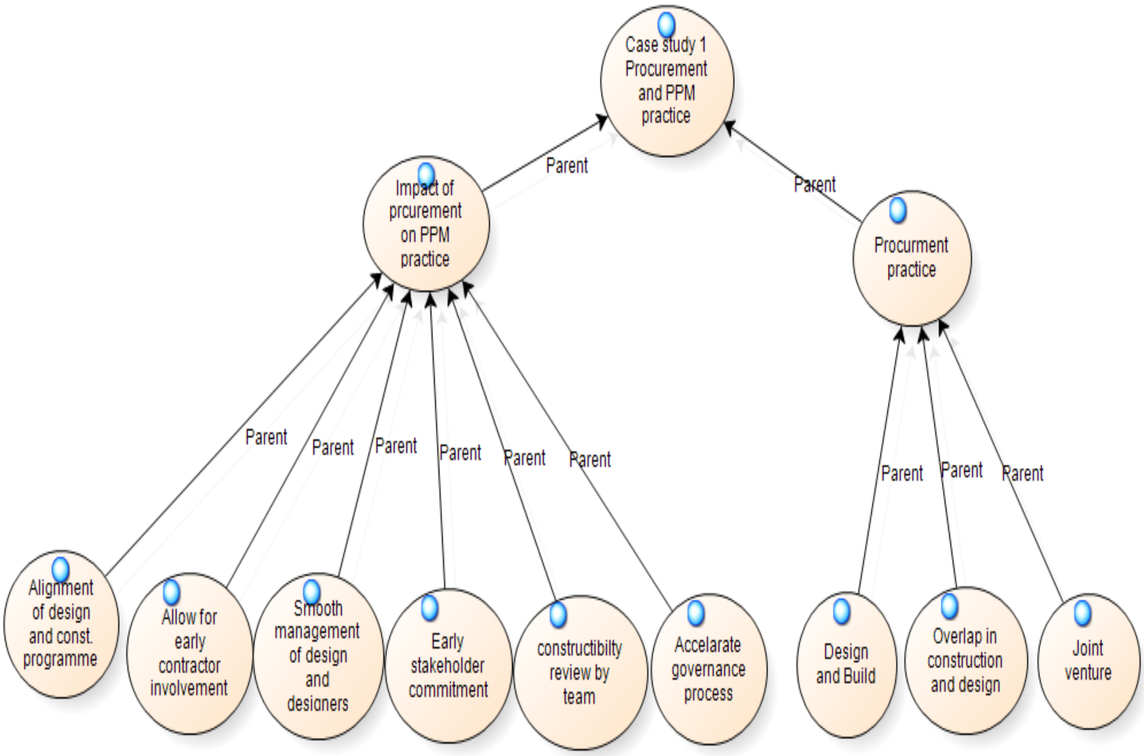

Figure 5.13: Result of procurement practice on CSP01 graphically presented with 'model tool' as exported from NVivo 10

5.7.4.6 Cross Case Analysis

The three case studies were analysed individually and then subjected to cross case analysis. Yin (2014) suggested that a case study report should contain the individual case study and cross case analysis. Also, Miles and Huberman (1994) observed that cross case analysis supports the generalisation of findings across the case and offers a better understanding of the phenomenon investigated. The cross case study analysis enabled the study to identify the current practices and the nature of support required for effective implementation of LPS and the impact of the current practices on construction process improvement. The cross case study analysis is presented and discussed in relation to literature in Chapter Eight.

5.7.4.7 Post Case Study Evaluation Survey

At the end of the case study, a mini survey was designed to access the impact of PP&C practices on construction process improvement. Participants were drawn from stakeholders that participated in the case study. The post case study evaluation instruments consisted of two major sections (see Appendix 8 for a copy). The instrument has both closed end and open ended questions. The closed ended questions were used by the researcher to seek some objectivity with regard to the impact of the PP&C practices and to also compare this across the cases. According to Bryman (2012), closed ended questions enhance comparison of results and also reduce variability in recording responses.

The closed ended questions focused on understanding the impact of PP&C practices on time, quality, rework, safety, and collaboration among others on each case study. This was measured on five point Likert scale with 1= strongly disagree and 5= strongly agree. Three points Likert scale was not used here because it would limit the research participants' response. The five point Likert scale provides allowance for more choice to be made. It also has the potential to relay or measure the level of agreement of the respondents with the statement. Unlike one indicator that could limit the response of the respondents (Bryman, 2012). The last part of the survey questions were open ended, and they centred on the respondents' views on PP&C practices as witnessed on the project and the identification of likely support needed for its effective implementation. The results are presented and discussed in Chapter Seven.

5.7.5 Phase 5: Development and Validation of Last Planner System Path Clearing Approach

Stage 5 which was the last stage of the study, dealt with the creation and evaluation of the LPS-PCA. The aim of the LPS-PCA was to support construction stakeholders (client, main contractor, subcontractor) to develop an understanding of what needed to be in place for the implementation of the LPS. Stages 1 to 4 of this study formed the building blocks for the development of the LPS-CPA. In developing this approach, the requirements for implementing LPS in construction were identified in stages 1 to 4 of this study. Also, the drivers, success factors, barriers, and mismatches in the current practice of implementing LPS were identified and characterised. To access the usability of the LPS-PCA, an evaluation checklist was developed (see Appendix 9 for copy). Ten participants were purposively sampled to participate in the evaluation, while six participated, four did not. Full description of the evaluation process is provided in chapter 8 of this thesis. The feedback from the evaluation was used to refine the initial LPS-PCA approach developed. All the major stakeholders were involved in the evaluation process to reduce bias in the result. The result from the evaluation and preliminary findings from pilot implementation of LPS-PCA are presented and discussed in Chapter Eight.

5.8 Quality of Research

In assessing credibility and quality of a research, criteria such as validity and reliability are used (Bryman, 2012; Sanders *et al.*, 2012). According to Bryman (2012), reliability and validity are commonly used in quantitative researches and have also been adapted in assessing the quality of qualitative researches. However, Guba and Lincoln (1994) suggested parallel names for this in qualitative research as shown in Table 5.7.

Table 5.7: Research Quality Criteria

Name in Quantitative Research	Equivalent name in Qualitative Research
Internal validity	Credibility
External validity	Transferability
Reliability	Dependability
Objectivity	Confirmability

The efforts made by the researcher to improve the quality of the research by minimising or achieving these are highlighted below.

5.8.1 Credibility (Internal validity)

The key question asked here is how believable are the research findings (Bryman, 2012)? The study overcame this by collecting data on the social reality being investigated (PP&C practices) from multiple sources such as on building, highways, and rail projects using different methods. The researcher observed all the standard procedures required for the study by diligently explaining the purpose of the study to the participants. This was done in addition to the invitation to participate in the study letter sent earlier to the respondents which captured the purpose of the study. Also, the final research output, that is, the LPS implementation approach was made available to the research participants for validation and feedback. All the methods were fully triangulated. The researcher had a prolonged engagement with the social setting as it supports the quality of the research result (Seale, 1999; Guba and Lincoln, 1994); in this study, over 12 months was spent in interacting with social setting.

5.8.2 Transferability (External validity)

This focuses on ascertaining the application of the findings in another context for generalisation. Although, the focus of this study was not to generalise the findings, effort was made in achieving external validity in the findings via the use of replication logic in conducting the 3 case studies in different project environments (settings) (Yin, 2014). Findings were also obtained from external participants who were not part of the case studies such as the interview participants in stage 2 and structured observation participants in stage 3. Also, detailed description of the case study context was given. This would provide readers with sufficient information to judge the application in another setting (Seale, 1999). Furthermore, the study sample cuts across the major high profile companies in the UK and the sample comprises the major stakeholders in the industry.

5.8.3 Dependability (Reliability)

This refers to the possibility of applying the current findings at other times. It has been observed that to achieve this, full documentation of the research process is imperative (Bryman, 2012; Seale, 1999; Guba and Lincoln, 1994). The study achieved this by developing standard protocols for data collection for the exploratory interviews, structured observation, case study and the mini post case study implementation survey (see Appendices 1 and 6). Only in very few cases were some of these protocols altered slightly to meet the reality on site. These standard protocols were used in collecting data at each stage to maintain consistency. In addition to keeping field notes and memos, the interviews were audio recorded and transcribed. Detailed description of the methodology and the methods used for the study were fully documented. Also, the research instrument and the data collected were further audited by the researcher's supervisory team.

5.8.4 Confirmability (Objectivity)

The consideration here is to know what extent the researcher's personal values influenced the research findings. It is well known that complete objectivity cannot be realised in a social science research (Bryman, 2012), however, this study used various approaches to improve it. The study used multiple approaches to collect data and the data from each source were analysed independently. Also, more objective responses were collected in stage 3 in the post implementation survey which further helped in confirming the qualitative data in stages 2 and 4 and in the evaluation of the developed LPS-PCA in stage 5. Standard data collection protocol was developed for each stage of the study which guided in collecting and interpreting the data. This helped the researcher in maintaining a neutral position. Furthermore, all stages of the study were constantly audited by the researcher's supervisory team.

5.9 Summary of Chapter

This chapter established the philosophical assumptions underpinning this study. From the description of the various research paradigms such as positivism and interpretivism, the chapter demonstrated why mixed research paradigm is the appropriate paradigm for the study. This was because the study required both qualitative and quantitative approaches to answer the research aim and objectives.

The chapter showed that research philosophy and paradigm influence the choice of research methodology and methods used in a study. However, some researchers pay less attention to this, thus mixing up the research process. The chapter provided detailed description of the various stages (1 to 5) of the research and the justification for the methods adopted.

This chapter demonstrated that the study was built on robust research methodology and methods. This suggests that the evidences provided and discussed in the subsequent chapters could be relied upon. The chapter captured some of this by providing the detailed account on how each method and approach were fully triangulated. This includes research approach triangulation as demonstrated in the mixed method approach and also the triangulation within methods such as collecting evidences from different sources as in the case of the structured observation and the case study. The chapter also showed the measures taken to improve the quality of the research findings with regard to the validity and reliability of the study. The next chapter (Chapter Six) presents and discusses the findings from the 30 exploratory interviews and the structured observations.

CHAPTER SIX: RESULTS AND DISCUSSIONS ON EXPLORATORY INTERVIEWS AND STRUCTURED OBSERVATIONS

6.1 Introduction

The previous chapter provided detailed information on the methodology and methods used in gathering evidence for answering the research question. This chapter presents and discusses the evidence gathered from the exploratory interviews and structured observations. Section 6.2 discusses the findings from the semi-structured interview on the current understanding and application of production planning and control principles based on the LPS in the UK. In section 6.3, the results from the structured observations on these practices from three different sectors in the UK construction industry are discussed. The chapter presents a general discussion on all the findings in section 6.4. It also provides an overview of the chapter summary in section 6.5. This chapter provides empirical evidences on how the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK align with the advocated principles of the LPS.

6.2 Phase 2: Semi-Structured Interviews

6.2.1 Analysis, Presentation, and Discussion of Semi-Structured Interviews

In this chapter, the term Last Planner System/ Collaborative Planning (LPS/CP) is used to describe the application of production planning and control (PP&C) principles based on the LPS in the UK construction industry. This chapter only presents and discusses the findings as the process used in collecting the data has been discussed extensively in the methodology chapter (Chapter Five). The findings presented and discussed in this section include: current view on construction planning and programming, current industrial perception on Last Planner System and Collaborative Planning in the UK, current success factors and drivers for implementing LPS/CP in the UK and the current benefits and barriers for implementation of the process in the UK.

6.2.2 Demographic Information of Interviewees

[8]Table 6.1 gives an overview of the distribution of the respondents across the 3 sectors (building, highway infrastructure, and rail) considered in the study. This suggests that the findings from this study should broadly reflect the current practice of production planning and control in the UK construction industry. The analysis of the interview response reveals that 60% are from main contractors, 20% are subcontractors, 13.3% are consultants, and 6.7% of respondents are clients. Since all the major stakeholders are represented in the interview, the level of bias in the findings is minimised and objectivity is improved.

Table 6. 1: Descriptions and Distribution of Interviewees across the UK Construction Sector

Respondents Code	Sector	Years of exp. in PP&C	Years of exp. in construction
MC01	Highway and Infrastructure	5	18
MC02	Highway and Infrastructure	3	17
MC03	Highway and Infrastructure	4	15
MC04	Highway and Infrastructure	4	6
MC05	Highway and Infrastructure	5	11
MC06	Highway and Infrastructure	5	10
MC07	Highway and Infrastructure	4	10
MC08	Building	10	10
MC09	Building	10	30
MC010	Building	12	20
MC011	Building	5	15
MC012	Building	6	15
MC13	Highway and Infrastructure	6	18

[8] Part of this has been published in Daniel, Pasquire Dickens and Ballard(2016). The relationship between the Last Planner System and collaborative planning in UK construction

MC14	Highway and Infrastructure	5	10
MC15	Highway and Infrastructure	4	30
MC16	Rail and Infrastructure	12	30
MC17	Rail and Infrastructure	3	30
MC18	Building	4	4
SC01	Highway and Infrastructure	5	21
SC02	Highway and Infrastructure	4	20
SC03	Building	6	15
SC04	Highway and Infrastructure	4	10
SC05	Building	5	15
SC06	Highway and Infrastructure	3	6
CO01	All sectors	10	32
CO02	All sectors	14	26
CO03	All sectors	15	15
CO04	All sectors	10	20
CL01	Building	3	11
CL02	Highway and Infrastructure	10	30

MC= Main contractor, SC subcontractor, CO= Consultants, CL= Client

In terms of experience in the application of production planning and control (PP&C) principles, the analysis reveals that, 53.3% claim to have 3-5 years' experience while 43.7% have 6-15 years' experience. This suggests that the respondents have some knowledge of the practice. Also, in terms of the interviewees' experience in the construction industry 46.7% have 6-15 years' experience, 30% have 16-25 years' experience, and 23.3% have over 26 years' experience. This implies that the majority of the respondents have significant experience in the UK construction industry, thus enhancing the quality and richness of the data obtained. It is worth stating that this also indicates that the practice of PP&C based on the LPS is still new in the UK construction industry. However, one of the respondents (CO03) claimed to be practising PP&C since joining the construction industry. This could be so since the respondent is a consultant and could have come into the industry as a lean consultant from another sector.

Comparing the knowledge of the respondents in PP&C practice to their years of experience in the construction industry gives an indication that the traditional approach of managing construction has been the dominant practice in the industry. The implication of this is that undoing or unlearning this traditional approach could be difficult. Ballard and Howell, (2004) observe that construction projects have since been viewed as managing contracts rather than managing production.

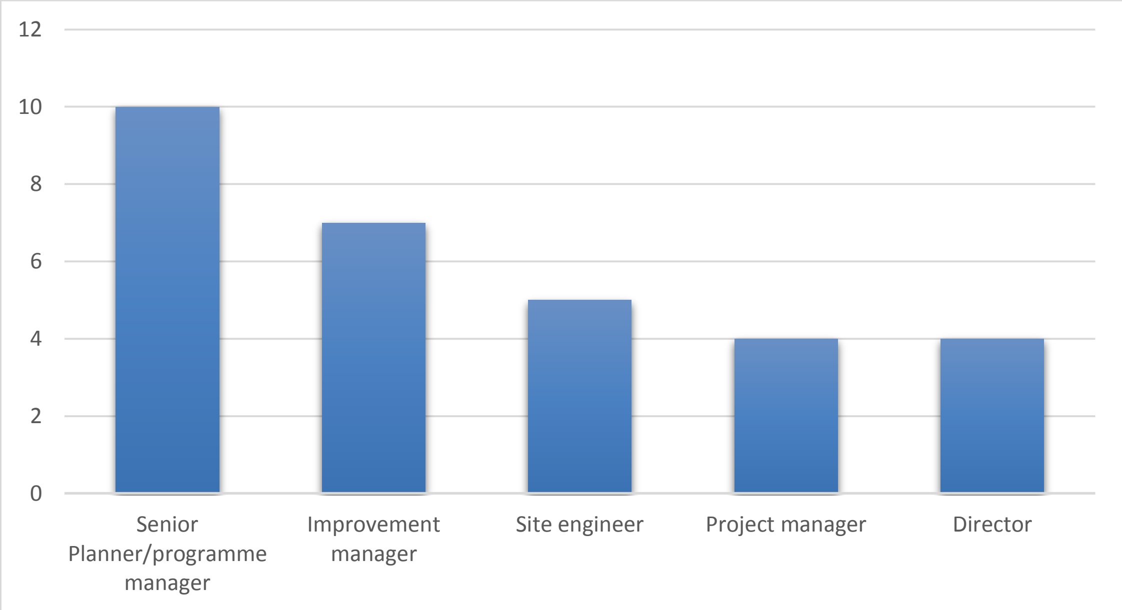

Figure 6.1: Positions Occupied by Interviewees

The respondents occupy various posts in their organisations as shown in Figure 6.1. The figure reveals that majority of the respondents are those charged with the responsibility of managing and developing construction programmes in their organisation. This implies that the information provided by them on the application of PP&C principles could be relied on. Also, all the respondents occupied positions at levels ranging from strategic to operational in the organisation, which supports the study to capture a wide perspective on the current practice in the industry. It further shows that the respondents are directly involved in the implementation process as well as preparation.

6.2.3 Current View on Construction Planning and Programming.

All the respondents interviewed agreed that construction planning is usually driven by the master programme which is developed for the client, with professional advice depending on the nature of the contract. For example, in a design and build (D&B) contract with reference to the client, the master programme is developed by the D&B contractor. While in a traditional arrangement, the main contractor may develop the contract programme. However, the start and finish dates are still determined by the client in both cases. One of the interviewees stated that:

> "*We start the programme in the traditional way with the Primarvera and Bar Chart programme, the client gives the start and finish date*" **[Senior Planner MC05]**.

Again, this shows the use of master programme or contract programme in construction planning has not changed, and the drive for its use in the future is still very strong. On all the projects observed, the master programme form the basis of other programmes developed and used in managing the construction processes. From the analysis of the interviews, four major themes emerged that describe the master programme as currently seen by construction practitioners. This is shown in Figure 6.2.

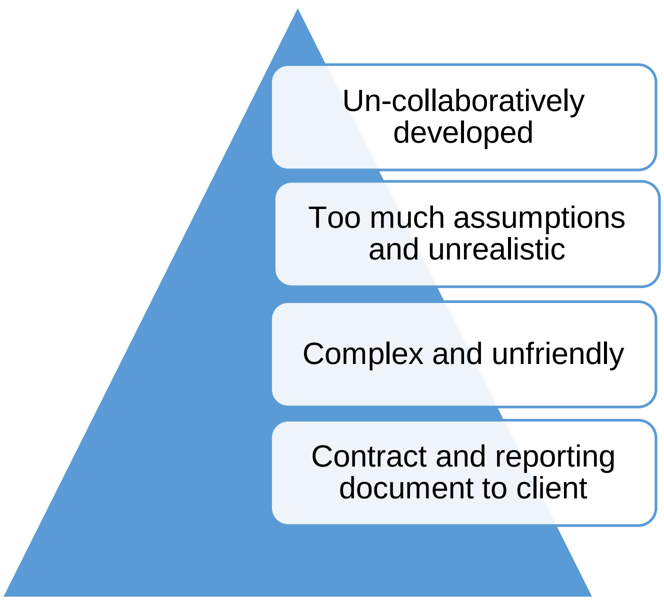

Figure 6.2: Current View on Master Programme

6.2.3.1 Un-collaboratively developed

The respondents were of the opinion that the master programme is usually developed by the planner and activities durations are usually arrived at based on the experience of the planner. This was clearly captured by one of the respondents;

> *"The client planner will develop this information based on the outline design available at the time resulting in a very high level master programme. Overall durations, sequence, and logic are stipulated by the client's planner in the master plan and are dependent on the knowledge and experience of the client's planner to produce a realistic programme".* **[MC11 Senior Planner]**

This suggests that those responsible for doing the work are not actually involved in developing the master programme, that is the concept and the implementation are separated. This evidence further supports the claim that the current approach used in the design, planning and construction could be likened to the rational comprehensive model (RCM) where it is believed that the knowledge needed for planning is with the chief planner alone (Daniel, *et al.*, 2014). However, according to Hayek, (1945) the knowledge needed for planning and allocating of resources is usually dispersed among individuals. The implication of developing the master programme un-collaboratively is that it cannot benefit from the expertise of the people doing the work, thus cannot be used to manage production and resources effectively on site.

6.2.3.2 Too much Assumption and Unrealistic

The study revealed that the duration of activities in the master programme are based on assumptions of the programme and they are unrealistic. A main contractor explained that though they usually received input from the subcontractors and specialist contractors in developing the tender programme, he stated that these durations were not realistic. He stated that:

> "*As you know, the duration given by subcontractors at this time is usually wrong".* **[MC16 Senior Planner]**

Another respondent also mentioned that at the tender stage, information may be limited.

> *"It must be noted that at this stage, the contractor is very much in 'sales mode' and there is an increased emphasis on winning the project and giving the client*

what they want so as not to disadvantage themselves in the face of competition" **[MC11, Senior Planner].** "

These findings also conform with those of Johansen and Greenwood, (1999) where they concluded that construction programming is usually done under pressure and the desired commitment to develop a realistic programme is lacking. They observed that in reality, construction programme is based on 'guesstimation' and activity durations are usually fudged.

6.2.4 Current Industrial Perception of Last Planner System and Collaborative Planning in the UK

The analysis of the interview results reveals 5 major themes on the current industrial perception on the LPS and CP in the UK construction industry as production planning and control approaches. These themes are presented in Figure 6.3 and discussed in section 6.2.4.1

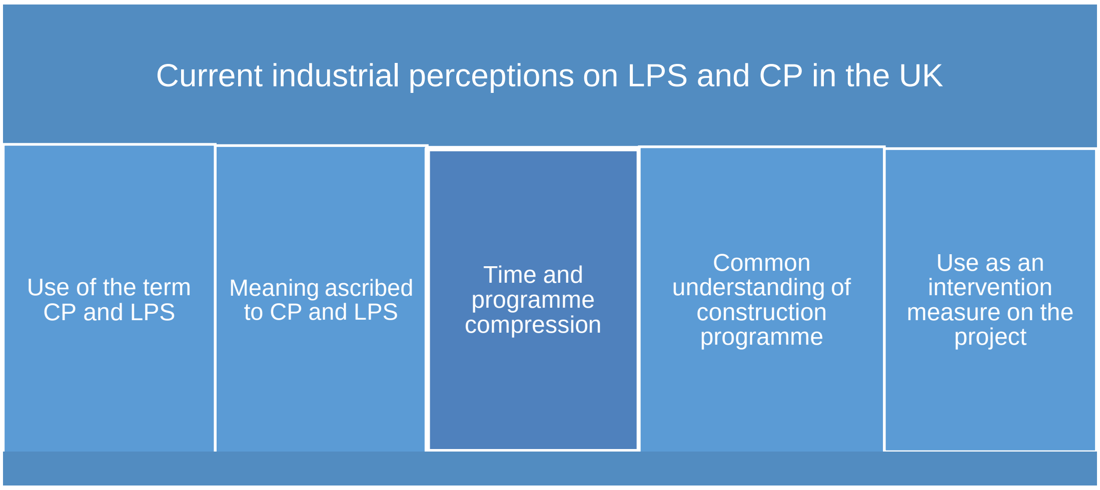

Figure 6.3: Current industrial perceptions on LPS and CP in the UK

6.2.4.1 Use of the terms "Collaborative Planning" and "Last Planner System"

The study revealed that there is confusion over the use of the terms "Last Planner System" and "Collaborative Planning" in the UK. Respondents all recognised the term CP and approximately 70% recognised the term "LPS" although often calling it simply "Last Planner". Some respondents used the terms CP and LPS interchangeably without any distinction in meaning. Some of the respondents stated that they were not using the term due to the trademark on the LPS. Here are some of the transcripts:

> *"We are not using the term 'Last Planner' on our project because of the trademark on it, we choose to call it collaborative planning, it is easier for the team to understand"* **(MC02)**, *"To us here, collaborative planning and last planner are the same, we take the principles of the last planner to suit our project" (***MC08**) *"Collaborative planning is the name for LPS in the UK"* (**CO01**).

To understand this confusion of terms, it is worth noting that majority of the respondents had received some form of support from external lean construction consultants before the application of CP/LPS on their projects. These consultants do not as a rule use the term "Last Planner System" because the trademark registered in the USA by Lean Construction Institute prohibits unregistered consultants from selling LPS training and consultancy (U.S. Patent No. 3020113, 2005).
However, regarding the direct impact of the US trademark on UK practitioners, the information available from the United State Patent and Trademark Office (USTPO) indicates that: a mark is only protected in the country where it is registered except if such mark is registered in another country under the international Madrid protocol (USPTO, 2016). Also, Trademark legal practitioners have also offered explanations on the impact of a mark in a country outside it registration. For instance BITLAW states that:

> *"A mark is infringed under U.S. trademark law when another person uses a device (a mark) so as to cause confusion as to the source or sponsorship of the goods or services involved. Multiple parties may use the same mark only where the goods of the parties are not so similar as to cause confusion among consumers. Where a mark is protected only under common law trademark rights, the same marks can be used where there is no geographic overlap in the use of the marks. Federally registered marks have a nation-wide geographic scope, and hence are protected throughout the United States" (BITLAW, 2015).*

All of the above statements suggest that the direct impact of the US trademark on UK practitioners is more about perception than legally valid restriction. Also, Last Planner has a registered trademark in the EU (EU Patent No. 004516324, 2006). However, most of the practitioners interviewed were not aware of the EU trademark and only made reference to the US trademark. The impact of the trademark registered in the EU is unclear and is currently being contested by the LCI (EU Patent No. 013369863, 2014). This does not entirely explain the confusion in the terms as other names such as "plan to save", "detail planning to completion", and "interactive planning" among others were also used. Also, some of the consultants still use the term "Last Planner".

Furthermore, most of the respondents agreed that CP is based on the LPS, while other respondents argued that there are other practices advocated in CP in the UK that were not in the LPS. For instance, one respondent stated that: "*To me LPS and CP are the same, but there is an amalgamation of other practices in CP such as the visual management that is not in the LPS" (CO02).* This further underlines the confusion around the practice as visual management is an established lean production practice (Liker 2004) directly imported from the automotive sector into lean construction and can support both CP and LPS equally if required.

6.2.4.2 Meaning Ascribed to the Last Planner System and Collaborative Planning

The study revealed that there is a consensus among the respondents that the LPS and CP are seen as the application of production planning and control (PP&C) principles in construction. However, further analysis of the interview shows that the meaning ascribed to them seems to be disjointed. Table 6.2 shows the current understanding of the respondents on LPS and CP by practitioners in the UK.

Table 6.2: Meaning ascribed to the Last Planner System and Collaborative Planning

Understanding on LPS and CP	Inference	View Influencers	Respondent Code
"*We did not use the LPS in detail due to the fact that this has not been taught to us. No detailed information on it. We are planning to do it on a new scheme*"	Only CP concept taught by the consultant	Lean consultant & CLIP	MC01, Director
"*CP is an active part of CLIP, it helps us to map out programme collaboratively with the supply chain. The LPS helps balance the flow of work better"*	"LPS" and "CP" viewed as two separate processes	CLIP	CL02, Director
"CP is all about having 2 weeks look-ahead, weekly and daily	Lean consultant driven	Lean consultant	MC03 Improvement

production meetings. This process is led by the consultant"			manager
"*CP is a process of bringing people together, while LPS is way of measuring performance*."	"LPS" and "CP" viewed as separate processes	Lean consultant	MC13, Senior planner
"*Collaborative programming is the first step in the LPS known as pull planning, phase planning, collaborative programming. It means the working together of subcontractor/main contractor to agree at a mutually agreed plan."*	CP viewed as an element characterised in the LPS	Experience from practice & Lean construction Institute, USA	CO01, Director
LPS is about measuring commitment in the 6 weeks look-ahead and weekly planning meeting	Narrow view on LPS	The practice in the organisation	MC16, senior planner

Table 6.2 reveals that the disjointed view held by the respondents was largely influenced by lean construction consultants in the UK who seem to be facilitators for most of the organisations attempting to implement PP&C based on the LPS on their projects for the first time. As shown in Table 6.2, some of the respondents (CL02, MC13) believed that the LPS is a separate process from CP, but this view was somehow refuted by another respondents as he stated that:

> "*Collaborative programming is the first step in the LPS known as pull planning, phase planning. It means the working together of subcontractor/main contractor to agree at a mutually agreed plan*. **[CO01, Director]**

According to Ballard, (2000) the LPS comprises of 5 key processes; the milestone planning, phase planning- (which is the collaborative element), look-ahead planning & make ready process, Weekly Work plan, and measurement and learning. It can be argued that the partial implementation of PP&C practice reported in the UK could have been influenced by the 'separation view' on LPS and its associated collaborative elements (Daniel *et al.*, 2016; Koch *et al.*, 2015).

This could have also been influenced by the distorted message received by the supply chain from some of the UK lean construction consultants on the application of PP&C principles based on the LPS in construction. However, respondent CO01 seem to maintain a balanced view on the application and practice of PP&C in construction as advocated in the LPS.

6.2.4.3 Time and Programme Compression

Most of the respondents interviewed agreed that CP focuses on programme and time compression of construction activities. One of the respondents stated that: *"The CP has been helping us to reduce our programme significantly, we enjoy twice as fast delivery of our process with CP"* **(MC06)**. Furthermore, most of the respondents interviewed indicated that they used collaborative programming/phase scheduling, and Weekly Work Planning meetings. However, other elements of the LPS such as the make-ready process, look-ahead planning, constraint analysis, consideration for flow and learning with action were not mentioned or demonstrated as much. One of the respondents stated that "*We are not doing all the bits, the site people are too busy, we only do high level collaborative programming"* **(MC05)**.

6.2.4.4 Common Understanding of Construction Programme

The study revealed that the CP process is viewed as an avenue to understand and develop a sound construction logic that is often lacking when the traditional project management approach is used. Some of the interviewees stated that:

> "*It (CP) raises the awareness of collaboration among the supply chain. Usually, we expect the supply chain to deliver our programme even without involving them but now CP makes it better"* **(MC02)**; "*We get ideas from the supply chain to develop a more workable programme"* **(CL01)**.

This suggests that the CP as practiced enables the project team to develop a better understanding of the relationship between activities on the programme. According to Pasquire (2012), for construction projects to flow as expected, all stakeholders need to have a common understanding of the tasks to be executed. This implies that the conversations that occur during the CP process have the potential to develop collaborative relationships among the project stakeholders thus helping to reduce fragmentation and engender stable workflow (Gonzalez *et al.*, 2015).

6.2.4.5 Intervention Measure

The study showed that CP is commonly used in UK construction when there are signs of failure on a project, especially in meeting the time requirement. For instance, some of the respondents stated that:

> *"Our management decided we use (LPS and) CP on this project because of the failure of our previous process, we have rebased this programme many*

times. We have been working in isolation" **(MC16)**. *"The key driver is the MD, because things are not going as initially planned"* **(MC17)**.

This is an indication that CP is used as an intervention measure rather than for transformation of the business process. The danger with such approach is that the organisation will only reap a one-off (and overall less) benefit from the practice. Additionally, the statements indicates that construction clients are not the only driver of the process, higher management from the contracting firm have an influence too.

6.2.5 Current Success Factors for Implementing LPS/CP in the UK

The analysis of the interviews revealed these key factors as presented in Figure 6.4. These factors are based on the emerging themes from the interview analysis and there is no weighting attached to them.

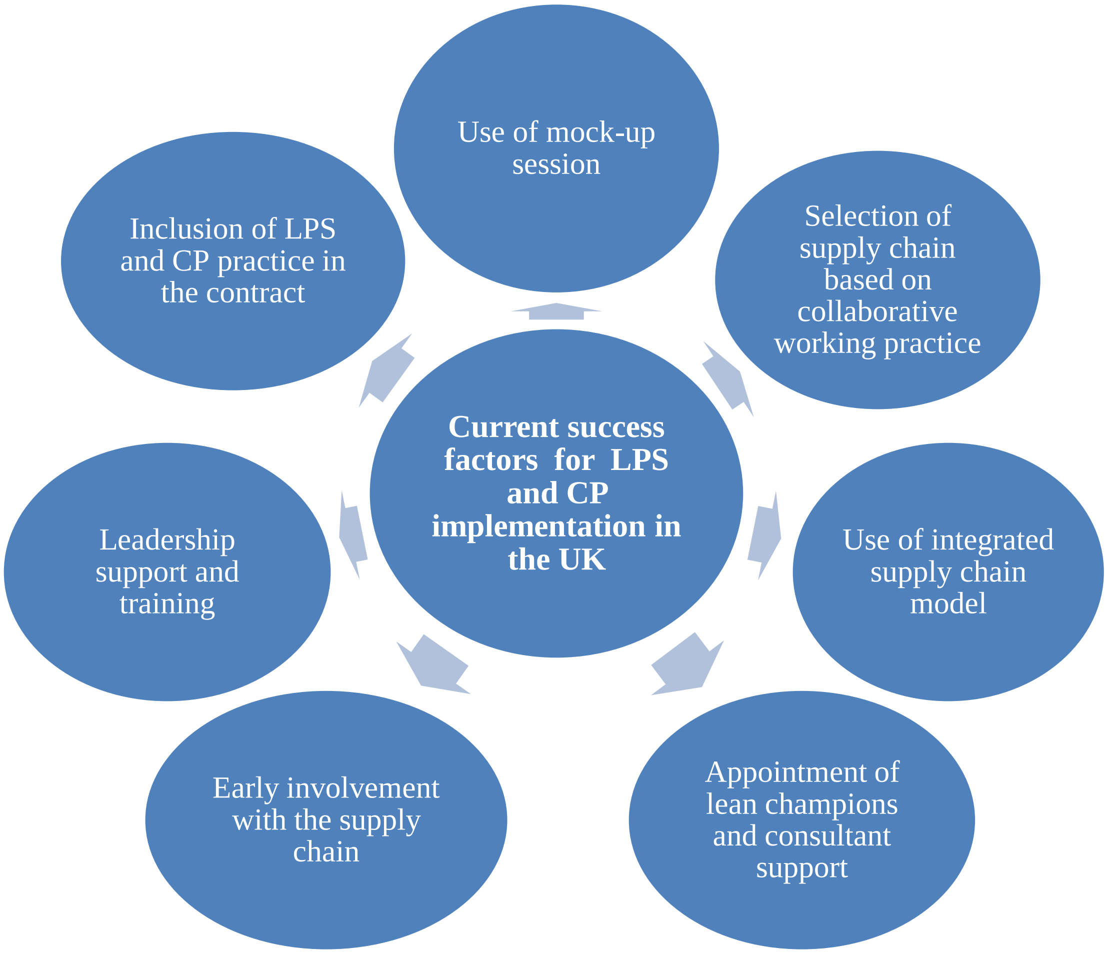

Figure 6.4: LPS/CP success factors in the UK Construction industry

6.2.5.1 Early Engagement with the Supply Chain

The study revealed that the early engagement with the supply chain contributes to the LPS/CP implementation on the projects. For example, some of the respondents stated that:

> *"The early involvement of the subcontractors with the development of framework has helped*" **[MC01, Director]**. *"The engagement of the subcontractors is key to the success of the process and also their buy-in"* **[MC02, Improvement Manager].**

This finding aligns with previous studies such as the recent review of IGLC papers on LPS by this author as presented in Chapter Four; Hamzeh and Bergstrom, (2010); and Ballard *et al.*, (2007) among others. While this is not new, it showed that production planning and control practice implementation success factors observed in the UK are similar to those found elsewhere. Also, there seemed to be a consensus among the respondents with regards to subcontractor engagement. However, one of the subcontractors observed that this does not always happen in practice on all projects that claim to use PP&C principles based on the LPS in the UK.

6.2.5.2 Use of Integrated Supply Chain Model

Most of the respondents interviewed observed that the use of what is best described as an "integrated supply chain model" is one of the major success factors in LPS/CP implementation in UK construction. The integrated supply chain model focuses on developing a long term relationship with the supply chain. This is done through a framework agreement with the supply chain which affords them the opportunity to work with a particular client or contractor over time. Some of the respondents stated that:

> *"The use of integrated supply has helped in our CP implementation. As a client, we select, develop, and maintain our supply chain. We also train them on CP and encourage them to train their staff too at the workforce level which adds to their point during lean maturity assessment"* **[CL02, Director].** *The desire or wish of the supply chain is continuity. Also, they want to be sure of the labour requirement each day and this need to be consistent, so that they can book their profit* **[MC13, Senior Planner].**

Again, this does not only show the need for maintaining the supply chain from one project to another, but also the need to take responsibility for working together, training of the supply chain, as well as lessons learnt. The benefits from this cannot be overemphasised, as it supports learning on the project. It also allows for the transfer of learning to other projects and the development of collaborative working relationship among the supply chain. A respondent stated that:

> *"To transfer lessons learned goes down to having a stable supply chain. A stable supply chain helps learning from the CP process. It is the supply chain philosophy that helps in transferring skills and lesson learned" [***CO02, Director].**

However, the narrow view thata construction project is a one-off activity could limit the embracement of this approach across the industry. Vrijhoef and Koskela, (2000) observed that the construction industry supply chain tends to be fragmented and unstable due to the one-off nature of construction projects.

6.2.5.3 Inclusion of LPS/CP in the Contract

The analysis of the interviews provides evidence that the formal inclusion of LPS/CP practice in the contract supports the buy-in from the supply chain. About 80% of the respondents comprising main contractors and client agreed that LPS/CP practice was included in the contract agreement with the supply chain. About 20% claimed not to have formally included it in the contract, though the supply chain members were aware that they will be doing it. Some of the respondents stated that:

> *"We include LPS practice in the contract with our supply chain; they know they will be doing it. This means we have paid for it* ??????" **[MC09, Senior Planner].**

> *"Early and prompt payment within 28 days to the subcontractors encourages them to participate and get [them] more committed and also the CP is signed into the contract at the early stage*" **[MC01, Director].**

This shows that the early inclusion of LPS/CP practice as part of the contract, will prepare the mind of the supply chain to get involved with process even before the commencement of the project. This implies that both clients and main contractors should make their expectations on production planning and control practice known to their supply chain early on the project. This will ensure there are no surprises to them at the start of work on site. It could be argued that the commitment to LPS/CP by the supply chain could be low on projects where the process is used as an intervention measure. This is because on such projects, the supply chain would not have been informed about the process. Thus, they would be reluctant to commit to the process. Some could also argue that the cost of attending production planning meetings is not part of their tender.

6.2.5.4 Appointment of Lean Champions and Support from Lean Consultants

All the respondents shown in Table 6.1 observed that the appointment of internal lean champions contributed to the implementation success. This shows the value of developing internal capacity in sustaining new practices in an organisation. Alarcon *et al.*, (2002) asserted that formation of internal lean committee both at the project and organisation levels help in driving the LPS implementation in construction organisations in South America. Again, this means that the internal lean champions should not be limited to the project level alone, but should also be extended to the organisational level. The study revealed that clients, main contractors, and subcontractors have had some form of support from independent lean construction consultants in the implementation process.

6.2.5.5 Procurement of Supply chain based Collaborative Practice

The study revealed that majority of the respondents comprising mainly clients, main contractor, and consultants agreed that the selection of the supply chain using some collaborative working practice contributed to the success of the LPS/CP implementation. Some respondents stated that:

> *"Procurement method has massive influence on the LPS/CP approach. In the LPS and CP process, one thing that is key is that both parties should know the 'spirit of the contract' and 'not just the letter' which most time leads to adversarial relationship. The contract should be win-win. We select our supply chain based on 80% quality and 20% cost and collaborative culture"* **[CL02, Director]**. *"We use more of selective tendering we select our supply chain based on key element of CP, their previous performance, and their like for CP*" **[MC01, Director].**

This shows that in selecting the supply chain for LPS/CP implementation in construction, the focus should not be on cost only, but rather on previous performance of the supply chain, collaborative working record and in developing robust relationship with the supply chain. This implies that the focus here is for every stakeholder on the project to benefit equally from the process. This is opposed to the traditional project management approach that focused on managing cost, contract, and individualistic self-interest (Pasquire, *et al.*, 2015; Ballard and Howell, 2004).

However, the LPS focuses on managing project production, and the interrelationship that exists between the activities and those required to perform them (the supply chain) (Fueman *et al.*, 2014; Mossman, 2014; Ballard and Howell, 2003). The study further revealed that the supply chain were physically engaged in collaborative working exercises, which gives the supply chain an understanding of what the customer wants. One of the clients stated that:

> "*The selection process of the team actually helped in the process. We do activities such as prototype workshop, prototype work, design for construction workshop. Their willingness to collaborate is a condition for their selection*" **[CL01, Director].**

It could be argued that if the supply chains are exposed to these practices before moving on to the project, the probability of committing to the process could be high.

6.2.6 Current Drivers for Implementing LPS/CP in UK Construction

Figures 6.5 presents the current drivers for implementing LPS/CP in the UK construction industry from the interview results. There is no weighting attached to the factors in the figure as it is based on the emerging themes obtained from the interview results. Some of these drivers are discussed under this section.

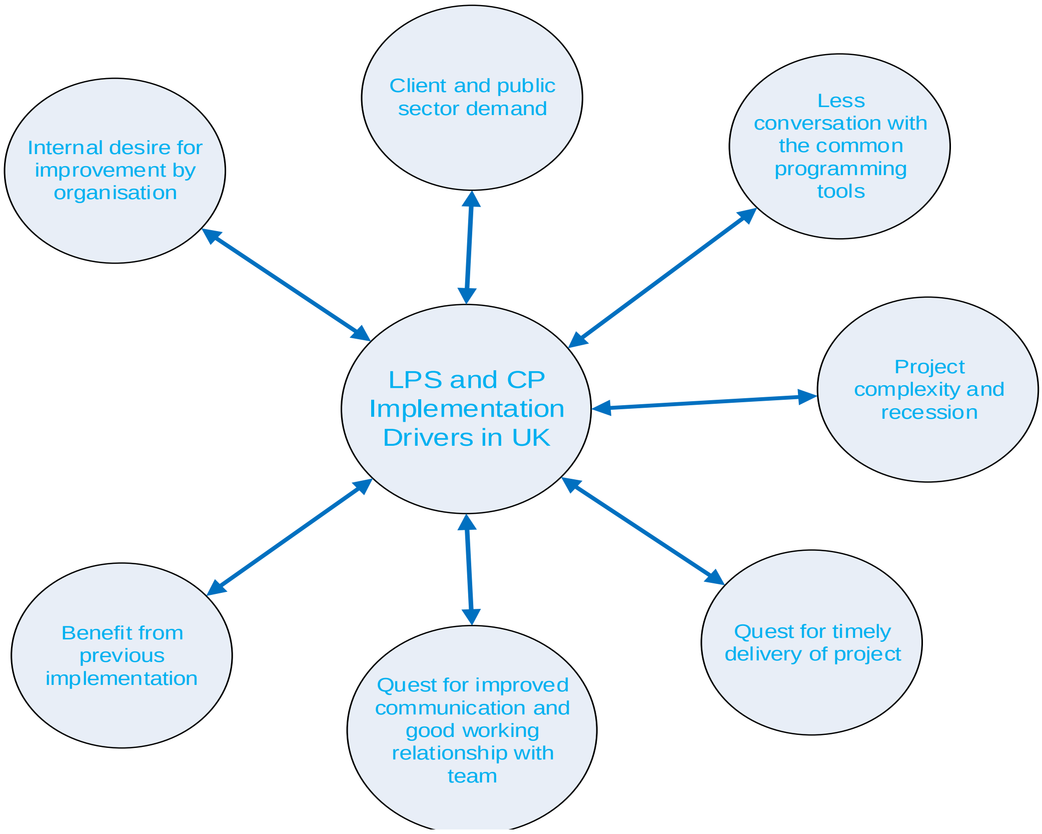

Figure 6.5: Drivers for implementing LPS/CP in the UK construction industry

6.2.6.1 Client and Public sector Demand

The study revealed that the demand for its use by the public sector clients remains the main driver for the use of LPS/CP on construction projects in the UK. Some respondents stated that:

> *"We are working to achieve our client's expectations; we are required to use it on this project. Also, we have a drive for efficiency within our organisation for continuous process improvement"* **[MC03, Improvement Manager]**.

> *"Client is the major driver, much of the leadership is coming from the client and the public sectors such as Highway Agency and Ministry of Justice"* **[MC05, Improvement Manager].**

The drive coming from the client and public sector in the UK seems contrary to what is commonly reported in other parts of the world such as North America and Brazil. In those places, contractors were the active agent in initiating and deploying the LPS in their businesses (Alarcon and Calderon, 2003 Miles, 1998; Soares *et al.*, 2002). It can be argued that, the slow and partial uptake of LPS/CP in the UK could be due to the push for the use of the system from public sector clients, rather than an internal motivation or pull from within the contractors. Although, the pace of uptake within the UK is slow, it has been observed that the uptake of lean production principles in construction is slow globally (Stevens, 2014).

However, the demand from the public sector shows the UK Government's continuous effort in improving the performance of the construction industry through all available opportunities (Egan, 1998; Latham, 1994).

6.2.6.2 Internal Drive for Continuous Improvement by Organisation

The analysis of the interviews revealed that 80% of the respondents agreed that client demands and the internal desire for continuous process improvement are among the core motivators for using LPS/CP on their construction projects. While only 20%, mainly main contractors, indicated that it was part of their internal process for driving continuous improvement across their business. Some main contractors stated that:

> *"The LPS/CP is adopted for our company and we use it across our projects. We have a standard process for carrying out CP on all our projects"* **[MC07, Business Improvement Manager]**; *"I can say the LPS/CP process on this project is internally motivated 70% from the organisation and 30% from the client"* **[MC06, Improvement Manager].**

Again, this shows that the push for an effective planning approach is not coming from the client alone. Even though the percentage is still very low, it gives an indication that more contractors could take personal initiative to embark on this as they see benefits from the process.

6.2.6.3 Benefit from Previous Implementation and Quest for Improved Working Relationship

Most of the respondents, mainly clients and main contractors observed that, the benefits from their previous implementations are among the current drivers for using it on their project. One of the clients stated that:

> *"We have seen the benefits from the process on our previous pilot projects. We were able to deliver our project on time and better profit of course*" **[CL02, Director]**

This shows the need for measuring the benefits realised from the implementation process, as people would not be interested to commit to the system if there is lack of evidence of its benefit. Smith, (2013) declared that measuring, reporting, and proper communication of benefits is critical to the success of lean in construction. This is true as no organisation or supply chain would be motivated to apply LPS/CP for the sake of the name.

However, the desire for improved communication and better working relationship seems to be the driver for the subcontractors. One of the subcontractors stated that: *"I love working in the best way. I love the CP approach to work, it makes our working process and relationship better"* **[SC01, Director].**

6.2.6.4 Quest for on Time delivery of Project and to Overcome Past Failures

Most of the respondents agreed that the need to complete the project on time is a key driver for implementing LPS/CP on their project. A main contractor observed that:

> *"Time saving is the most important motivating factor for us, people making saving in time is now essentials especially after the recession to avoid liquidation and damages*" **[MC09, Assistant Site Manager].**

This emphasises the need to have time certainty in the delivery of construction project. The quest for this by most of the respondents is no surprise, since it has been reported that 50% of construction projects suffer time and cost overruns (Crotty, 2012). However, the LPS as a PP&C methodology uses its collaborative elements in stabilising the production process, thereby improving time certainty of the construction programme (Papke and Dove, 2013; Ballard and Howell, 2003; Ballard, 2000).

6.2.7 Benefits of Implementing LPS/CP Observed in the UK construction

The analysis of the interviews revealed the various benefits associated with the implementation of LPS/CP in the UK construction industry. The identified benefits are classified into three categories. These are: (1) general benefits (2) process benefits and (3) social benefits as presented in Figure 6.6.

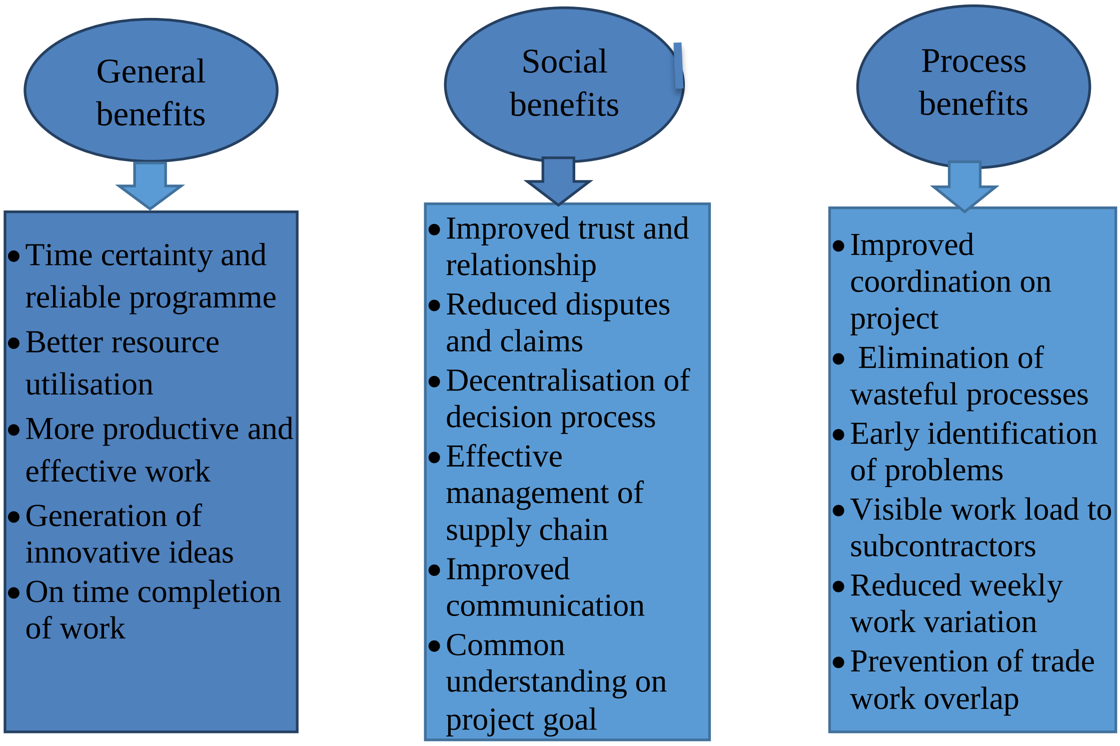

Figure 6.6: Categorisation of the benefits of implementing LPS/CP in the UK

6.2.7.1 General Benefits of Implementing LPS/CP Observed in the UK

Figure 6.6 show the general benefits of implementing LPS/CP on projects in the UK. General benefits here refer to the gain made from the implementation process in relation to the key project performance indicators. Almost all the respondents identified the factors listed under the general benefits in Figure 6.6. Majority of the respondents stated that they observed time reduction and more certainty in the construction programme. Some of the interviewees stated that:

> *"The process has helped us to save a lot of time, we shall meet the finish date despite all the challenges"* **[MC06, Improvement Manager]** "*The process gives us some security of finishing the job on time"* **[MC12, Senior Planner].** *The process enables my clients to experience twice faster in delivery* **[CO01, Director].**

The time reduction and certainty observed could have occurred as a result of the phase planning or collaborative programming meeting, WWP meetings and look-ahead planning process (Mossman, 2014; Ballard, 2000). However, the focus of implementing PP&C principles in construction as advocated in the LPS goes beyond time reduction to stabilising and making the work process more reliable and predictable (Hamzeh *et al.*, 2015; Ballard *et al.*, 2009). Actually, the process is centred on workflow and creation of value for customers (Koskela, 2000).

Some of the respondents claimed not to have measured these benefits in detail but believed they had made some gain in time, cost, quality, client satisfaction, and safety. The respondents observed that the subcontractor also used their labour resource more productively and effectively on site. For instance a main contractor stated:

> *"You know the certainty and predictability nature of our work, a subcontractor working on six projects needs to be certain on how to move his workforce around the project which CP has helped on this project"* **[MC06, Improvement Manager].**

This shows the importance of work certainty and predictability. However, it is worth noting that to achieve certainty and predictability in the production process as advocated in the LPS, more attention must be given to workflow, levelling of load and batch sizing (Pasquire *et al.*, 2015; Ballard and Howell, 2003; Alves and Formoso, 2000).

6.1.7.2 Social Benefits of Implementing LPS/CP in Construction

Social benefits as used here refer to those benefits that address relationship issues among stakeholders on the project. These benefits are listed in Figure 6.6. Majority of the respondents explained that there had been obvious improvement in communication and a better working relationship. Some of the respondents commented that:

> *"The process has helped us greatly. It has improved our communication with our supply chain. It brings closer working relationship with all the members on the project*" [**CL02, Director]**. *The process enables us to improve the level of communication among us; the team working on this project* [**SC01, Director].**

All the respondents agreed that the process had greatly improved the level of communication among the stakeholders on the project. This indicates that traditionally, there is little avenue for construction stakeholders to communicate on projects. According to Dainty *et al.*, (2007) the project based nature of construction projects and the sheer number of stakeholders involved in the process makes communication complex. This also contributes to the adversarial relationship. However, Toor and Ogunlana (2008), suggested that if all the required stakeholders constantly communicate, confrontation could be reduced, this includes face to face communication. This is clearly supported in the various conversation processes that occur in the LPS such as, phase planning and WWP among others. As observed by the respondents, this reduce disputes among the parties on the project.

Also, the respondents observed that the process enabled them to build more trust in the team. This is a key benefit in managing construction project based on the LPS principles. Kim and Ballard, (2010) observed that trust is usually developed among project participants when there is reliability in the programme. They argued that the trust developed here is based on relationship and not on mere commitment to the contract.

6.2.7.3 Process Benefits of Implementing LPS/CP Observed in the UK

Process benefits refer to the gains observed in the delivery process from the implementation of LPS/CP on the project. The specific benefits associated with the process are itemised in Figure 6.6. Majority of the respondents observed that the process had improved the coordination of project activities and elimination of wasteful processes. Some of the respondents stated that:

> *"The CP has helped us to reduce non-value adding activities from the construction process. We do a mock-up session to eliminate wasteful processes. The mock session enable us to identify the problem areas and get them addressed before construction"* **[MC01, Director].**

> *"We are enjoying better coordination on our project sites now as the site engineers now work closer with the foremen on site. Also, the team now understand each other's work better"* **[MC05, Project Manager].**

This shows the importance of collaborative conversation in improving the delivery of construction products. The mock-up session used in eliminating the non-value adding (NVA) activities is technically known as the First Run Studies (FRS) in the LPS. The process allows the team to collaboratively explore opportunities and identify the best approach to deliver the product more efficiently before the commencement of construction on site. According to Ballard and Howell, (1998) it is used on critical production processes and repetitive products. However, Mossman, (2014) argued that FRS should not be limited to repetitive activities alone as all activities are critical to the success of the project.

6.2.7.4 Level of Benefits from LPS/CP Implementation on Projects in the UK

To examine the level of benefits observed from LPS/CP implementation in the UK, the respondents were asked to identify which of the stakeholders benefited most from the implementation process. The study revealed that 100% of the stakeholders interviewed agreed that all the stakeholders benefited from the process, however their view on which of the stakeholders benefited most is diverse. Below are the transcripts from some of the respondents:

> "*I believe the process enables the entire team to develop an understanding of the construction process, but I think the potential benefit in terms of time goes to the client"* **[MC10, Senior Planner]**.
>
> *"Based on my experience in implementing LPS and CP in construction, it is the project as whole that benefits from the process and not just an individual"* **[MC05, Improvement Manager].**
>
> *"To me, the project as a whole benefits, but the subcontractors benefit more because they spend less time on site when CP is used, thus making more profits"* **[MC12, Project Manager]**.
>
> *The benefits from the process is pretty whole rather than looking at the output being for one single party, but of course, the potential benefits goes to the client* **[MC17, Planner].**
>
> *"Everyone benefits from the process; to me everyone is a winner when it works well***" [SC01, Director]**
>
> *"The subcontractor gets a general benefit of the process because there will be less rework, completion of work on time and high quality"* **[MC07, Improvement Manager]**

From the above transcripts, it is clear that all stakeholders benefit, however there is no clear consensus on who benefits most. Each stakeholder seems to hold a different view on who benefited most from the process. This suggests that to assume all the stakeholder benefits equally from the implementation process may not be true. However, going into the extreme of believing that one stakeholder benefits more could hinder the buy-in and commitment to the process from others who may feel they do not benefit as much. Stevens, (2014) emphasised the need to develop and refocus the benefits of implementing lean principles in construction with due consideration to the stakeholders involved in the process. This shows the need to model and prioritise the benefits of implementing LPS in construction projects using the lens of the different stakeholders involved in the process.

6.2.7.5 Modelling the Benefits of Implementing LPS/CP Observed in the UK

The study revealed that the respondents tend to emphasise the benefit which is of high priority to them in performing their role on the project. Table 6.3 presents the priority of the benefits as seen through the lens of stakeholders interviewed. In the Table, level 1 means very high priority while level 2 means high priority.

Table 6.3: Prioritisation of LPS/CP benefits using the lens of the stakeholders

	LPS/CP Benefits Observed	Stakeholder's view on LPS/CP Benefits	
		Level 1	**Level 2**
1	Visibility of work to subcontractor and other stakeholders	SC	MC
2	Development of more predictable and reliable overall programme	CL	MC, SC
3	Cheaper price from subcontractors based on long term relationship	MC	
4	Reduced variation, weekly overhead and time overrun	CL	MC
5	Improvement in the quality of final product and better client satisfaction	CL	MC
6	Improved communication and coordination	SC	MC
7	Better resource utilisation	SC	MC
8	On time completion of work	SC, MC, CL	
8	Better management of supply chain	CL	MC
10	Elimination of wasteful processes	SC	MC
12	Prevention of trade overlap	SC	MC
13	Improved trust and relationship	CL, MC, SC	

Key: CL= client, MC= main contractor, SC= subcontractor; Level 1= very high priority, level 2 = high priority

These benefit levels were determined based on the number of times they were mentioned by the interviewees. As shown Table 6.3, developing a more reliable and predictable overall construction programme and improvement in the quality of final product is of a very high priority to the client. On the other hand making the workload visible and better utilisation of resources on the project seems to be a major priority to subcontractors. The findings above shed more light on the areas of benefit to focus on when integrating stakeholders in the implementation of the LPS in construction. Although, all the stakeholders (main contract, client and subcontractor) collectively agreed that they benefited from the process, their priority area of benefits differed. This has not been clearly highlighted in previous research on the application of LPS principles in construction projects. The absence of a clear model of the benefits of LPS in construction to stakeholders could have contributed to its low uptake by stakeholders in the industry.

For instance, it has been observed that there is low adoption of lean construction principles among contractors (Stevens, 2015; McGraw Hill, 2013). Furthermore, Stevens, (2015); Stevens, (2014) concluded that this could be due to the misalignment of lean methodologies with the values of the stakeholders on the project. Again, all these demonstrate the need to prioritise LPS implementation benefits from the perspectives of the stakeholders as this could support their buy-in.

6.2.8 Barriers to Implementing LPS/CP in the UK Construction

Figure 6.7 indicates the current barriers to implementing LPS/CP in the UK construction industry as revealed from the interview results. Some of these barriers are discussed in relation to previous studies in the section below.

6.2.8.1 Cultural Issues at Project and Organisational Levels

Although, some of the challenges identified in this study are similar to those reported globally with regard to the implementation of lean principles (Alsehaimi *et al.*, 2014, Gao and Pheng, 2014; Fernandez-Solis *et al.*, 2012), it is striking to know that [9]100% of the respondents identified cultural issues as the major barrier to LPS/CP implementations on the project. This finding is contrary to previous studies such as the review of LPS implementation barriers from the review of IGLC papers between

[9] Part of this work has been published in Pasquire, Daniel and Dickens, 2015c. Snapshot Report

1993 and 2014 presented in Chapter Four, and Porwal *et al.*, (2010) where lack of training was identified as the topmost barrier.

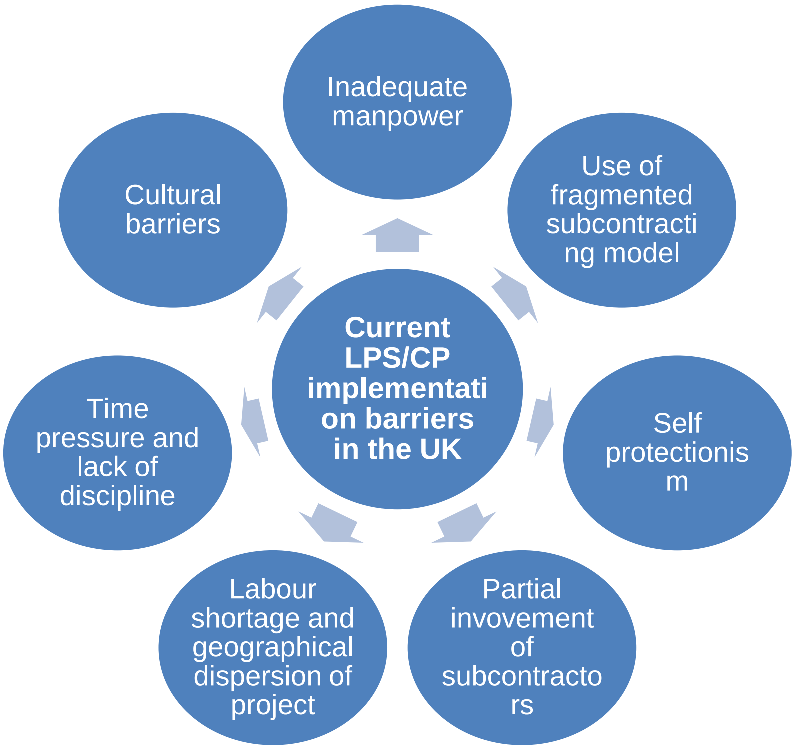

Figure 6.7: Current LPS/CP implementation barriers in the UK

The cultural issues identified occur both at project and organisational levels. One of the cultural issues that occurs both at the project and organisational levels is "*resistance to change*". All the respondents interviewed identified it as a major barrier at the project phase and in the organisation implementing the process. Some transcripts from the respondents are presented below:

> *"They like doing it their own way, people are too busy, they go into firefighting approach".* **[CO01, Director]**

> *"Changing the way people work is very challenging. It is difficult to embrace all the tools. We only do the high level planning. The site people are too busy to do all the bits."* **[MC05, Improvement Manager]**

> *"The guys doing the job for 30 years will always ask; why do you want me to do it differently?"* **[CO03, Operation Director].**

The above statements present an overview of the resistance to the new way of working in the UK construction industry. Although this finding may not be necessarily new, it shows how deep rooted the cultural issues affecting the implementation of the LPS/CP in UK construction are. For instance, Johansen and Porter, (2003) identified cultural and structural issues as barriers to the implementation of the LPS in the UK construction industry.

6.2.8.2 The Use of Fragmented Subcontracting Model

The use of "fragmented subcontracting model" was also seen as a barrier to the implementation of LPS/CP on projects. "Fragmented subcontracting model" is an approach that supports the changing of subcontractors as well as viewing subcontractors as tools to be used and dumped. This model does not encourage the development of collaborative relationship among project stakeholders as organisations tend to change subcontractors as they move from one project to another. Here are transcripts from some of the respondents:

> *"The use of fragmented subcontracting model makes most company focus on their engineers and management staff alone, while they keep changing the subcontractors which will affect the LPS/CP development in the organisation"* **[CL02, Director].**

> *"The difference between manufacturing and the construction industry is that we keep changing the team, which is a barrier. Too much 'going for shopping' in the construction industry"* **[CO01, Director]**.

Subcontracting is a common practice on construction projects and in the UK in particular. 80% of construction works are undertaken by subcontractors and the UK construction industry houses over 280,000 companies (BIS, 2013). This shows the different firms operating in the UK construction industry (BIS UK construction, 2013). The implication of using fragmented subcontractor's model in the implementation of LPS/CP is that, it reduces the ability of the supply chain to work collaboratively (BIS Supply chain analysis, 2013).

6.2.8.3 Partial Involvement of Subcontractors

The study revealed that subcontractors were only partially involved in the LPS/CP implementation process. A subcontractor stated that:

> *"There are projects where the subcontractors are not involved in the LPS/CP implementation process, writing it in the contract could help in this regard"* **[SC01, Director]**.

Again, this shows the need to formally include the implementation of LPS/CP practice in the contract. This would put more obligations on the main contractor to include the subcontractors in the process, which would benefit the entire project.

6.2.8.4 Time Pressure and Lack of Discipline

Another barrier is time pressure and lack of discipline in implementing the PP&C principles. Some of the research participants complained that it was time consuming. Some of the respondents stated that:

> *"The challenge is in the implementation of all the tools into the business. There is reluctance towards forward and weekly planning. We did not measure PPC at all time. What works well is the collaborative programming?"* **[MC05, Improvement Manager]**

> *"People believe they don't have the time to do it"* **[CO01, Operation Director]**

> *"The site guys and men are too busy to do all the bits of the system"* **[MC07, Improvement Manager]**

These comments clearly indicate that there is lack of discipline and commitment to the implementation of LPS principles at the projects level in the UK. Kalsaas *et al.*, (2014) also observed partial implementation of LPS principles at the project level in their Norway study. These findings show that the major barriers to LPS implementation are around people and not the process or technology.

6.2.8.5 Self Protectionism

The study revealed that protection of self-interest by some of the stakeholders especially between the main contractors and the subcontractor is a barrier to the process. A main contractor observed that:

> *"There is lack of openness to collective decision making a lot of self - protection subcontractors trying to protect their interest not minding what happens to the team"* **[MC12, Assistant Site Manager]**

Previous studies have shown that construction stakeholders tend to distrust each other and are always trying to protect their own interest (Briscoe and Dainty, 2003). This is not expected to occur on lean projects where the goal is to 'collaborate and deliver value' for the client. The emergence of this on a lean project shows that some of the stakeholders have not truly thrown away the traditional ideas of managing projects.

6.3 Stage 3: Structured Observations

The aim of the structured observation was to enable the study obtain the current practice of production planning and control based on the LPS in all aspects on the projects observed. Fifteen (15) projects were observed. This was done in a systematic manner in relation to the identified production planning and control principles advocated in the LPS so as to identify the level of implementations on the projects observed and to compare the implementation across sectors.

6.3.1 Results and Discussion

Data were obtained from 3 sources:

- record analysis,
- physical condition analysis and
- physical process analysis.

The above three processes have been described in detail in Chapter Five. The results and discussion are presented below.

6.3.2 Description of Projects Observed

Table 6.4 gives an overview of the construction projects observed in the study. [10]All the organisations observed are among the top 20 UK construction contractors and their facilitators claimed to be knowledgeable in production planning and control practice in construction. Additionally, the observation was not limited in scope, as it includes its use in highway, building, and rail projects, thus giving a wider perspective. Also, the project durations are long enough to enable a trend in the current practice to be clearly captured.

[10] Part of this work has been published in Daniel, Pasquire and Dickens, (2015b). Assessing the impact of PPM on construction process improvement based on the LPS in UK

Table 6.4: Description of project observed & evaluated for production planning and control Practice

Project code	Sector	Project Duration	Point of Application	Facilitation	PP&C exp. Yrs.
A01	Highway & infrastructure	36 months	Construction	Internal improvement manager	5
A02	Highway& infrastructure	119 months	Design/ construction	Project manager & internal lean practitioner	3
A03	Highway& infrastructure	40 months	Construction	Principal planner & project manager	4
A04	Highway & infrastructure	36 months	Construction	External consultant & internal lean team	4
A05	Highway & infrastructure	22 months	Construction	External consultant & internal lean team	5
A06	Highway & infrastructure	39 months	Construction	Internal improvement manager	5
A07	Highway & infrastructure	22 months	Construction	Internal site agent	4
A08	Highway& infrastructure	36 months	Construction	Internally facilitated	5
B01	Building	18 months	Construction	Internal senior planner	10
B02	Building	13 months	Construction	Consultant/Internal site manager	10
B03	Building	30 months	Construction	Internal senior planner	12
B04	Building	24 months	Construction	Internal lean team	5
B05	Building	12 months	Construction	Internal lean team	10
C01	Rail and infrastructure	36 months	Construction	External consultant and principal planner	6
C02	Rail and infrastructure	36 months	Construction	External consultant	3

The analysis revealed that all the projects observed had been using PP&C based on the LPS principles for a period of between 3 and 12 years. This implies that the observations and their responses could be relied upon.

6.3.3 Results of Record and Physical Condition Analysis

On all the projects observed, a designated meeting space was provided for production planning and controls. This was usually tagged "CP" meeting room or production planning and control centre.

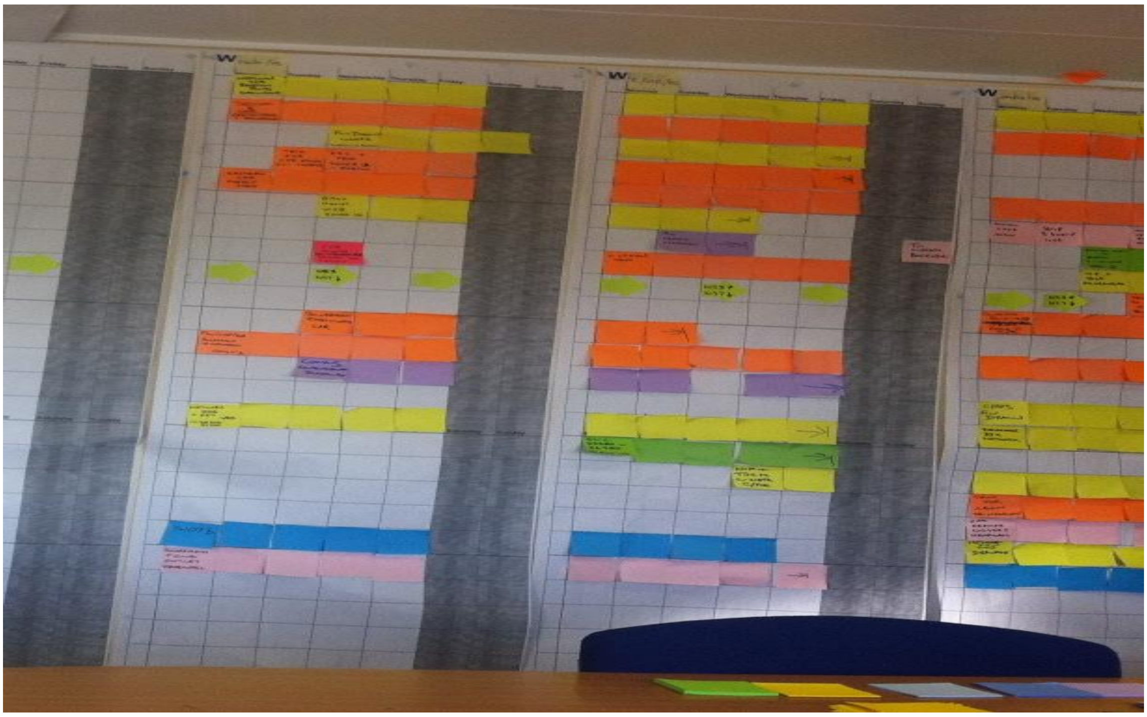

Figure 6.8: Pull Planning or Collaborative Programming board with Sticky-Notes for scheduling

Figure 6.9: Pull Planning or Collaborative Programming board with temporary marker for scheduling

Most of the projects observed made provision for a permanent collaborative programming or pull planning board and either used sticky-notes on the board for scheduling of activities or temporary markers of different colours as shown in Figures 6.8 and 6.9 respectively.

Also, magnetic collaborative programming boards (Figure 6.10) were used on some projects to provide a robust working medium while other projects were working towards using electronic collaborative programming boards. Other record analysis observed in the physical condition includes the display of PPC chart, RNC chart, display of RNC observed, and display of monthly project objective target achievement.

In addition to the collaborative programming meetings or pull planning meetings, Weekly Work Planning meetings were also held. However, on some of the projects observed, the activities within these meetings had become fragmented to the extent that they were separated out into additional meetings with a different team of people. For example, look-ahead activities took place in a separate meeting from make-ready activities. Also, the daily stand-up meeting was observed on some of the projects which could be likened to the “daily Huddle meeting” in the LPS.

However, there are differences in the practice of daily stand up meeting on some of the projects observed when compared with the daily Huddle meeting in LPS. For instance, the daily stand-up meeting as observed seemed to be the reporting of progress daily which was done individually. This approach does not create the needed platform that could result in collaborative conversations among the team in order to collaboratively agree on how an identified constraint can be solved before the next day work. The use of a form of visual management to communicate progress was seen on some of the projects as shown in Figure 6.10. Document analysis revealed that the collaborative programme/phase planning was usually developed from the Primavera programme known as P6, which is generally considered to be the contract programme.

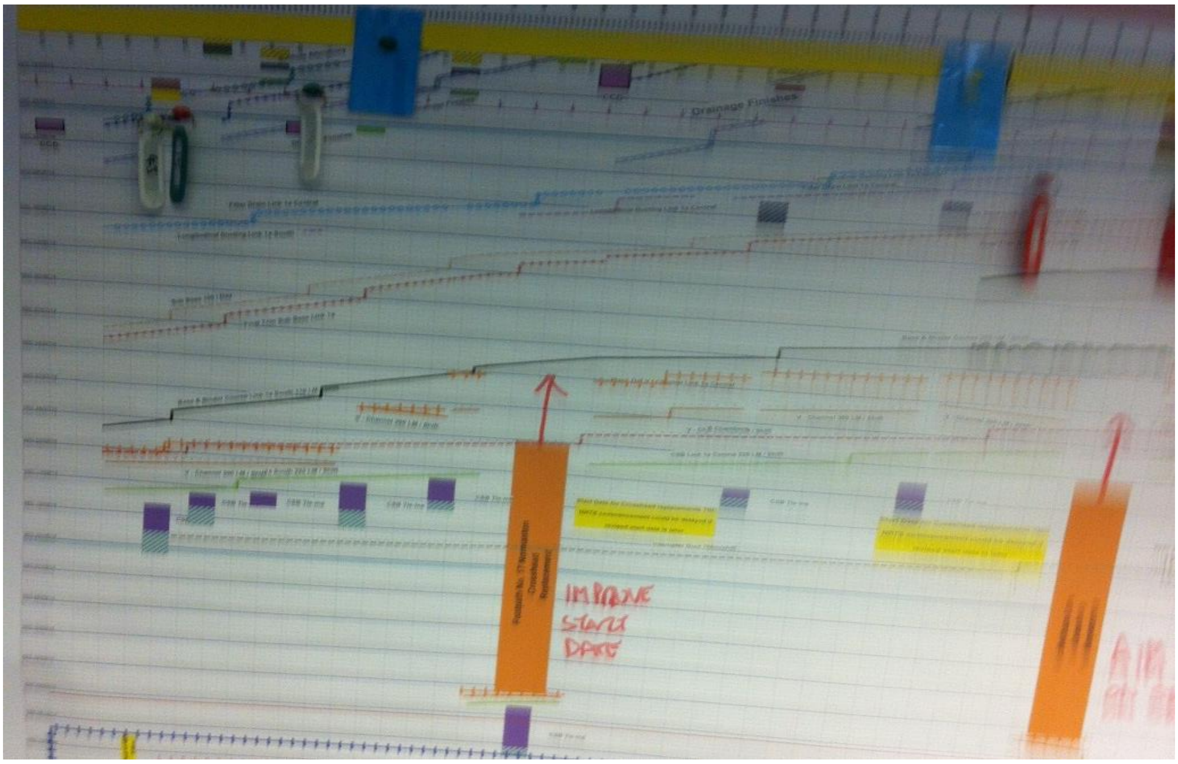

Figure 6.10: Visual Management Board to Communicate Progress of Work

6.3.4 Results of Physical Process Analysis

The aim of the physical process analysis is to enable the study objectively identify how the current practice of 'Collaborative Planning' used in delivering construction projects in the UK align with the advocated principles of the LPS.

6.3.4.1 Production Planning and Control Practices Observed

[11]To identify how the current practice of "CP" for delivering construction projects in the UK aligned with the LPS, 17 major practices associated with the implementation of LPS were identified.

[11] Part of this has been published in Daniel, Pasquire and Dickens, Ballard, G. (2016) The relationship between the LPS and CP in UK construction

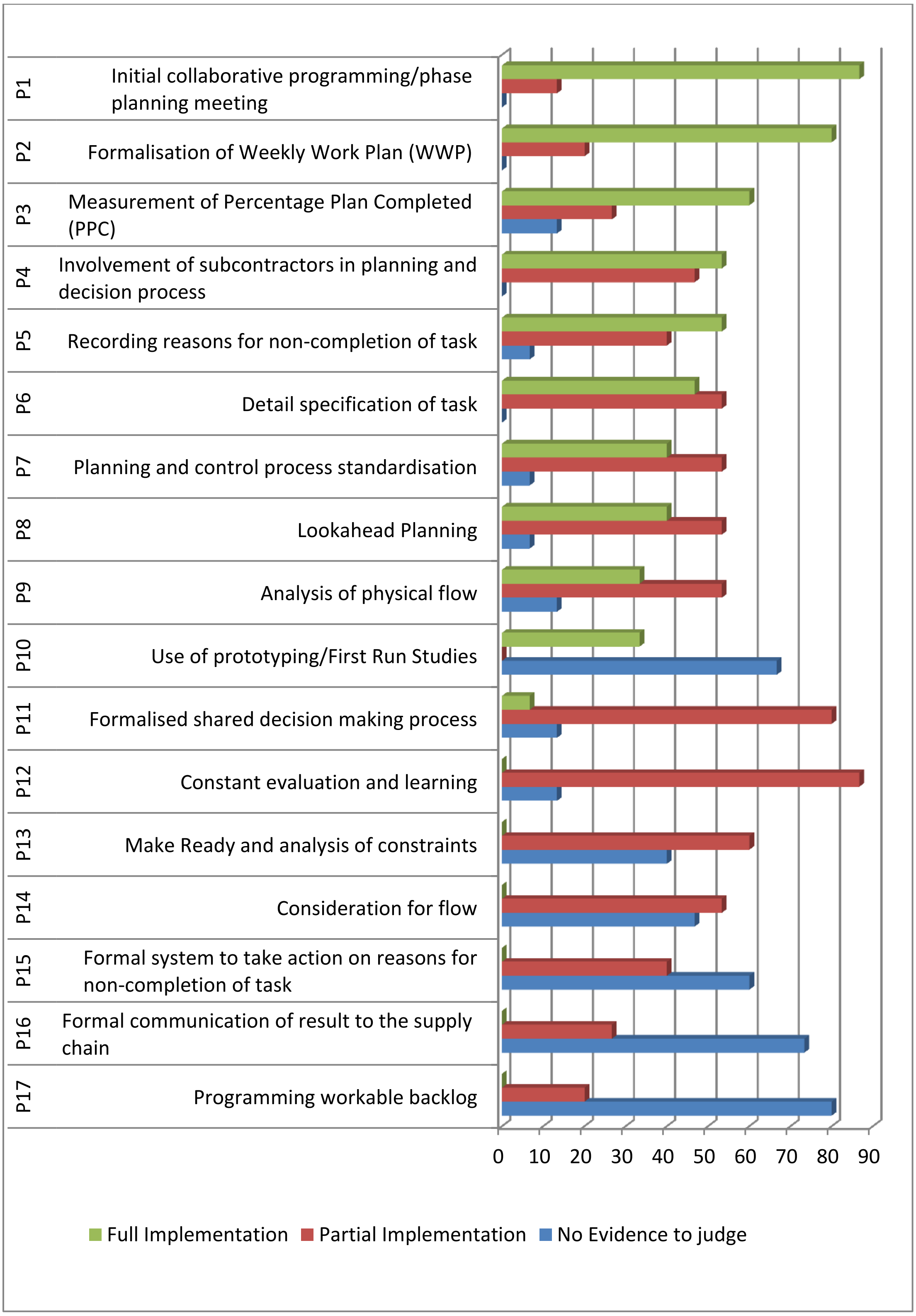

Figure 6.11: Level of Implementation of production planning and control principles on projects observed

These are presented in Figure 6.11 along with the incidences of observed practice. How these practices were identified and the evaluation process has been described in

Chapter Five.In Figure 6.11, it can be seen that only one practice ('*having initial collaborative programming/phase scheduling meetings'*) was fully implemented on 86% of the projects observed, whilst five practices were fully implemented on between 40 – 80% of the projects observed. These are: '*measurement of Percent Plan Complete (PPC) at 60%* '; '*having Weekly Work Plan (WWP) meetings at 80%'*; *'planning and control process standardisation'at 40%; 'involvement of subcontractors' at 60%* and *'look-ahead planning' at 40%. R*ecording of *'reasons for non-completion (RNC) of task'* was fully implemented on 53% of the projects observed.

However, full implementation of *a 'formal system to take action on the RNC of tasks'* practice was not observed on 60% of the projects. The study further revealed that constant evaluation and learning was only partially done on most projects observed, specifically, it was done partially on 86.67% of the projects. Again, this shows that the full benefits of the implementation of LPS principles in UK construction has not been fully harnessed, since no clear mechanism has been put in the place to achieve this on most of the project observed. Learning is a key element of the LPS, it supports continuous improvement both at the project and organisation levels.

The study also identified other practices that were absent on 40% – 80% of the projects observed. These include: '*programming a workable backlog' was not done on 80% of the projects observed; 'Consideration for flow' was not done on 46.67% of the projects; 'use of prototype/first run study' was not done on 66.67% of the project observed; and 'make ready and constraint removal' was not done on 40% of the projects observed .*

Furthermore '*analysis of physical flow'* was done partially on 53.3% of the project observed. Analysis of physical flows focuses on the criteria for tasks to be included in a production plan (such as information, materials, tools, equipment, prior work, people, external conditions). Consideration for flow focuses on what needs to be done when there is a change in the production.

For instance, during the interview, the respondents were asked; what do you do when a task is completed earlier than planned? Some of the respondents said (a) "we do nothing", (b) "we re-plan", (c) we take it as a bonus. Responses (a) and (c) show that there is a lack of consideration for maintaining synchronised work flow. The respondents interviewed here failed to recognise that some changes had occurred in production, which needed to be addressed either by re-planning, increasing, or decreasing resource in order to keep production stable and prevent a knock-on effect.

6.3.4.2 Effectiveness of Production Planning and Control Practices Observed Across Projects in the UK

Table 6.5 indicates the effectiveness of PP&C practices based on the LPS principles as observed on the projects. The study revealed that the most comprehensive implementation observed on any project was 67.7% of the principles. This was observed on only three projects (A06, A07, and B01). No single project implemented all the practices. Previous studies such as Priven and Sacks, (2015), Bernades and Formoso, (2002) also observed lack of implementation of all the principles in an Israeli and Brazilian study respectively. Table 6.5 reveals that the least implementation observed was 29.4% on project (C02). The reason is not far-fetched, as it was observed that PP&C principles were used on the project mainly to repair when things went wrong. The site team could have discontinued with some of the other practices after the initial gain from the collaborative programming or phase planning. Also, the initial process was externally facilitated and it is possible the process was not developed further in the organisation. Again, this shows the need for developing internal capacity to drive the process. For instance, most of the projects with high implementation score were internally facilitated.

The analysis also revealed that these practices can be implemented effectively on any type of project. For instance, 67.7% implementation was observed on highway (A06) and building projects (B01), while 58.8% was observed on a rail project (C01). This shows that the nature of the project does not influence the effectiveness of the LPS principles. It can thus be argued that low scores on some projects could be due to lack of discipline on the part of the team rather than the nature of the project. According to Mossman (2014), the LPS principle is applicable to any system that requires the management of human and physical resources.

However, the use of prototyping/First Run Studies was only observed on building projects. For instance, it was observed on 80% of the building projects, while none was observed on the highway and rail projects. This could be due to the large number of different activities on building projects. The study observed that the prototyping or First run studies was used during the finishing stage of the project.

Table 6.5: Practices observed across projects

Production Planning and control practice	Project code														
	A01	**A02**	**A03**	**A04**	**A05**	**A06**	**A07**	**A08**	**B01**	**B02**	**B03**	**B04**	**B05**	**C01**	**C02**
Initial collaborative programming/phase planning meeting	F	F	F	F	F	F	F	F	F	F	P	F	F	F	P
Formalisation of Weekly Work Plan (WWP)	F	F	P	F	F	F	F	F	F	F	F	P	P	F	F
Measurement of Percentage Plan Completed (PPC)	F	F	F	N	F	F	F	F	F	P	P	F	N	P	P
Planning and control process standardisation	F	F	F	N	F	P	P	F	P	P	P	P	P	F	P
Involvement of subcontractors in planning and decision process	F	P	P	P	P	F	F	P	F	F	F	F	P	F	P
Formalised shared decision making process	P	P	P	P	N	P	P	P	P	P	P	N	P	F	P
Look-ahead Planning	F	P	P	P	P	F	F	F	F	N	P	P	P	F	P
Detail specification of task	F	F	F	P	P	F	F	P	F	P	P	P	F	P	P
Recording reasons for non-completion of task	F	P	F	F	F	F	F	F	F	P	P	P	P	P	N
Formal system to take action on reasons for non-completion of task	N	P	N	N	N	P	P	N	P	N	N	N	P	P	N
Analysis of physical flow	P	F	F	P	P	F	F	N	P	P	P	F	P	P	N
Make Ready and analysis of constraints	P	P	P	N	N	P	P	N	P	N	N	P	P	P	N
Use of prototyping/First Run Studies	N	N	F	N	N	N	N	N	F	F	N	F	F	N	N
Constant evaluation and learning	P	P	P	P	P	P	P	P	P	P	P	N	N	P	P
Formal communication of result to supply chain using visual device	N	N	N	N	N	P	P	N	P	P	N	N	N	N	N
Detail consideration for flow	N	P	P	P	P	N	P	N	N	P	N	P	P	N	N
Programming workable backlog	N	N	P	N	N	P	N	N	N	N	N	N	N	P	N
Score expressed in (%)	**58.8**	**58.8**	**64.7**	**38.2**	**50**	**67.7**	**67.7**	**47.1**	**67.7**	**47.1**	**38.2**	**50**	**47.1**	**58.8**	**29.4**

F - fully implemented =1.0, P- partially implemented= 0.5, N- no evidence of implementation= 0.0

A01- A05= Highways and Infrastructure, B01- B05= Building projects, C01- C02= Rail projects

6.3.5 Mapping of Collaborative Planning Practice in the UK with the Last Planner System

The degree to which the observed practices map across to components of LPS is shown in Figure 6.12.

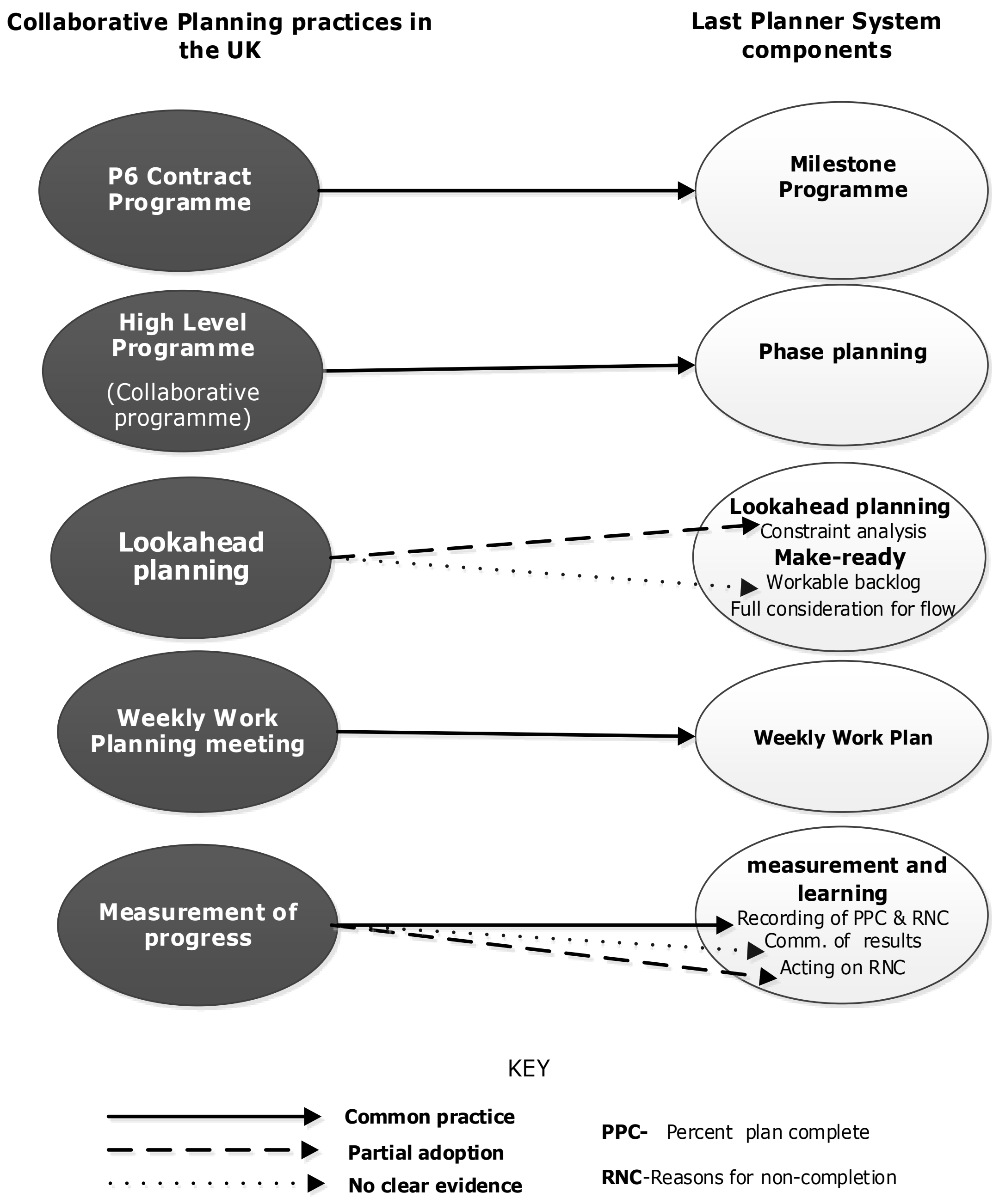

Figure 6.12: Comparing Collaborative Planning in the UK with the Last Planner System Components

The figure shows a strong correlation between the current practice and the LPS at Contract/Milestone programme and the high-level programme/phase planning elements. There is an equally strong relationship at the levels of recording PPC, WWP and RNC. However, WWP was only supplemented with daily huddle meetings on few projects. As observed on the projects, the daily huddle meeting was more of activity reporting rather than an avenue to make needed adjustments to tasks that were slipping off schedule. The depth of application of the more complex attributes contained in the LPS is weak or missing in the CP practice in the UK. Overall, Figure 6.12 shows that there is only partial alignment of current CP practice in the UK to the elements of the LPS on the projects observed.

6.4 Discussion of Findings on Collaborative Planning Practice Observed with LPS Principles

All the interviewees felt the CP approach offered benefit. In general, not formally implementing the full range of components within the LPS means maximum benefit is not being realised. The comparison of current practice of CP with the LPS components in Figure 6.12 partially aligns with practices elsewhere in the world. Previous studies such as (Daniel *et al.,* 2015; Sterzi *et al.*, 2007; Bernardes, and Formoso, 2002) show the measurement of PPC, WWP meetings (short-term planning) and collaborative programming/phase scheduling to be among the elements of the LPS most consistently reported as implemented in previous studies published by the IGLC[12]. However, the practices varied in detail from one project to another. While CP was done with full involvement of the supply chains on some projects, the supply chains were only partially involved on other projects as revealed by the interview.

For instance, a senior planner interviewed on **MC03** stated that: "*We only involve the principal subcontractors in the collaborative programming, we plan and give the programme to the smaller subcontractors".* This implies that not all the supply chains are involved in developing the high-level collaborative programme. Furthermore, gauging the current CP practice with the LPS prescriptions such as planning backwards, defining plan scope by the players involved, narrowing scope when needed to untie knots, building floats into plans and allocating them to risky and critical tasks, (Ballard, 2000), reveals they only occurred partly on some of the projects observed. CP as practiced tends to only provide the platform for

[12] International Group for Lean Construction www.iglc.net

stakeholders to have conversations on the proposed schedule and is deficient in the process rigor as prescribed in the LPS. This is due to too much focus on the execution of tasks and the absence of robust supporting mechanisms to enable flow in the approach.

Clearly, a number of key LPS elements are missing in the present approach. The most apparent of these is the lack of formal action on the RNC recorded. For example, an interviewee stated that *"We used to log the reason for non-completion of task into an excel sheet but we have not developed any formal approach for analysing this data"* **(MC07)**. According to Ballard, (2000) the purpose of recording RNC in the LPS is to enable the team collectively act on identified issues and to prevent future occurrence, which enhances learning. It can be argued that if no formal actions are taken to address the RNC recorded, the recording itself becomes a waste of time and resources. Typical action on RNC should include at least a formal root cause analysis. That no collaborative actions (either formally or informally) are taken on the reason for non-completion recorded removes the opportunity to generate innovation, provide learning, enable action and improve collaboration among the project stakeholders.

Other missing elements are the development of a workable backlog (Plan B) and the consideration for flow, which forms part of the make-ready process in the LPS. The lack of consideration and analysis of flow was evident on most of the projects evaluated. For instance, during the interview, one of the respondents was asked; *"what action do you take when an action is completed earlier than planned?"* The response is "*we don't do anything; we take it as a bonus*" **(MC01)**. This shows a lack of understanding of flow and the importance of load levelling and stability in the production process once the phase plan is agreed. Unplanned early completion is most likely to be a benefit for a contractor who is only managing the sub-contract packages but may be benefit neutral or detrimental to subcontractors as it increases uncertainty across their multi-project environment. When the focus of the production system is shifted from the management of workflow to the pursuit of cost and/or time reduction, the entire production system could collapse (Conte *et al.,* 1998).

It can be argued that the prevailing practice of CP focuses more on time reduction and programme reduction than achieving a smooth workflow across the project. Finishing early is most likely to be the result of planning too little work in the first place or from the removal of a constraint not identified in the make-ready process which permitted work that did not meet the four criteria (sound, sized, sequenced, and detailed) into the WWP. It is clear then that a reduced make-ready process that sends work to the work phase (weekly or daily) without meeting the four criteria of production planning results in reduced productivity and associated programme and margin slippage (Court *et al.*, 2009). It is important to note that PPC is a predictor of productivity because of the 4 requirements for a committable task; i.e., sound, sequenced, sized, and well defined (see Liu and Ballard, 2008, Ballard, 1999). However, PPC can be 100% and the project still behind schedule because work is not being made ready in the right sequence and rate (Hamzeh, *et al.*, 2012).

Related to the make-ready process is the look-ahead process. Observation of this also indicated some limitation in practice, notably, a look-ahead window of two weeks was too short to allow sound assignments to be developed. Additionally, whilst metrics such as PPC were measured and recorded, these metrics were not formally communicated to the supply chain on some of the projects observed. For instance, one of the respondents stated that;

> "*We do not publish PPC and RNC to the subcontractors, if I am showing this to the subcontractors, I am going too low. We only make this available to the senior management team. Some of the subcontractors get confrontational and defensive about this, especially if the work was delayed by the main contractors"* **(MC08)**.

This is another indication of a limit to the scale of adoption of collaborative practices despite the use of the term "CP" to describe the approach. The safeguarding practices observed appear to be deeply embedded in the prevailing practice and serve as a significant barrier to collaboration (Pasquire *et al.*, 2015)

6.5 Chapter Summary

This chapter presented empirical evidence on the current understanding and application of CP and LPS in the UK construction industry. It determined how the current practice of CP for delivering construction projects in the UK align with advocated principles of the LPS. The chapter demonstrated that the term "Last Planner" and "Collaborative Planning" are used interchangeably to describe the application of production planning and control principles based on the LPS by construction practitioners in the UK. The chapter showed that there is variation in the current understanding of production planning and control principles based on the LPS among the practitioners interviewed.

The chapter identified the current industrial practitioners' perception on LPS and CP, drivers, success factors, benefits and barriers in implementing LPS/CP in the UK construction industry. The chapter showed that the drivers, benefits, barriers, and successful factors for implementing LPS/CP observed in the UK are not entirely different from what had been reported in previous studies elsewhere. However, cultural issues were seen as a major barrier while the push from public sector clients was among the major drivers for implementing LPS/CP in the UK. It also showed that modelling and prioritising the benefits of LPS implementation could support the integration of the stakeholders in the LPS implementation process.

The chapter established that the currents practice of CP as observed in the major sectors of the UK construction industry aligned with some of the generally advocated principles of the LPS acknowledged in the literature; specifically, the high level collaborative programming, WWP meetings, and the measurement of PPC and the charting RNC. However, the chapter revealed that the current practice of CP in the UK has not explored all components of the LPS. Overall, the chapter showed that there is only partial alignment of current CP practice in the UK to the elements of the LPS on the projects observed. This situation inhibits the extent of benefit that can be realised and even the advancement of industry performance.

The chapter revealed the components of the LPS missing in the current practice. The components not used include look-ahead planning; aspects of the make-ready process such as consideration for workflow and developing a workable backlog; and acting on reasons for non-completion of tasks among others. Furthermore, the absence of these elements indicates a poor understanding of construction as a production process and the importance of flow in successful project delivery and benefit realisation. The next chapter (Chapter Seven) presents and discusses the findings from the three case studies.

CHAPTER SEVEN: MULTIPLE CASE STUDY DATA ANALYSIS, CROSS CASE-COMPARISON AND DISCUSSION

7.1 Introduction

The previous chapter (Chapter Six) presented and discussed the findings from the exploratory interviews and the structured observation. This chapter focuses on the three multiple case studies conducted. The case study investigates the nature of support required for Last Planner System/Collaborative Planning (LPS/CP) implementation in the UK construction industry. The chapter is structured thus; sections 7.1, 7.2 and 7.3 present the findings from the three individual case study projects, while section 7.4 presents the cross case-comparison and discussion. Each case study identifies LPS/CP practice, the impacts of procurement practice on its implementation, the support for rapid and successful LPS/CP implementation, and its impacts on construction process improvement. Some of the findings were also triangulated with the findings in stage 3 to authenticate the results from each stage.The chapter closes with the chapter summary in section 7.5 which brings section 7.1 to 7.4 together.

7.2 Stage 4: Multiple Case Studies Overview

Three case study projects were conducted; two on highways infrastructure projects and one on a building project. In each case, vital information such as the description of the case study project and the demographic data on the research participants are presented. This was done to enable the researcher to discuss the result in the context of the real life project. Evidence was obtained through four sources, namely: documents analysis, unstructured observation, semi-structured interviews, and structured survey. The main reason for selecting multiple cases study projects has already been discussed in Chapter Five.

7.3 Case Study Project One (CSP01): Highways and Infrastructure

a. Description of Case Study Project One

The case study project one (CSP01) is located in the North of Yorkshire, England. It is a highway infrastructure project which is an upgrade to replace a dual carriageway with a three lane motorway. The full description of the project attribute is presented Table 7.1. It also includes the construction of associated facilities such as bridges among others. Other aims of the project include the provision of a new local access road alongside the new motorway, and provision of access to the strategic road network so as to improve safety and journey time reliability. The project comprises of different facets and many stakeholders, which requires coordination and management. This shows the complexity of the project. For effective coordination and management of the project; the project was divided into three sections: the north, the south, and the central section. All the sections of the project were managed using the LPS/CP with three different supervisors and one central coordinator.

Table 7.1: CSPO1 Project Attributes

Project Attributes	Observed attributes on CSP01
Nature of project	Highway and Infrastructure
Location of project	North of Yorkshire, England
Nature of work	Upgrade to replace existing dual carriage way with three new lane
Type of client	Public client
Mode of contractor selection	Framework agreement and ECI
Proposed project duration	30 months
Stage of the project at the end of the case study	57% completion
Procurement arrangement	D&B, joint venture
Contract sum	£380 million
Current number of subcontractors on site	10
Point of application of LPS/CP principles	Construction
LPS/CP facilitation process	Internally facilitated

The two main contractors on the project were into a joint venture (JV), the two contractors are among the UK top 10 contractors by the value of work won in 2015 (Construction news, 2015). Both contractors have a long history and expertise in the delivery of construction and engineering projects. However, one of the contractors has a strong record in the delivery of mega highways infrastructure projects with sustainable approaches. The JV was formed to benefit from this, due to the scale and critical nature of the project.

Both contractors claimed to have used LPS/CP principles on their previous projects. Also, the use of LPS/CP principles was mandated by the client on this project. Design and Build (D&B) and Early Contractor Involvement (ECI) were used in procuring the project. Table 7.1 presents the project characteristics. The table shows that CSP01 project duration is long enough to capture LPS/CP practices on the project. The researcher observed CSP01 over a period of 10 months, which started at the construction phase. This enabled the study to gain insight into the nature of support to be put in place for effective implementation of the LPS. Project status indicated that CSP01 was at 57% completion when the researcher left the site, this shows that LPS/CP practice on this project could have matured to a level. Thus, a pattern could be identified from the case study findings. Also, since the two main contractors in the joint venture claimed to have used LPS/CP principles on their previous projects, their previous experience could be brought to bear on this project.

b. Demographic Information of Respondents on CSP01

Table 7.2 indicates the respondents interviewed on CSP01. These include; 5 senior managers (SM01-05); 2 middle managers (MM01-02); 2 operation manager (OM01-02) and 2 subcontractors (SC01-02).

The Table reveals that the respondents interviewed on CSP01 cut across the major stakeholders that are directly involved in making decisions on production planning on the project. This suggests a balanced view could be received from the interview response. All respondents have between 1 and 5 years' experience in LPS/CP practice. The table reveals that only few subcontractors participated in the interview. The low number of subcontractors interviewed is largely due to their unavailability for interview, as they complained of lack of time to talk to the researcher and the variableness of their stay on site due to the nature of their work. Furthermore, the analysis reveals that 82% of the respondents on CSP01 have over 10 years' experience in construction, however only 18% have above 4 years' experience in LPS/CP. This could imply that the use of collaborative approach in construction planning was less practiced in scheduling of work in the past.

Table 7.2: Description of respondents interviewed CSP01

S/NO	**Respondent code**	**Role categorisation on the project**	**Specific role in organisation**	**Years of exp. in LPS/CP**	**Year of Exp. in const.**
1	CSP01SM01	Senior manager	Planning manager	2	10
2	CSP01SM02	Senior manager	Excellence manager	5	18
3	CSP01SM03	Senior manager	Construction manager	5	20
4	CSP01SM04	Senior manager	Senior planner	1	16
5	CSP01SM05	Senior manager	Senior engineer	1	9
6	CSP01MM01	Middle manager	Section engineer	3	10
7	CSP01MM02	Middle manager	Section engineer	1	20
8	CSP01OM01	Operational manager	Site Agent	1	14
9	CSP010M02	Operation manager	Planner	1	3
10	CSP01SC01	Subcontractor	Director	3	15
11	CSP01SC02	Subcontractor	Project manager	2	12

7.3.1 Last Planner/Collaborative Planning Practice on CSP01

The data on LPS/CP practice on CSP01 were obtained via documents analysis, unstructured observation, and interviews. The practices observed are discussed under the following emerging themes: (1) application of LPS/CP principles (2) pre-construction practice (3) Nature of LPS/CP meetings and (4) Percent Plan Complete (PPC) and reason for non-completion (RNC) practice.

7.3.1.1 Application of Last Planner/Collaborative Planning on CSP01

The application of LPS/CP on CSP01 started with the first activity on the construction programme on the project and its use on the project was agreed by the stakeholders on the project. A workshop was held with stakeholders to reiterate this before the commencement of construction activities on site. The three sections (North, South, and Central) of CSP01 were independently managed with LPS/CP principles. However, the process was centrally coordinated by the Senior Excellence Operational Manager and an Assistant Excellence Operational Manger with the support of the planners, section engineers, and construction managers. This implies that the central coordinators are not required to always be present at all the sessions as the teams are capable of facilitating the process also. However, it was observed that the level of discipline in applying the LPS/CP principles varied across the three sections.

For instance, the teams at the North and Central sections were committed to LPS/CP process as the researcher was opportune to be in several sessions. This was not the case in the south section, as there seemed to be a tussle among senior project team members in the section, thus, most of the LPS/CP principles were not followed. It is worth noting that the researcher was not even provided the opportunity to attend any LPS/CP session at the south section throughout the case study. Again, this shows that even when LPS/CP is mandated on a project, if the traditional mind-set is not removed, the process could still be faced with challenges. Some of the conflicting LPS/CP practices on south section include; not publishing of constraint log, lack of detailed plan with sticky-note on board, PPC not published, and no constraint analysis. However, the LPS/CP process in the south section of CSP01 was later reviewed and repositioned. On all the project sections, the collaborative programme/phase planning was developed from the master programme. It is worth mentioning that the two contractors in the JV operated as a single organisation. The implementation of the LPS/CP was a project based initiated driven by the JV partners and the client.

7.3.1.2 Pre-construction Practice

The study revealed that some collaborative processes were applied on CSP01 at the pre-construction phase. These include the collaborative involvement of the key stakeholders in the early stage and the engagement of the main contractor in the development of the design. One SM stated that:

"At the early stage or phase 1 of the project, we did a lot of collaborative meetings with the stakeholders such as the land management, client, designers, and the main contractors" **[CSP01SM01, Planning manager]**

This shows that the construction team members were involved in the collaborative meetings at the pre-construction phase. It can be argued that the approach adopted here could have also been favoured by the procurement route used. The planning manager further explained that: *"we did this to enable us hit the date, because our* *goal is to accelerate the scheme. It is one of the fastest scheme and the collaborative meetings helps".*

7.3.1.3 Nature of Last Planner/Collaborative Planning Meeting on CSP01

Various meetings were held to support the implementation of LPS/CP principles on CSP01. These included; monthly project brief meeting, central senior managers' look-ahead planning meeting, and weekly production planning meeting. During the monthly project brief meeting, the project director, section managers, and the health and safety manager made presentations on the status of the project in terms of time, cost, quality, and safety. The central senior management look-ahead planning meeting mostly involves the construction managers where strategic decisions on the project are made.

It is worth noting that the senior management look-ahead meeting done here was not the same with the look-ahead planning as advocated in the LPS (Ballard, 2000), as it did not involve any form of make-ready process. In addition to this, weekly production planning was done with the subcontractors, construction managers, and work package managers among others. Also, a six week look-ahead, some constraints, and the make-ready process were observed in the North and Central sections. However, there was less discipline and commitment to the constraints and make-ready process in some of the process observed. For instance, during one of the sessions, the constraints board was not logged and on another occasion, no one was assigned to address the identified constraint.

7.3.1.4 Percentage Plan Complete and Reason for Non-Completion Practice

This section presents the findings on LPS/CP practice, from document analysis and observation. The study reveals that PPC and RNC were recorded on CSP01. Figure 7.1 shows a sample of PPC chart on CSP01. Figure 7.1 shows that the average PPC on CSP01 for period consider here (10 weeks) was 72.29%, however, there seems to be a lot of variableness in the weekly PPC as shown in the figure. For instance, 0% was recorded in one of the weeks. When the planner was asked to explain the reason for this, he stated that: "*It is due to overestimation of work by those doing the work. Some of the subcontractors make promises with little resource on site"* [**CSP01SM04, Senior Planner**].

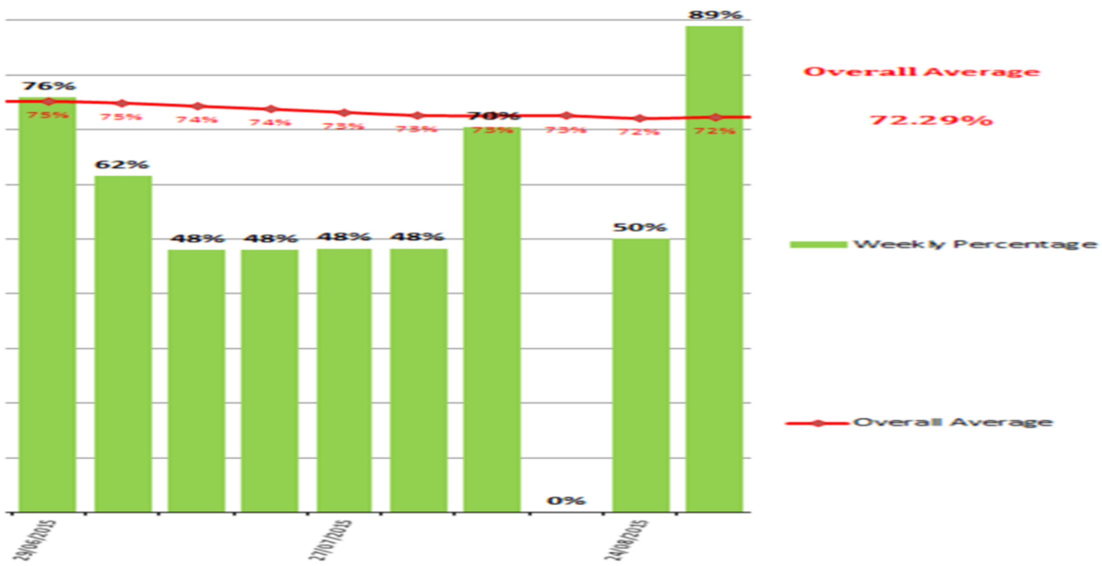

Figure 7.1: Average PPC on CSP01 (A sample of document analysed)

Source: CSP01 production planning document file (used with permission)

It could be argued that the lack of make-ready process and clear removal of constraints from the planned activities was also a contributory factor to this occurrence. Additionally, the statement by the senior planner further shows the importance of honesty and truth in making reliable promises.

The reasons for non-completion (RNC) were also published on CSP01 as shown in Figure 7.2. However, it seems not much was being done with it. For instance, the planning manager stated that "*we record RNC but I don't think the guys do anything with it*" **[CSP01SM01, Senior Manager].** The figure shows previous activity not complete and under estimation as some of the causes of RNC on CSP01. This could mean that the make-ready process was insufficiently done.

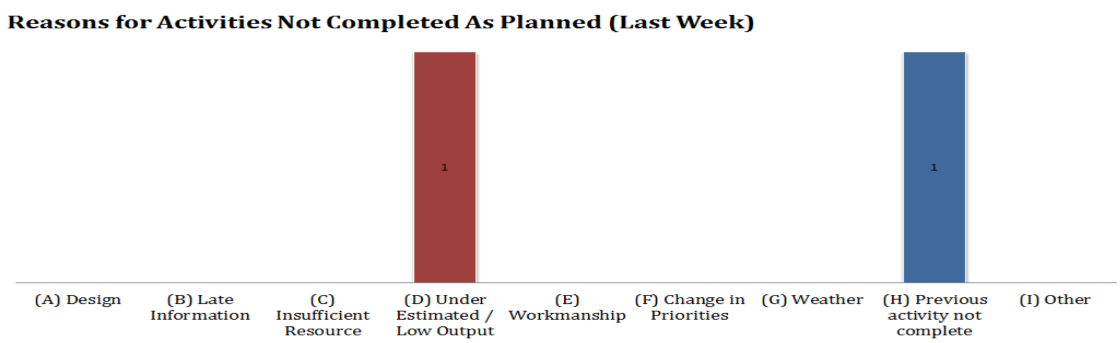

Figure 7.2: Reason for non-completion of activities on CSP01

Source: CSP01 production planning document file (used with permission)

7.3.2 Support required for LPS/CP Implementation as Observed on CSP01

Figure 7.3 reveals the emerging themes and sub-themes from the interview data analysis on the support required for the successful implementation of LPS principles. Figure 7.3 was generated using Nvivo 10 model tool. Nvivo is a qualitative data analysis software used in analysing the data at this stage. The emerging themes are categorised into three; (1) support required at the organisational level (2) support required at the project level and (3) external support.

7.3.2.1 Process and Support required at the Organisational Level.

The analysis of the interview result reveals four key factors required from the organisation for smooth implementation of LPS/CP. Some of these key factors as shown in Figure 7.3 are discussed below.

a. Provision of Training

Some of the respondents suggested that the organisation must be committed to training of its employees on the new approach. Some of the respondents on CSP01 stated that:

> "*There is need to educate others on the project on LPS/CP and invite other site representative to be involved in the process"* [**CSP01MM01, Section Engineer].** Also, a senior manager (SM) stated that "*for an organisation that is venturing into it, there is need to provide training and demonstration of tangible benefits from previous implementation"* [**CSP01SM01, Planning Manager**]

This shows that at the organisational level, procedure should be put in place to support training and facilitate the practice of LPS/CP across different business units

b. Inclusion of Last Planner/Collaborative Planning Practice in contract

Furthermore, some of the respondents were of the view that the process should be part of the company policy for delivering its business and could include mandating it in the contract with the supply chain. Some of the respondents stated that:

> *"There should be a point where it has to be mandated and written into the contract and benefits should be shared"* **[CSP01SM02, Excellence Manager]**.*"Make it a company policy"* [**CSP01MM01, Section Engineer].**

The subcontractors on CSP01 are also strongly in support of the inclusion of LPS/CP practice in the contract.

c. Continuous Support from the Management

Full management support and the use of collaborative form of procurement were also viewed as necessary at the organisational level. This entails making it a company policy. A construction manager stated that:

> "*The project director is very proactive on the application of collaboration principles on this project, the full support of the management is key to bringing the subcontractor into the session"* [**CSP01SM03, Construction Manager**]

Again, this shows that the management has an important role to play for the successful implementation of LPS/CP principles on a project.

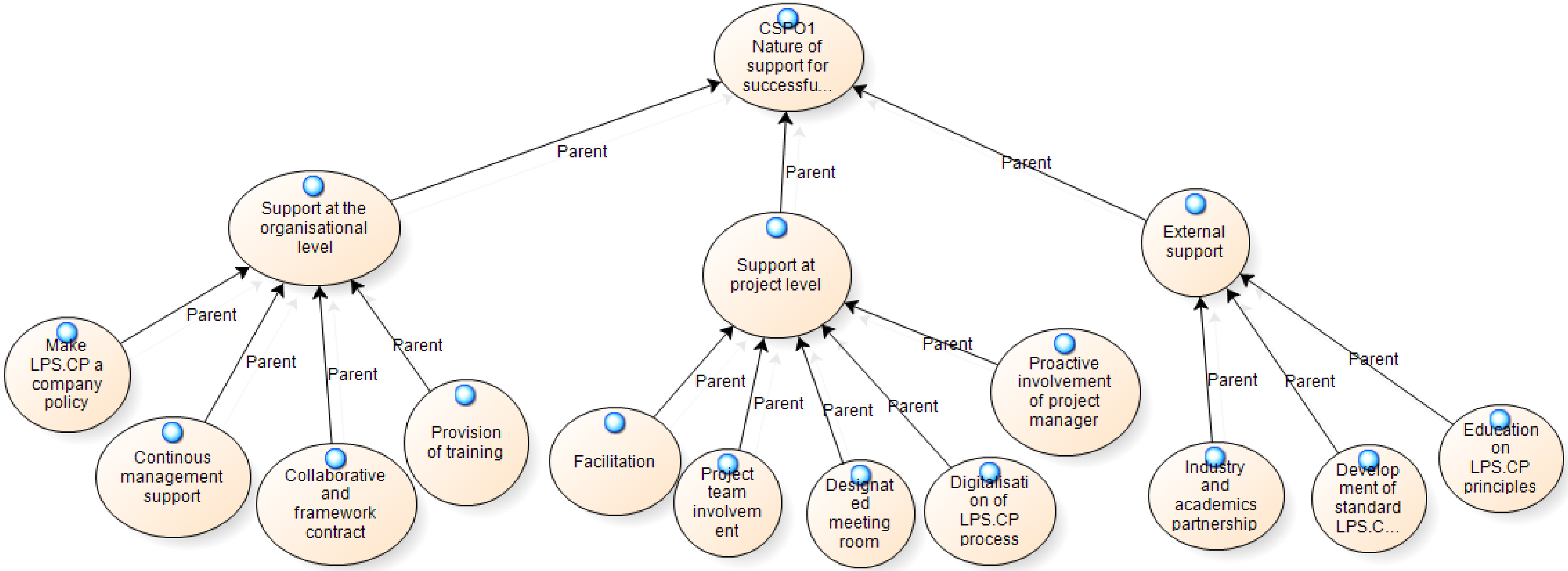

Figure 7.3: Support for successful implementation of Last Planner/Collaborative Planning

7.3.2.2 Process and Support required at the Project Level

The analysis of the interviews revealed some of the support required at the project level as observed on CSP01. Five key supports were identified. These include; (1) Appointment of facilitator, (2) Involvement of the team required, (3) Digitalisation of Post-It Note, (4) Provision of LPS/CP room on site, and (5) Proactive involvement of the construction manager. These factors are now discussed below.

a. Appointment of a Facilitator and Involvement of Team Members Required

Some of respondents were of the view that a facilitator is an essential support required at the project level. For instance, one of the middle managers stated that: "*A facilitator is needed to coordinate the process for the initial start, this is an early stage support"* **[CSP01MM02, Section Engineer].** This is because the process cannot really progress if it is not duly facilitated, as observed in the South section of this project. However, some of the respondents were of the view that facilitators should be limited to the early stage only. This is with the belief that the team could carry on with the process after the initial facilitation. One of the respondents argued that: *My view is that initially, it needs facilitation, but as the process goes, the team should do it themselves* **[CSP01SM01, Planning Manager].** It is worth noting that this respondent has only two years' experience in LPS/CP practice.

b. Digitalisation of the use of Post-It® Notes

Some of the respondents suggested that digitising the sticky-notes and collaborative programming board could improve the level of interaction among the men on site. Thus, it could reduce non-value adding activities by the men on site which may arise from movements. The Planning Manager stated that: "*We are planning to use 'touch screen' instead of post-it note. The post-it note is stock in the room and cannot be distributed",* **CSP01SM01, Planning Manager].**

Digitalisation of the LPS/CP could support the process, however, this cannot in any way replace the face to face meeting which is essential in developing the programme in the first instance. Previous studies have shown that face-to-face discussion is the most efficient communication channel in construction (Murray *et al.*, 2000; Gorse *et al.*, 1999). However, the digitalisation of the LPS process has shown to support the implementation on projects (Ghafari 2015; Couch, 2015). For instance, Cough (2015), observed that '*Touch Screen Plan',* (a software that has been integrated with the LPS), saves time in making changes to the handwritten sticky notes and provides real time information to the team on promises and commitments made.

c. Provision of Production Planning and Control Centre on Site

The respondents were of the view that a designated room for LPS/CP meetings should be provided on site. One of the subcontractors stated that: *"Allow for a suitable rooms/facility on site for CP meetings and session"* [**CSP01SC02, Project Manager]**. This is essential as such room/facility could further provide information visually to other members of the team who were unable to participate in meetings in real time. Also, visiting the room would give everyone an idea of project activities on site.

However, setting the room outside the project site could reduce such benefits and could contribute to non-value adding activities. This is because it would require site workers travelling to the head office to view the board. But siting the production planning and control centre on site would create a feeling of belonging to the site team.

d. Proactive Involvement of Construction Manager

The active involvement of the construction manager in the LPS/CP meetings was also seen as an essential support required at the project level for LPS/CP implementation on CSP01. The active involvement of the construction or project manager at the project level would help the project team to see the process as the company process of delivering its business. Practically, this entails attending and contributing in production planning meetings by the project manager. According to McConaughy and Shirkey, (2013) and Hamzeh and Bergstrom, (2010), when a process on a project is viewed as external or ad hoc, there would be less commitment from the team.

7.3.2.3 External Process Support Required

The external support and process referred to here are those supports needed that could be coming from outside the organisation and the project environment. Two of these supports were identified by the respondents on CSP01. These are: (1) Development of standard metrics for LPS/CP implementation (2) Industry and academic partnership.

a. Development of LPS/CP Principle Standard/ Metrics

LPS/CP implementation process standardisation was identified as an external support and process required for successful LPS/CP implementation. For instance, a Senior Manager stated that: "*There is need to bring out CP principle implementation metrics"* **[CSP01SM04, Senior Planner].**

The above statement shows that there is lack of consistency in the current application of CP/LPS practiced on projects. Also, this may be due to ignorance, since the LPS has standard principles and metrics (Ballard, 2000). This indicates that more awareness and support is still required for effective implementation.

b. Industry and Academic Partnership

Some of the respondents on CSP01 observed that a close partnership between the construction companies and the academic institution could further support the LPS/CP implementation in the industry. One of the managers suggested that:

> *"There is a need for more alliance between the academia and the industry. More articulation and pro-activeness in communicating improvement and findings to industry. More emphasis should be placed on the correlation between the industry and the institution"* **[CSP01SM02, Excellence Manager].**

7.3.3 Procurement and LPS/CP on CSP01

Two broad themes emerged from LPS/CP practice in relation to the procurement approach used on CSP01. These are; the procurement practice and the impact of the procurement practice on LPS/CP implementation on CSP01.

7.3.3.1 Procurement Practice Observed on CSP01

The two main contractors on the project were into a joint venture and the researcher was made to understand that the team is viewed as a single entity. This implies that all members of staff on the project have to ignore their original company culture or identity in performing their responsibility on the project and create a shared culture. One of the strategies adopted to reduce parent company culture and integration of the team was; the recruitment of some staff directly on the JV, hence such staff only had one identity at the time. According to Smith,

(1994) for a joint venture to work successfully, there is a need to make provision for cultural compatibility, shared ownership, and joint control.

The other factor that also supported the joint venture on CSP01 was the fact that the two contractors had been in a similar joint venture in the past. However, every project is unique and the team on the previous could be different from the current team. Also, the subcontractors were into a framework agreement with the joint venture. The project was procured using design and build (D&B) and early contractor involvement (ECI) approach. This integrated approach to project delivery contributed to the level of collaborative working experienced on CSP01. Dave *et al.*, (2015b) pointed out that an integrated project delivery process breaks organisational boundaries and aligns the goals of the parties in the process to achieve the project objectives. This is largely supported by lean principles (Howell, 2013).

However, this does not sum it all as there were issues with the design not meeting up with the construction, in term of time. This was because the design was only at 50% completion when construction commenced on site. Thus, much pressure was on the design team as the construction programme was being accelerated. The planning manager stated that:

> "*The design phase has a lot of issues, we spent a lot of time in design. The problem is not in the quality of the design, but the time the design needs to be complete. The key issue is the need for alignment between design and construction. It was more a just-in-time approach that was used for design and construction"* **[CSP01SM01, Planning Manager]**.

Apparently, since design was only at 50% completion before construction, this could be expected.. More so since the construction programme was accelerated as a result of the use of LPS/CP principles. However, this shows the need to properly and carefully plan on how design and construction would align on a D&B project, especially when there is an understanding that the construction programme could be accelerated.

7.3.3.2 Impact of Procurement Practice on LPS/CP on CSP01

The study reveals three impacts of procurement on LPS/CP practice on CSP01. These are: (1) Opportunity for buildability/constructability review (2) Allowing for early stakeholders involvement and (3) Management of design and design team. Some of these are discussed below.

a. Opportunity for Buildability/Constructability Review

The study revealed that using the D&B and ECI approach on CSP01 allowed the construction team and the design team to engage in constructability review. One of the respondents stated that:

> *"Using the ECI, all the designs are reviewed by the construction team to get things out early. We get value out of the process since we make all the decisions together"* **[CSP01SM03, Construction Manager]**

It can be argued that the benefit coming from the process is not only in getting the design out early but also the value created as a result of the input from the construction team. According to Othman, (2011) design constructability/buildability review improves the performance of the constructed facility by reducing cost, improving quality of the end product and accelerating completion time. Traditionally, design tends to be separated from construction which also contributes to the poor performance of the industry (CIOB Report, 2010). However, lean construction principles such as the LPS encourage collaboration from design to delivery, thus improving the final product (Howell, 2013; Koskela, *et al.,* 1997).

b. Management of Design and the Design Team

The study also observed that the project managers were in charge of the design process and the design team. This is largely due to the fact that the designers are part of the joint venture and they all work to achieve the overall project goal. The planning manager argued that:

> *"We will not be able to do this in a traditional approach! We do have everything ourselves. We are in a better position to manage the design and also manage the design team"* **[CSP01SM01, Planning Manager]**.

In addition, it was observed that the designers, the contractors, and subcontractors shared the same office. This increased the level of conversation between the design and construction teams. The design team was also involved in the key production planning meetings. This contributed to the quick feedback the construction team received from the design team when required.

However, it could be argued that the contract alone cannot make the team on the project to collaborate, rather, it is the paradigm shift from the traditional mind-set among the project team. Ballard and Howell, (2005) observed that on D&B projects where the traditional mind-set and practice dominate, design could still be separated from construction. This suggests that the conversations that occurred during the various LPS/CP meetings on CSP01 contributed to the development of collaborative working practice on the project. The procurement approach is more of a platform for .collaborative working practice to develop.

7.3.4 Impact of LPS/CP Practice on Construction Process Improvement on CSP01

The evidence on the impact of LPS/CP practice on construction process improvement (CPI) was sourced through the semi-structured interviews and structured survey. Both the interviews and survey were used for methodological triangulation. The structured survey enabled the study to obtain objective data on the impact and to triangulate the findings from the interviews. Figure 7.4 reveals the findings from the semi-structured interview as generated and exported from Nvivo 10 using “Model tool”. While Figure 7.5 presents the survey results analysed using Statistical Package for Social Science 21 (SPSS 21). The findings presented in Figures 7.4 and 7.5 on the impacts of LPS/CP on construction process improvement are discussed concurrently in the next section.

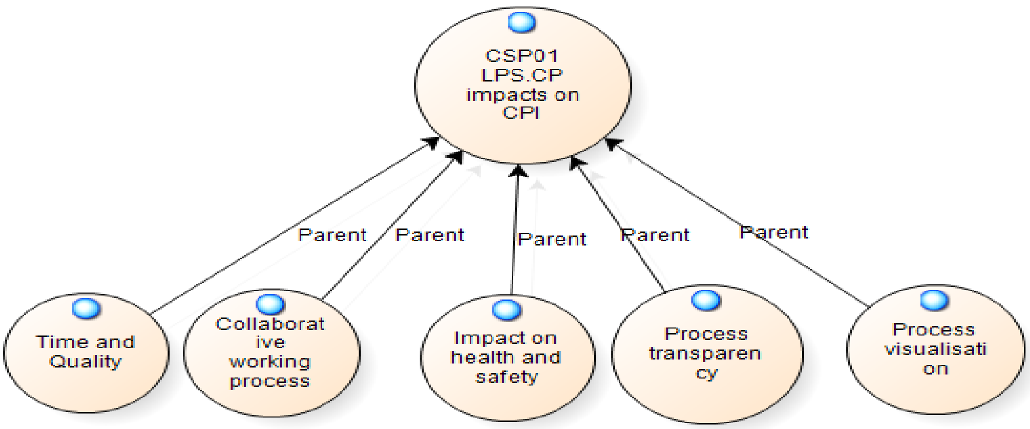

Figure 7.4: Impacts of LPS/CP on CPI observed on CSP01 (interview results)

7.3.4.1 Impact on Time

The analysis in Figure 7.5 reveals that 100% of the respondents on CSP01 agreed to have gained more time from the use of LPS/CP principles on the project. This was further confirmed by the construction manager from the interview:

> *"It has positive impact on the project, things are done on time on the project, and we work better because we plan ahead"* [**CSP01SM03, Construction Manager]**.

The result further showed that 85.7% of the respondents indicated that the LPS/CP implementation did not slow down the progress of work on CSP01

7.3.4.2 Collaborative Working Practice, Communication, and Process Transparency

Figure 7.5 reveals that 100% of the respondents agree that their collaborative working practice has improved for better on the project. This could have occurred as a result of improvement in communication among the project stakeholders which the LPS principles support. For instance, 57.1% of the respondents strongly agreed that the implementation of LPS/CP had improved the level of communication among the stakeholders on the project. This was further confirmed in the interview responses: Some of the respondents stated that*:*

> *It helps us to bring the people together to impact on their action, people like to remain in silo in their areas. This helps to bring them together. It helps improve communication which influences the process* **[CSP01SM01, Planning Manager]**. "*It gets everyone at the site level involved in the delivery process"* **[CSP01SM05, Senior Engineer]**

This shows the LPS/CP implementation supports collaborative communication and the holistic involvement of stakeholders in the decision making process. For example, the survey revealed that 100% of the respondents had good understanding of the project goal as a result of their involvement in the LPS/CP meetings. This shows the importance of engagement and involvement in developing common understanding of project activity and objectives. According to Pasquire, (2012) developing a common understanding of the project goals drives out unnecessary work and keeps the team productive. This was further confirmed with this statement

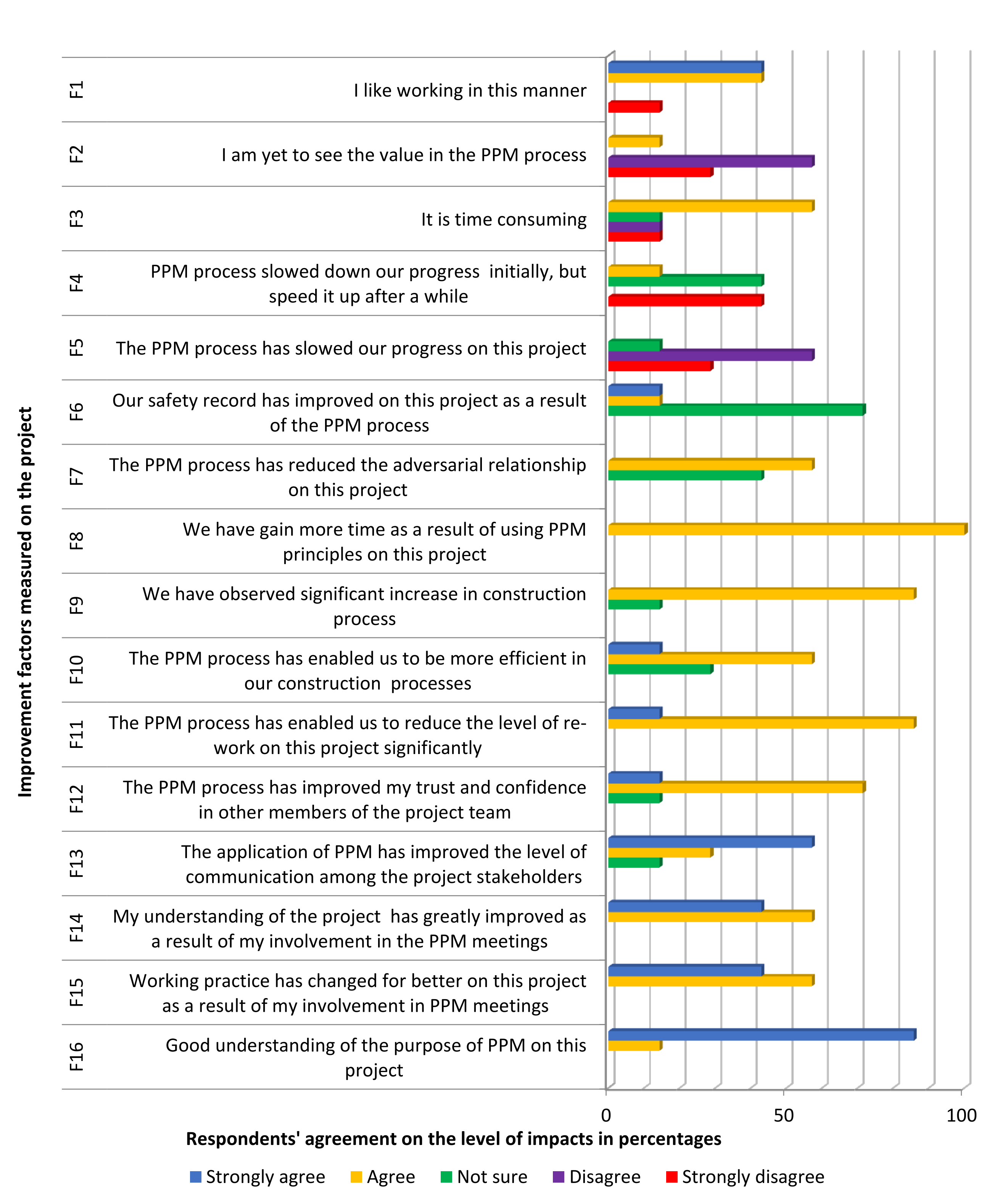

Figure 7.5: Last Planner/Collaborative planning impacts on construction process improvement on CSP01

by the planning manager: "*It helps everyone to understand what is required, it keeps everyone on the same page".* This shows that the LPS/CP process supports transparency**.**

7.3.4.3 Impact on Re-work, Safety, and General Process Improvement

The analysis in Figure 7.5 reveals that 85.7% of respondents believe that the LPS/CP process significantly reduced the level of re-work on the project. Practices such as buildability design review, collaborative programming/phase planning, and look-ahead planning meetings among others could have contributed to this. From the study, 57.1% of the respondents agreed that the LPS/CP process enabled the team to be more efficient in the construction process. This is because the LPS/CP process supports transparency and visualisation of processes on the project. During the interview, one of the respondents stated that:

> *"The collaborative programming session using Post-It Notes help us to put our thought on the wall, which makes us to see the difference in what works*" **[CSP01SM01, Planning Manager]**.

In term of safety, 71.4% of the respondents claimed not to be sure if the safety record had improved as a result of the LPS/CP process on the project while 28.6% agreed it had. This could mean that majority of the respondents have not really recognised the impact of the LPS/CP processes on safety performance on the project. For instance, the safety record data board on CSP01 indicated that 1.5 million hours of work had been done without accident. Also, during the interview, one respondent stated that:

> "*Since the CP process allows one to determine what to be done, it makes the process clear. It helps coordination, thus, it helps with health and safety"* **[CSP01MM02, Section Engineer].**

Furthermore, majority of the respondents (85.7%) agreed to have experienced significant improvement in all construction processes on the project. Thus, it is no surprise that over 80% indicated they were happy to work using the current approach.

7.4 Case Study Project Two (CSP02): Highways Infrastructure

a. Description of CSP02

The case study project two (CSP02) is located in the West of Yorkshire, England. It is a highway infrastructure project. The aim of the project was to reduce congestion on the network using technology to vary speed limits. The project was divided into two main sections; North bound and South bound sections. Each section was further divided into three links, to help in managing the entire project with the LPS/CP process. A single production planning session was held for all the sections at the project site office. The process was internally facilitated by the site agent with the support of the programme manager and the work package managers.

The two main contractors on CSP02 were not exactly the same with those on CSP01. For instance, contractor A on CSP02 was not involved in CSP01, but contractor B was involved on CSP01. This could be due to the framework agreement the client has entered with with these contractors. It is worth mentioning that CSP01 and CSP02 are for the same client.

The project is an improvement of an existing motorway to a smart motorway. Contractor A on CSP02 has expertise in transforming roads into intelligent network using technology, while contractor B has a good record of successful delivery of highways infrastructure projects. The JV was formed to harness the skills and expertise from the different organisations. Both contractors claimed to have used LPS/CP on their previous projects. The attributes of CSP02 are presented in Table 7.3.

Table 7.3: CSPO2 Project Attributes

Project Attributes	Observed attributes on CSP02
Nature of project	Highway and Infrastructure
Location of project	West of Yorkshire, England
Nature of works	Improve of motorway to Smart motorway
Type of client	Public client
Proposed project duration	24 months
Stage of project at the end of the case study	80% completion
Procurement arrangement	Traditional design bid build
Procurement mode	Joint venture

Contract sum	£120 million
Number of subcontractors on site	9
Subcontracting arrangement	Framework agreement
Point of application of LPS/CP principles	Construction
LPS/CP facilitation process	Internally facilitated

Based on the data collected, CSPO2 was procured with traditional design-bid-build (DBB). However, the subcontractors on the project were on a framework agreement. As at the end of the case study, the project was at 80% completion. This shows the project had progressed enough to capture LPS/CP practices and its impact on construction process improvement on the project.

b. Demographic Information of the Respondents on CSP02

Table 7.4 reveals that the respondents interviewed on CSP02 have some practical experience on the application of LPS/CP as revealed in their years of experience. This implies that the respondents would be able to explain the process currently used on the project.

Also, the respondents are fairly distributed across the various stakeholders on the project, which could further minimise the level of bias in their response. Table 7.4 shows that the respondents have a lot of experience in LPS/CP this could be due to their working together on previous projects where LPS/CP was used. This suggests that their response in this study could be relied on. Also, the findings could be used as one of the basis for developing an approach to improve the current LPS/CP practice in the UK construction industry.

Table 7.4: Demographic Information of the Respondents on CSP02

S/NO	Respondent code	Categorisation of role on the project	Specific Position	Years of exp. in LPS/CP	Year of exp. in const.
1	CSP02SM01	Senior manager	Planning manager	7	28
2	CSP02SM02	Senior manager	Senior excellence manager	2	16
3	CSP02SM03	Senior manager	Construction	6	30

			manager		
4	CSP02MM01	Middle manager	Senior planner	4	25
5	CSP02MM02	Middle manager	Senior engineer	4	20
6	CSP02OM01	Operational manager	Section engineer	3.5	12
7	CSP02OM02	Operation manager	Section engineer	1	15
8	CSP02SC01	Subcontractor	Project manager	4	16
9	CSP02SC02	Subcontractor	Project Coordinator	3	15

7.4.1 Last Planner/Collaborative Planning Practice Observed on CSP02

The data on LPS/CP practice on CSP02 were obtained via documents analysis, unstructured observation, and semi-structured interviews. The LPS/CP practice observed are discussed under the following emerging themes: (1) Application of principles (2) Pre-construction practice (3) Nature of production planning meetings and (4) PPC and RNC practices.

7.4.1.1 Application of Last Planner and Collaborative Planning on CSP02

The application of LPS/CP on CSP02 started at the construction stage and it was among the key processes adopted in the delivery of the project. . On CSP02, there was a dedicated room and collaborative programming board for production planning meetings. Non-permanent markers of different colours were used for activity scheduling on the collaborative programming board. Visual management was also used to indicate the status of the project. Document analysis revealed that PPC and RNC were usually sent to the management and also made available on the notice board on the project site. It was further observed that the subcontractors shared the same office with the main contractor which offered them the opportunity to see the published PPC and RNC.

7.4.1.2 Pre-construction Practice

It was observed that the contractors did not have much input at the pre-construction stage. For instance, the contractors were not involved in the design phase due to the nature of the contract, one of the respondents stated that:

> *"The designers were employed by the client but the risk is borne by the joint venture. The joint venture was not involved in the design stage and the design is incomplete and the scope of work has changed over this time. If it is D&B*

> *it would be better, because it will give us the opportunity to control the designers, for instance, we have the designers on site, but if we have design issues it takes time to get back to us"* **[CSP02SM02, Site Agent/Production Planning Manager].**

Again, this shows that even with the DBB procurement, the design was still not at 100% completion before the commencement of the construction phase.

7.4.1.3 Nature of Production Planning Meetings on CSP02

There were various meetings during the construction stage, designed to support the production planning and control on the project. These meetings include: the collaborative programming/phase planning meetings, technical planning meetings, and the weekly planning meetings. Initially, the collaborative programing meeting was held once in a month, but this was later increased to twice a month at the peak of the project. During the collaborative programming meeting, the subcontractors, construction managers, the planner, and subcontractor's work package managers were involved.

However, further investigation revealed that only major subcontractors were frequently involved in the sessions. The smaller subcontractors were only involved when their task was on the critical path. The six week look-ahead planning was usually done during the collaborative programming meeting. Constraints were also identified and the responsibility for constraint removal assigned.

However, it was observed that not all the people assigned to remove the identified constraints were involved in the meeting, for example, the designers. This further impacted the level of commitment that was made by the participants at the meeting. To address this, technical meetings were held with the design team to sort out the observed design issues at the collaborative programming meeting on another day. This shows that the make-ready process was done outside the look-ahead meeting. WWP planning was also held on CSP02 and it was called weekly production planning meeting/senior management meeting.

7.4.1.4 Percentage Plan Complete and Reason for Non-completion Practice

The document analysis revealed that PPC and RNC were recorded on CSP02. As shown in Figure 7.6 (A sample of the document analysed), the average PPC observed on the project was 90% (for a 5 month period). PPC was also described as a programme certainty monitor on CSP02. Figure 7.6 further shows that the PPC average on CSP02 was fairly stable over some weeks.

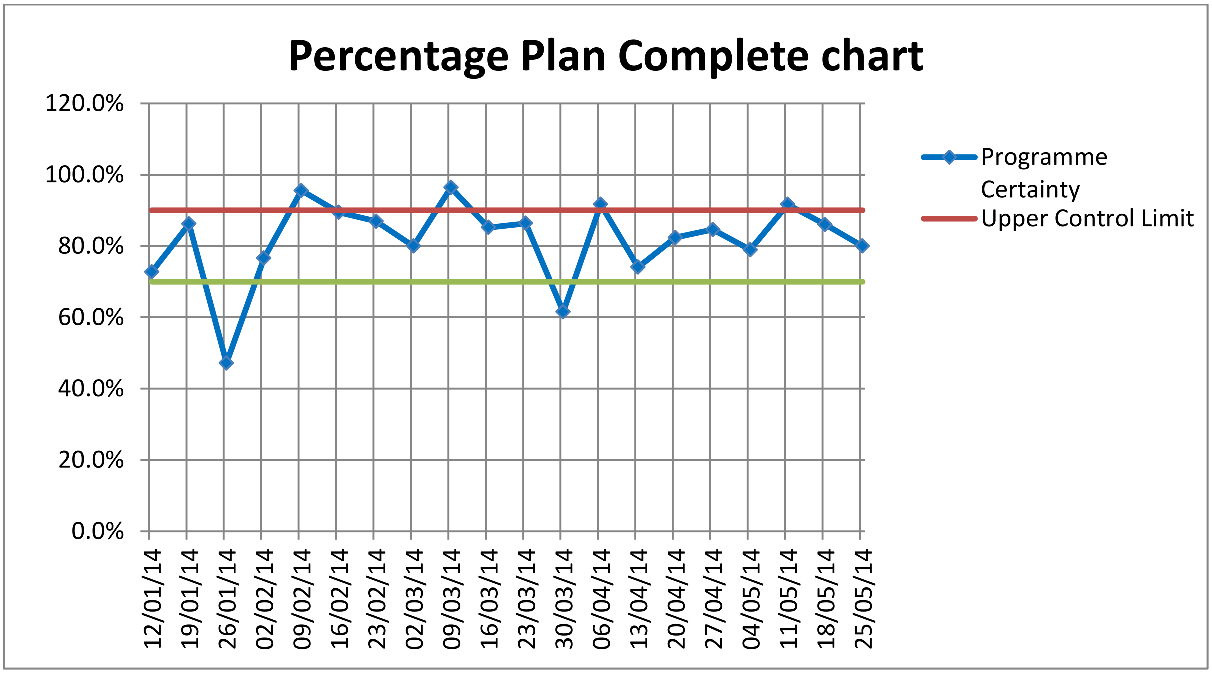

Figure 7.6: Average PPC chart on CSP02 (A sample of document analysed).

Source: CSP02 production planning document file (used with permission)

However as indicated in Figure 7.7, frequent changes in priority, changes to design, insufficient labour, and late design were the main RNC which influenced the PPC weekly average.

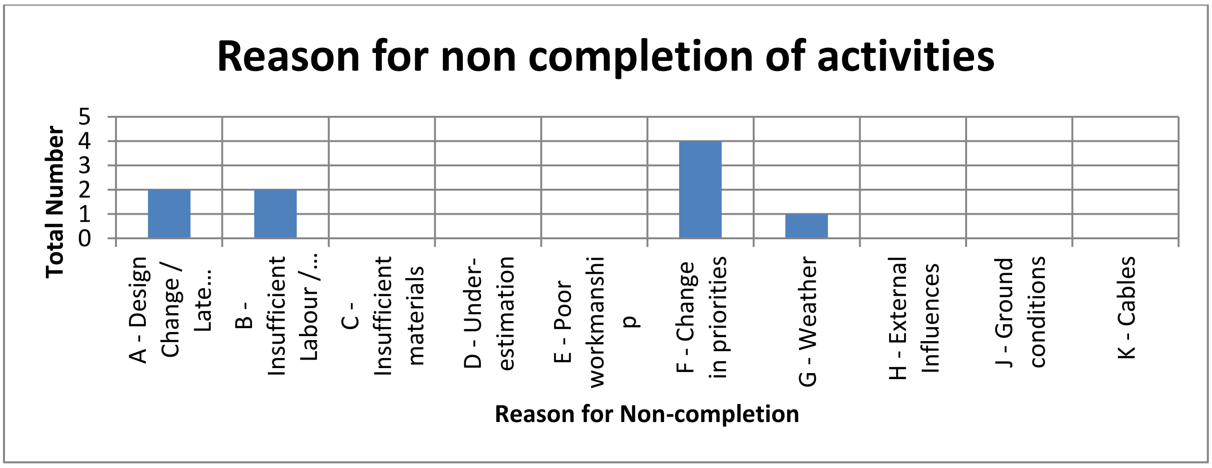

Figure 7.7: Reasons for non-completion of activities (A sample of document analysed)

Source: CSP02 production planning document file (used with permission)

It was observed that on CSP02, when the client made changes to the design and scope of work, the construction team had to shift focus to the current client demand. One of the respondents stated that:

> *"The biggest problem we have got is to have a client who does not know what he wants, is always changing things. The problem is how to manage those changes"* **[CSP02SM01, Programme Manager]**

This further shows that these changes could be impromptu, since the activities have to be included in the WWP. Also, there could be some issues in the constraint removal (make-ready process) in the look-ahead planning with regard to the late design information. However, this may not sum it all as the joint venture did not have control over the design team, thus, not much could be done when such issues came up.

7.4.2 Support required for Last Planner/Collaborative Planning

Figure 7.8 reveals the emerging themes and sub-themes from the interview data on the support required for successful implementation of LPS/CP as observed on CSP02.

7.4.2.1 Support required at the Organisational Level

The support required from the organisation for successful implementation of LPS/CP observed on CSP02 include; (1) Provision of training, (2) Mandating it in contract and (3) Creation of awareness.

a. Training Support

Majority of the respondents, including the subcontractors and those working directly for the joint venture on CSP02, identified the need for provision of training by clients and main contractors. For instance, some of the respondents stated that:

> "*There is need for guidance on LPS/CP right from conception by the management, we do receive some training on* LPS/CP" **[CSP02SC01, Project Manager]**. The need for provision of training was also identified by the programme manager *"Training is very essential, without it the facilitation would not work"* **[CSP02SM01, Senior Manager].**

Another senior manager suggested that the nature of training to be provided should be tailored for each stakeholder on the project. For instance, it was argued that the initial training for the smaller subcontractor should be to explain the benefits of the process in order to get their buy-in before full implementation.

b. Awareness Creation and Mandating it in the Contract

The respondents observed that creation of awareness on LPS/CP practice and its inclusion in the contract with the supply chain are essential. One of the respondents stated that:

> *"The company intranet, newsletter should be used and more importantly, making it part of the company procedure that could be rolled"* **[CSP02SM02, Site Agent].**

Making LPS/CP a part of the company policy could further support the practice in the organisation and across its supply chain. Furthermore, the respondents on CSP02 suggested that the process should be formally included in the contract by the organisation **[CSP02MM01, Agent; CSP02SM02, Site Agent; CSP02SM01, Site Agent].**

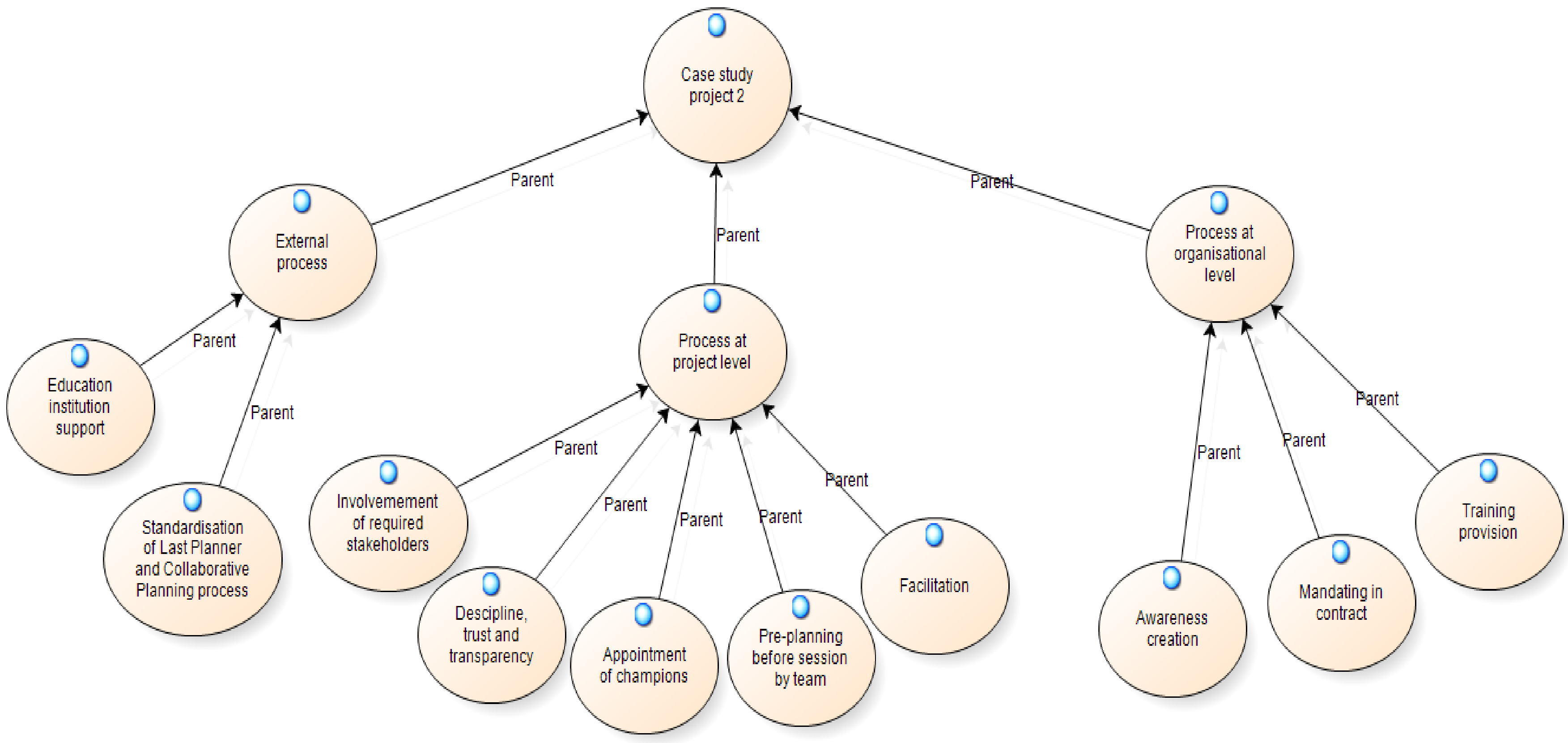

Figure 7.8: Support for successful implementation of LPS/CP

7.4.2.2 Support Required at the Project Level

The support required at the project level as observed on CSP02 include; (1) Pre-planning by the team before production planning session (2) Discipline of all team and transparency (3) Facilitation and appointment of champions (4) Involvement of the required stakeholders.

a. Pre-planning by the Team before Production planning session.

The respondents interviewed on CSP02 observed that pre-planning by the subcontractors and work packages managers before CP session is essential for success at the project level. Some of the respondents stated that:

> *"The subcontractors must come with realistic programme, not just the duration on the contract programme*" **[CSP02MM02, Site Agent]**. *"Prepare a plan before the collaborative planning session (base programme)"* **[CSP02SM02, Production Planning Manager].**

The need for pre-planning before the collaborative production planning sessions cannot be overemphasised, as it keeps all the team in the right state to make meaningful contribution during the session.

b. Discipline of all Team and Transparency

The study reveals that discipline and transparency are essential at the project level for successful implementation of LPS/CP. The discipline and transparency required here are in terms of telling the truth. Some of the respondents stated that:

> *"One of the biggest thing during the CP session is people not telling the truth, you got to be honest with yourself and rest member of the team, it is no use to say I will finish the work today while you know you still need 3 or more days. It is no good to say I will do it next week and you know you have not got the men to do"* **[CSP02SM01, Programme Manager].**

The above statement suggests that some project team members make unrealistic promises.

c. Facilitation and Appointment of Champions

The study reveals the need for appointment of a facilitator and champions to be essential at the project level. Some of the respondents stated that:

> *"A facilitator is needed to promote the benefits of LPS/CP, an external facilitator within the 1-4 weeks and internal facilitation to continue the process. Also, appoint lean managers, both at the project and organisational levels to promote the practice across the business"* **[CSP02SM01, Programme Manager]**. "*The session should be facilitated by someone who has knowledge of the work involved to present a bigger picture"* **[CSP02MM02, Site Agent].** "*Have a champion to promote it"* **[CSP02MM01, Section Engineer].**

The above statements from respondents show the need for facilitators and champions for driving the process. The statement further suggests that the facilitator should have some level of understanding on the nature of work executed. For example, this knowledge of the construction process would be particularly useful in making effective decision in scheduling of activity.

d. Involvement of all the Required Stakeholders

The respondents believed that full engagement of all "required stakeholder" (those that have the required capability to make decisions during production planning meetings), is essential for its success at the project level. One of the respondents stated that:

> "*The collaborative programming session should involve the client, the designers, main contractors, and subcontractors"* **[CSP02SM03, Manager].**

Again, this call by the respondents shows that not all the required stakeholders are engaged in the collaborative programming session. For instance, it was observed that the designers were not usually involved in the session due to the nature of the procurement used; DBB. The implication of non-all-inclusive engagement of the stakeholders in the process is that the make-ready and constraint removal process would be incomplete. This increases the level of uncertainty in the activity scheduled.

7.4.2.3 External Support required for LP and CP Implementation

The external support for LPS/CP implementation identified on CSP02 include: (1) Industry and academic partnership and (2) Process standardisation.

a. Industry and Academic Partnership

Some of the respondents believed that higher education institutions which provide training in construction project management, and civil engineering among others have a role to play in passing on the knowledge to their students. This could support the implementation of the process. One of the respondents argued that:

> "*There is need to adopt some of this concept such as collaborative planning in their training and teaching. The curriculum should be updated to what is happening in the industry, CP should be included in the project management programme"* **[CSP02SM02, Production Planning Manager].**

This shows that construction management and civil engineering training should not only focus on the hard or technical skills alone, but other soft management skills such as those encouraged in lean principles should also be taught**.** It has been observed that the current traditional approach to construction project management is that of "command and control" with little or no opportunity to receive feedback as encouraged in the LPS processes (Parrish, 2014; Ballard, 2000; Ballard, 1997).

Studies have shown that previous academic knowledge on lean principles support the implementation of LPS on construction projects (Kim and Jang, 2006; Alarcon *et al.*, 2002). It is no surprise that higher institutions offering programmes in construction project management and civil engineering are now offering modules in lean construction. Example of such institutions are; University of California, Berkeley USA, Nottingham Trent University, UK, and Michigan State University, USA, USA among others (Nottingham Trent University, 2016; UC Berkeley, 2016; Michigan State University, 2016).

b. Process Standardisation

On CSP02, the respondents observed that a common or standard approach to LPS/CP implementation would support its rapid implementation. Some of the respondents interviewed are of the opinion that the approach seem to vary from one project to another. One of the subcontractors stated that:

> "*People tend to view collaborative planning differently, there is need to have one format or approach. There should be one approach across projects"*
> **[CSP02SC01, Subcontractor's Project Manager].**

This statement further shows that LPS/CP practices as observed by the respondents are not consistent across the projects they have been involved in, in the past. However, that does not mean the LPS does not have a standard process (see Ballard, (2000)), the variation observed could be due to lack of discipline in the implementation of the components or ignorance on the process.

7.4.3 Procurement and LPS/CP on CSP02

Two broad themes emerge from LPS/CP practices in relation to the procurement approach used on CSP02. These are; the procurement practice and the impact of the procurement practice on CSP02.

7.4.3.1 Procurement Practice on CSP02

CSP02 is a joint venture project comprising of two major top UK contractors. The project was procured using Design Bid Build, this means the design has been completed before the main contractors, and subcontractors were brought in. This also influenced the implementation of LPS/CP on the project.

7.4.3.2 Impact of Procurement on LPS/CP Practice on CSP02

The study reveals that the procurement approach used had some impact on the implementation of LPS/CP on CSP02. Some of the impacts include; (1) frequent occurrence of constructability issues (2) long lead time in response to design issues from the designers and (3) design changes and absence of designers in CP meetings.

a. Frequent occurrence of Buildability/Constructability Issues

The study reveals that constructability was a reoccurring incidence on CSP02 as captured in the interview and observation. One of the subcontractors stated that:

> *"The barrier here has that the design is not been met. When you set out to work in a particular area and the design is not ready there is not much you can do. The drawing is not working as expected by the contractor. Some of the information used in the design were wrong and also client changes his decision at some point"* **[CSP02SC01, Project Manager].**

This shows that the lack of involvement of the construction team in the design process, coupled with the use of wrong information by the designers further contributed to the constructability issues observed in the construction phase. The implication of this for the implementation of LPS/CP principles on the CSP02 is that the promises made at the various production planning meetings could still be faced with other design challenges on site. However, this should be expected when there is no constructability review of design before construction (Othman, 2011). On CSP02, constructability or buildability review was limited due to the nature of procurement adopted.

b. Long-lead Time in Response to Designs Issues from the Designer Team

The study reveals that there is long lead time in receiving response from the designers on design issues. This could be largely due to the fact that the designers were not employed by the joint venture. Some of the respondents stated that:

> "*If it were D&B it will be better because it will give us the opportunity to control the designer. We have the designers on site but if we have design issues it takes time to get back to us"* [**CSP02SM02, Production Planning Manager]**.

> *"The designers are employed by the client and it does affect the collaborative planning, we only have liaison meeting with the designer rather than CP to try and focus on the priority, but it does not help. The best way to control somebody is when you are paying them. If you are paying somebody, they listen more than when someone else is paying them. It is not as it used to be initially, they try to listen a bit. The designers have little appreciation of the commercial implications of what they do and they don't do. It is very difficult but we have to manage it"* **[CSP02SC01, Project Manager].**

The above statements show the impact of the procurement approach on LPS/CP implementation. The argument that the designers seem not to understand the commercial implication of their action somewhat suggests that the design team was only working to achieve their individualist goal on the project not minding what became of other stakeholders on the project. This could have been largely informed by the traditional mind-set or approach to managing construction project as they also exhibited signs of unwillingness to get involved in the collaborative programming meeting session with other stakeholders on the project. However, the idea of controlling the designers as expressed by the contractors **[CSP02SM02; CSP02SC01],** still shows frustration.

7.4.4 Impact of LPS/ CP Practice on Construction Process Improvement on CSP02

Figure 7.9 presents findings on the impact of LPS/CP implementation on CSP02 on CPI captured from the interviews. Figure 7.10 presents the impacts from the survey. The findings shown in both figures are discussed concurrently below.

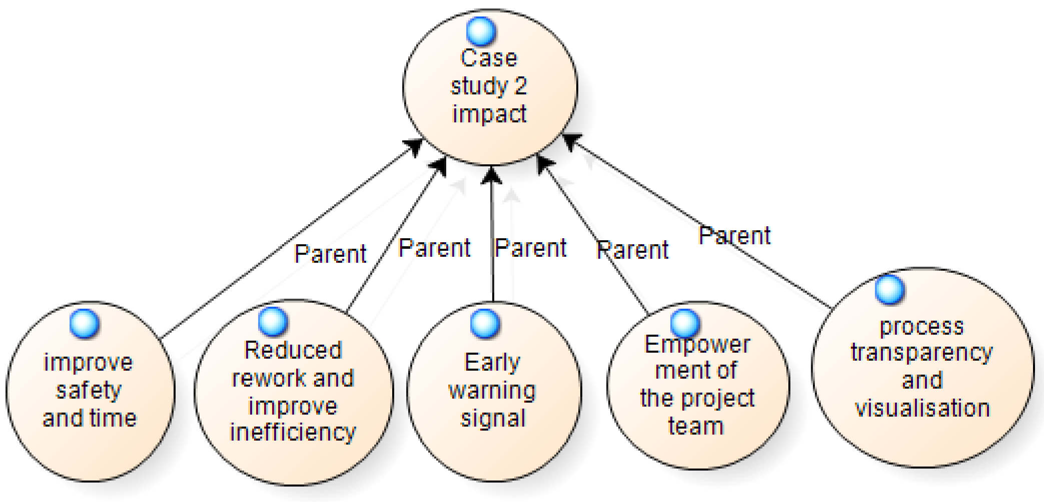

Figure 7.9: Impacts of LPS/CP practice on CPI observed on CSP02 (interview results)

7.4.4.1 Impact on Time and Programme

The analysis results of the survey as presented in Figure 7.10 reveals that 50% of the respondents agreed to have gained more time on the project through the use of LPS/CP while 50% claim not to be sure. The uncertainty expressed by some of the respondents could be due to the fact that the project was still on-going. The interview result further confirmed measurable gain with respect to time. Some of the respondents stated that:

> *Our initial programme was 80 weeks and we have reduced it to 60 week and now we are on week 57, the collaborative planning has helped in achieving this. The remaining time will be used to do extra work* **[CSP02SC01, Subcontractor's Project Manager]**.

> *"We did collaborative planning on pre-cast concrete on the road, through this, we were able to reduce the activity duration by four days"* **[CSP02SM02, Production Planning Manager].**

"On this scheme the client has introduced many changes, if it is added end to end, it will take many months to build. We have been asked to finish it in two months as addition to the contract time, this is how big an issue it is, without collaborative planning and Last Planner approach we can't do it".[**CSP02SM01, Programme Manager]**

This shows that LPS/CP processes have significant impact on the time gain on the project. However, majority of the respondents (about 62.5%) indicated that the process was time consuming. It is interesting to note that majority of them (62.5%) also believe there is added value in the time spent in the process.

7.4.4.2 Collaborative Working Practice, Communication, and Process Transparency

Figure 7.10 reveals that 85% of the respondents agreed that their working practice had improved for better on the project as a result of the LPS/CP process. Also, all respondents indicated that the implementation of LPS and CP had improved the level of communication among the stakeholders on the project. The level of adversarial relationship also reduced, as indicated by over 75% of the respondents. Furthermore, the survey result reveals that 100% of the respondents have good understanding of the project as a result of their involvement in the LPS/CP meetings. This was further confirmed from the interview response, as one of the respondents stated that:

"*There is less conversation with the Gantt chart and primavera, but high conversation in the CP process. It helps the foremen to understand the programme. The white board and the post it-note help to increase and create better understanding of the project to the least team on site"* [**CSP02SM02, Production Planning Manager].**

This shows that the LPS/CP process supports transparency and process visualisation. A study by Tezel *et al.,* (2010) revealed that process visualisation does not only support transparency, but also leads to improved communication across the project team members. In addition, about 50% of the respondents indicated that their confidence and trust in other stakeholders on the project had improved as a result of the LPS/CP process on the project, 25% disagreed while 25% claimed not to be sure.

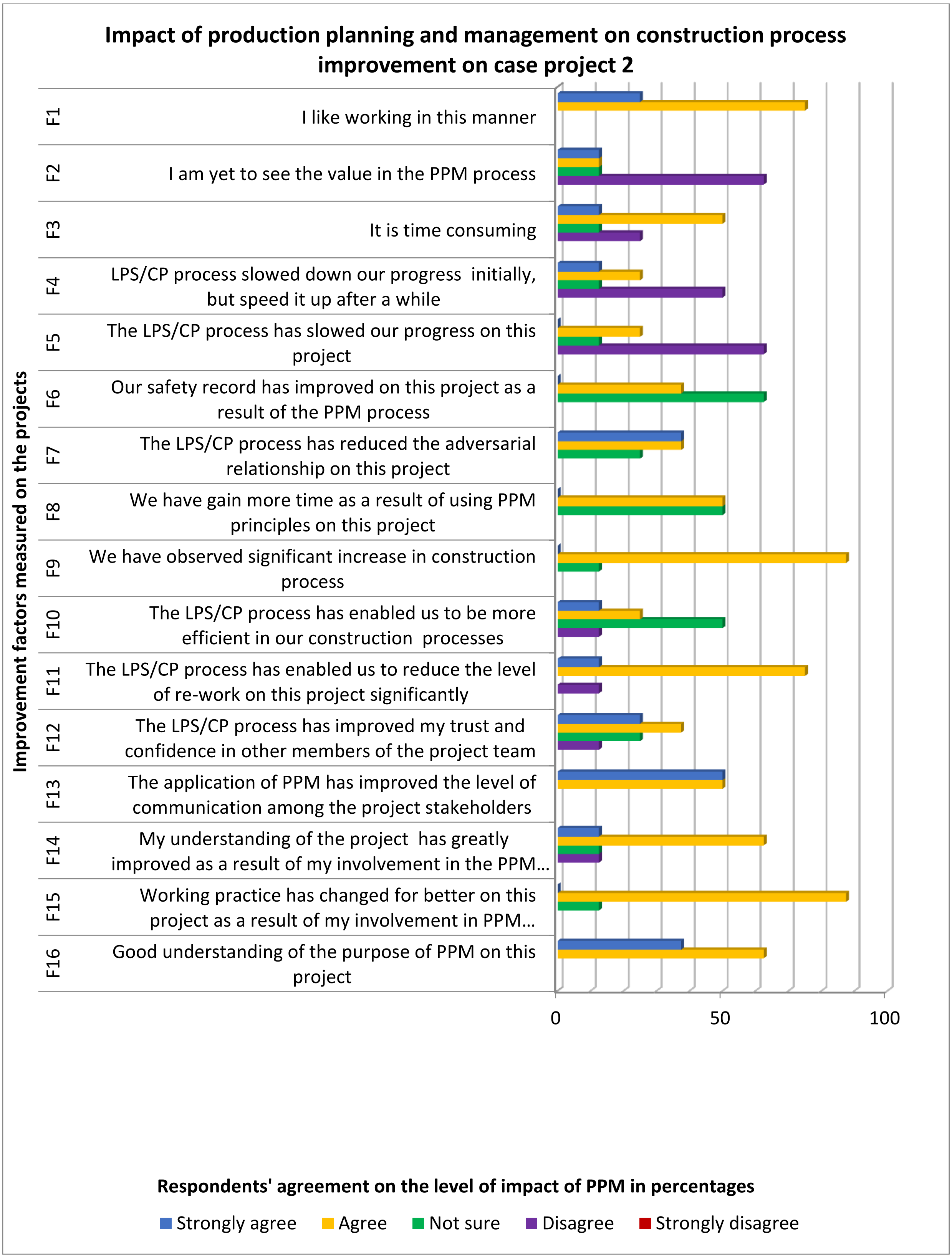

Figure 7.10: Last Planner/Collaborative planning impacts on construction process improvement on CSP02

7.4.4.3 Impact on Re-work, Safety, and General Process Improvement

87.5% of the respondents indicated to have observed a substantial increase in the construction process improvement on the project. Also, 75% of the respondents agreed that the level of re-work had reduced significantly on the project. This was further confirmed in the interview where a subcontractor stated that:

> *"We become more efficient and we can drive the programme which we may not do normally. Since issues get resolved early, you do not have to go back and do rework"* **[CSP02SC01, Subcontractor's Project Manager].**

The above statement could also indicate that the process has enabled the team to be more efficient. However, in terms of safety record improvement, the survey results revealed that 62.5% claimed not to be sure, while only 37.5% indicated that the practice had improved the safety record on the project. Some of the respondents interviewed stated that the LPS/CP process supports better safety decisions, for instance, one of the respondents stated that:

> "*One thing with CP is that people are entitled to their opinion about safety. A subcontractor could say, hang on a minute, the safety barrier has been removed we will not work in such area. You remember the guy said during the meeting we can't do it, the safety guard has been removed"*
> [**CSP02SM01, Programme Manager]**

This shows that the LPS/CP process could have supported safety decisions on the project. However, with many claiming not be sure, could mean it was not clearly measured and understood by some of the respondents.

7.5 Case Study Project Three (CSP03): Educational New Build

a. Description of Case Study Project Three

The case study project three (CSP03) is located in the West Midland, England. It is a new educational building project. The educational building comprised of three floors and occupied a total floor area of 9290.30m^2. The new build was to provide facilities such as teaching spaces, school hall, office space for staff, and laboratories among others. The main contractor on the project is one of the top UK building construction contractors with over 30 years' experience in the UK building construction industry.

In the past, the contractor had been involved in various construction process improvements championed by the UK Government, such as the Construction Lean Improvement Programme (CLIP) conducted by the Building Research Establishment and the Department of Trade and Industry (BRE, 2006). Also, the main contractor had been in a framework agreement with all its supply chain for over five years. The mode of procurement used is design and build (D&B). Table 7.5 gives further attributes of CSP03. LPS/CP principles were used in managing the production processes. Although, the client on CSP03 is a public client, the use of LPS/CP on the project was motivated by the main contractor. It is worth noting that the application of LPS/CP is part of the process used by the main contractor in delivering services to its numerous clients over the years.

Table 7.5: CSP01 Project Attributes

Project Attributes	Observed attributes on CSP03
Nature of project	Building construction project
Location of project	West Midland, England
Nature of works	Educational new build
Type of client	Public client
Mode of contractor selection	Framework agreement and ECI
Proposed project duration	30 months
Project status at end of case study	85% completion
Procurement arrangement	D&B
Contract sum	£20 million
Current number of subcontractors on site	16
Point of application of LPS/CP	Construction
Facilitation process	Internally facilitated

b. Demographic Information of Respondents on CSP03

Table 7.6 indicates that the respondents interviewed cut across all the key people managing production on the project. However, over 50% of the interviewees were drawn from the subcontractors. This is because the project had more subcontractors and they were equally willing to participate in the study.

Table 7.6: Demographic information of respondents interviewed on CSP03

S/NO	Respondent code	Role categorisation on the project	Specific role in the organisation	Years of exp. in LPS/CP	Years of exp. in const.
1	CSP03SM01	Senior manager	Senior planner	10	30
2	CSP03MM01	Middle manager	Build manager	3	37
3	CSP03SM02	Middle manager	Build manager	1	34
4	CSP03SC01	Subcontractor	Senior site manager	6	14
5	CSP03SC02	Subcontractor	Senior project engineer	10	26
6	CSP03SC03	Subcontractor	Contract manager	8	10
7	CSP03SC04	Subcontractor	Project manager	5	10

All the respondents have vast experience in the UK construction industry. They also claim to have valuable experience in the application of LPS/CP principles in construction.

7.5.1 Last Planner /Collaborative Planning Practice Observed on CSP03

The LPS/CP practices on CSP03 are discussed under the following emerging themes: (1) Application of principles (2) pre-construction practice (3) Nature of production planning meetings and (4) PPC and RNC practice.

7.5.1.1 Application of Last Planner and Collaborative Planning on CSP03

The formal application of LPS/CP on CSP03 started at the construction stage, as it was part of the main contractor’s approach for delivering its business. All the subcontractors were aware of this. However, some of the subcontractors and specialist contractors were involved in the design stage. There was a dedicated room and collaborative programming board for LPS/CP meetings. Sticky-notes of different colours were used for activity scheduling on the collaborative programming board. However, it was said that on a different project handled by the same main contractor, the process was done electronically. The senior planner stated that:

> *“On this project as you have seen, we use post-it notes on the wall, although it seems to be old fashioned. On other projects we do it electronically with projector. It depends on the nature of the project, each format you use produce the same result”* **[CSP03SM01, Senior Planner]**.

The use of electronic board for phase scheduling/collaborative programming further shows a progression in the current practice. Both approaches could produce some similar results, if managed properly. However, this cannot replace the face to face conversation that occurs during the production planning sessions.

The LPS/CP was internally facilitated by the senior planner on the project. It was observed that most of the subcontractors were usually present at the production planning meeting. The document analysis revealed that other forms of visual management such as project safety performance status, project monthly performance etc., were used to indicate project status, KPIs, and set targets on mobile board on site.

7.5.1.2 Activity Scheduling as Observed on CSP03

It was observed on CSP03 that the working drawing was used in scheduling of activities during production planning meetings. The working drawings were labelled with different colours to show each work section or zone .This could suggest that LPS/CP was implemented with other production planning principles such as *Line of Balance* and *working zoning*. However, as observed, this was not a formal process. It was only an approach used on the project to assist the team in the collaborative programming/phase scheduling process.

This could be due to the large number of activities involved on the project and prototype nature of floors and rooms. Also, '*Prototyping'* or '*First Run Studies'* was done for various activities scheduled on the project. The process enabled the team to identify constraints and drive out waste before the actual construction. The interphase between activities seems to be short (in hours and days) in some cases compared to the operation on highway and infrastructure project. The interphase between some activities on the project was in hours and days.

7.5.1.3 Nature of Production Planning and Control Meetings on CSP03

On CSP03, there were various meetings designed to support the production planning and control process on the project. These include; collaborative programming meeting, and weekly planning meetings. The 6 week look-ahead planning was done during the collaborative programming meeting. The researcher was in attendance on some of the collaborative programming meetings as an observer. Constraints to planned activities were also identified, and then developed into an action lists which was sent out electronically.

Although constraints were identified, they were not published openly in the collaborative programming room. Such practice could reduce the level of transparency in communication. The weekly work planning was held each week and the process was championed by the site managers alongside the subcontractors. One of the respondents stated that:

> *"The weekly planning meeting focuses on everyday activity that will occur next week and review of last week's work planned. In addition to this, is the work that would be done in that week, we have daily huddle every morning, looking at the weekly plan seeing what needs to be doing in the week"* **[Subcontractor's, Senior Project Engineer].**

PPC was claimed to be recorded on CSP03 and it was called '*percentage activity complete'* the RNC was also tracked. However, for confidentiality, this data is not published here as done on CSP01 and CSP02. The data were not made available to the researcher, thus it is not presented in this report. This was due to the company policy.

7.5.2 Procurement and LPS/CP on CSP03

Two broad themes emerge from LPS/CP practice in relation to the procurement approach used on CSP03. They are: the procurement practice and the impact of the procurement practice on LPS/CP.

7.5.2.1 Pre-construction Practice

On CSP03, the major subcontractors and specialist subcontractors were involved right from the design stage. They were also involved in developing the construction programme which was called the '*delivery programme'.* This process was largely supported by the D&B and ECI procurement approach was adopted.

One of the respondents stated that:

> *"Delivery programme is a more detailed programme. In the delivery programme, the main subcontractors were involved in developing it. For example, the M&E produced a detailed programme for their insulation work,*

and it was subsequently integrated into the construction programme" **[CSP03SM01, Senior Planner]**.

Also, the subcontractors were into a framework agreement with the main contractor.

7.5.2.2 Impact of Procurement Practice on LPS/CP Implementation on CSP03

In terms of the influence of the procurement practice on the implementation of LPS/CP on CSP03, there seemed to be divergent views. While some of respondents believed that the procurement process supported the implementation of LPS/CP on the project, other respondents argued that the LPS/CP could have been still been applied successfully irrespective of the procurement route taken. Here are some of their responses:

> *"I am not sure if things could have worked differently if another procurement route is used. To me, irrespective of how the job is procured we can still involve the people in the LPS/CP process and still have the same outcome. However if the subcontractors are involved at the tender stage the construction programme will be better"* **[CSP03SM0, Senior Planner]**

> *"The procurement route helps in the implementation. On this project, we are using standard JCT and D&B contract which actively support collaboration between the subcontractors. It is opposed to NEC contract which is more programme focused and rigid, but with this contract we rather pull together"* **[Subcontractor's, Project Manager].**

The above statements indicate that the success of the LPS/CP implementation cannot be attributed to the procurement route alone, however it creates the platform for the process to function.

a. Transfer of Lessons Learned and Long Term Working Relationship

The study reveals that the framework agreement used on the project supports the transfer of lessons learned from project to project among the subcontractors. Some of the respondents stated that:

> *"We are in a framework agreement, we have been working with the M&E, the building envelop subcontractor. We have worked together on four different projects which is a benefit to us all on this project. We passed on the*

> *lesson learned from the previous projects to this which makes us more successful"* **[Subcontractor's, Contract Manager].**

It was further explained that, *"each subcontractor on this project have worked together previously, thus, we understand each other's capability and we know we are all working to achieve the same goal"*. Again, this shows that the procurement approach supports the development of good working relationship among the team.

7.5.3 Support required for Last Planner/Collaborative Planning

Figure 7.11 reveals the emerging themes and sub-themes from the interviews data on the process/support required for successful implementation of LP/CP principles from CSP03.

7.5.3.1 Support required at the Organisational Level

The support required from the organisation for successful implementation of LPS/CP as identified on CSP03 includes: (1) Inclusion of the commercial team in the LPS/CP process (2) Mandating of LPS/CP in the contract and (3) Use of collaborative form of contract and supply chain working together on a regular basis

a. Inclusion of the Commercial Team in the LPS/CP Process

Some of the interviewees on CSP03 believed that the inclusion of the commercial team such as the quantity surveyor, commercial managers, cost controllers, and cost engineers among others in the LPS/CP process would further support the system in the organisation. One of the respondents stated that:

> *"I think the built environment team and the planning team are involved in this process, the commercial side of the business tend to be in the loop in term of delays or acceleration in the programme. The commercial side of the business should be kept in the loop"* **[Subcontractor's, Contract Manager].**

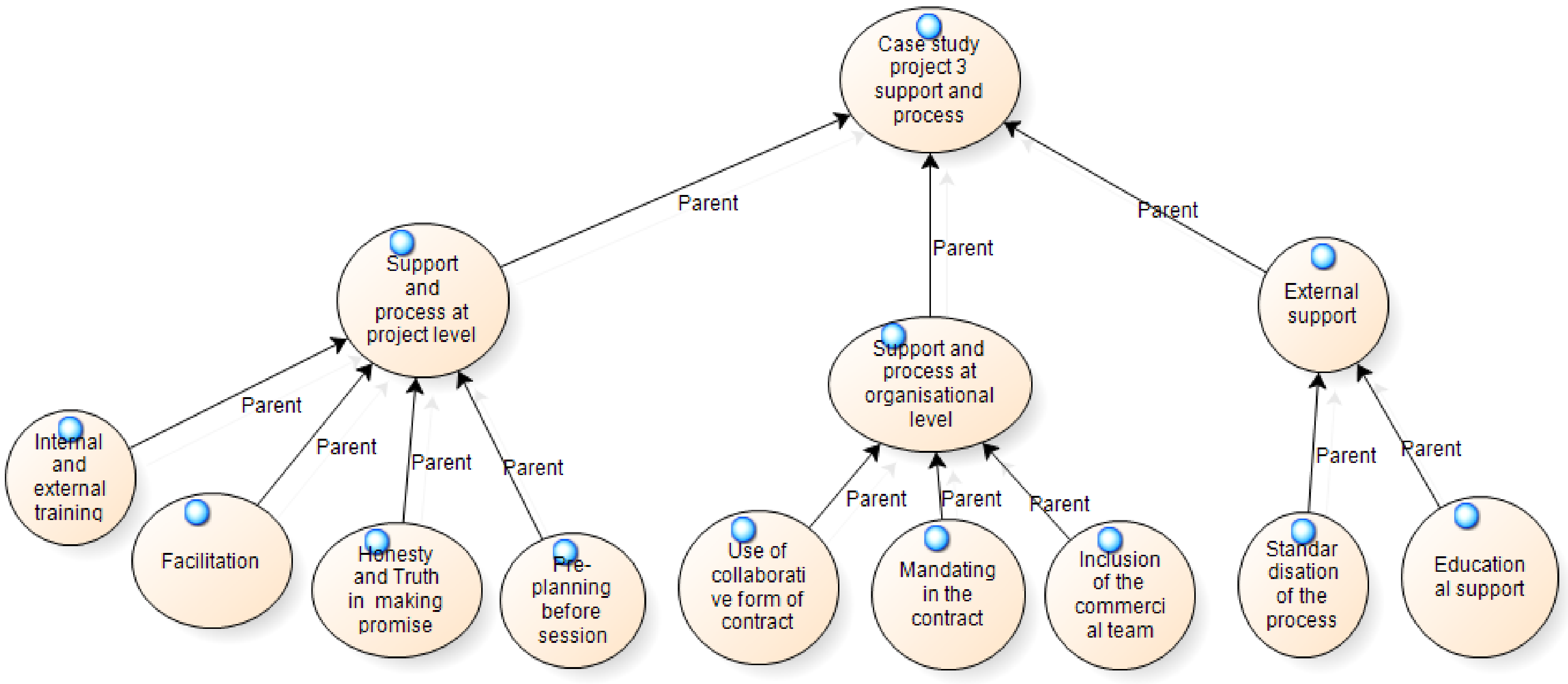

Figure 7.11: Support required for successful implementation of LPS/CP Observed on CSP03

b. Mandating LPS/CP in the Contract and Use of Collaborative form of Contract

Mandating the process and use of collaborative forms of contract were also identified on CSP03 as part of the support the organisation could provide for smooth implementation of the process. For instance, one of the respondents observed that because the LPS/CP was part of the contract, it motivated everyone on the project to get committed to the process **[CSP03SM01, Senior Planner].** Also, a subcontractor stated that:

> *"It is part of the main contractor's policy, so if we do not want to do it, we can't go away with it. My signing into it in the contract supports my commitment to it and it benefits us as subcontractors*" **[Subcontractor's, Senior Site Manager]**.

Provision of training and formalisation of the process both at organisational and project levels were also suggested by the respondents. One of the subcontractor interviewed stated that: *"we also provide internal training to our team on this"* **[Subcontractor's, Contract Manager].**

7.5.3.2 Process and Support required at the Project Level on CSP03

From the analysis of the interviews conducted on CSP03, five key processes and supports were identified. These are; (1) Honesty and truth in promising (2) Pre-planning before CP session by the team (3) Engagement and collaborative plan of work at site level (4) Whole process facilitation and (5) Internal and external training on LPS. Considering that majority of the factors identified here are similar to those on CSP01 and CSP02, only the new ones identified will be discussed.

a. Honesty and Truth in making promise at the project level.

Some of the respondents interviewed stated that honesty in making promises and giving out of information especially at the production planning meetings is essential. Some of the respondents stated that:

> *"Some subcontractors agree dates knowing they cannot achieve it!!!"* **[Subcontractor's, Senior Site Manager].**

> *"The process is fine, one of the barriers is people committing to things they cannot do and also unrealistic expectation from the main contractor"* **[Subcontractor's, Contract Manager].**

The statements above further highlights why the stakeholders at the project level should not be pressurised into making promises or commitments, as such promises could turn out to be unrealistic sometimes. In making promises in the LPS approach of managing construction project, workers are not pressured into making promises, rather, they are empowered to make promises on what they can do. This approach supports reliable promising. According to Macomber and Howell, (2001); Macomber and Howell, (2003) in the LPS workflow reliability is achieved via reliable promising.

b. Pre-planning before CP Session by the Team and Facilitation

On CSP03 the need for the team to make a realistic plan before coming to the session and the appointment of a facilitator to manage the process was identified. One of the subcontractors stated that: *"The way the process is facilitated supports our buy-in, we can't do this without the support of the main contractor and their planning staff"* **[Subcontractor's, Contract Manager].**

7.5.3.3 External Support required for LPS/CP implementation

The external support observed on CSP03 include: (1) Refresher training on the process (2) Standardisation of Process. Both main contractors and subcontractors interviewed on CSP03 identified the need for standardisation of the process across projects.

Refresher training

The need for refresher courses was identified. Here is a transcript:

> *"We use to have some form of external support when we started years ago, the idea is to educate myself and the project managers. We are having a refresher course next month on LPS/CP across the business to standardise how we do it, some people tend to do it differently, we need a standard approach to do it with our subcontractors"* **[CSP03SM01, Senior Planner].**

The refresher trainings provide an opportunity for those facilitating the LPS/CP process to update their knowledge based on current practice. This could be done internally in an organisation to standardise the process across projects and to also ensure everyone is operating on the same page.

7.5.4 Impact of LPS/CP Practice on Construction Process Improvement

Figures 7.12 and 7.13 present findings on the impact of LPS/CP implementation on CSP03. While Figure 7.12 presents the impacts of LPS/CP observed from the semi-structured interviews, Figure 7.13 presents the result of the survey. Both results are discussed concurrently under this section.

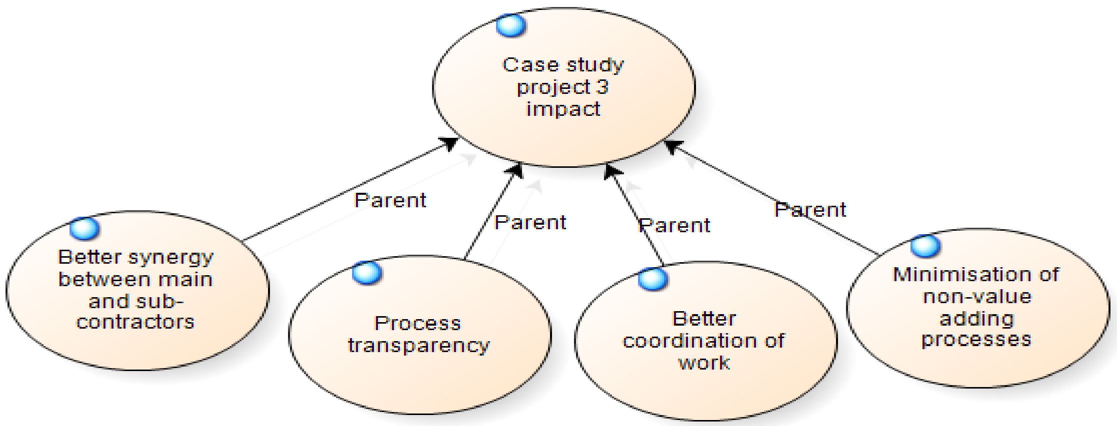

Figure 7.12: Impacts of LPS/CP on CPI observed CSP03 (interview results)

7. 5.4.1 Impact on Time and Programme

Figure 7.13 reveals that 50% of the respondents agreed that the LPS/CP implementation on CSP03 had enabled the team to make significant time saving. This was further confirmed in the interview as one of the respondents stated that:

> *"Overall, the process has worked well on this project, it helps us to recover lost months. On this project, we were 8 months late before the commencement of work on site, now we are only 4 weeks late which we hope to recover before the end of the project*" **[CSP03SM01, Senior Planner].**

Furthermore, 66.7% of the respondents indicated that the implementation did not slow down the progress work on the project. In term of time committed to the process, 50% of the respondents claimed that the process was not time consuming. However, from the interview and observation, some of the respondents complained that the 2.5 hours collaborative programming meeting should be reduced. Nevertheless, 83.3% strongly agreed there are benefits in implementing the principles on the project. It is no surprise that all the respondents would like to work in this manner. This evidence demonstrates that the LPS/CP implementation has positive impact on construction process improvement.

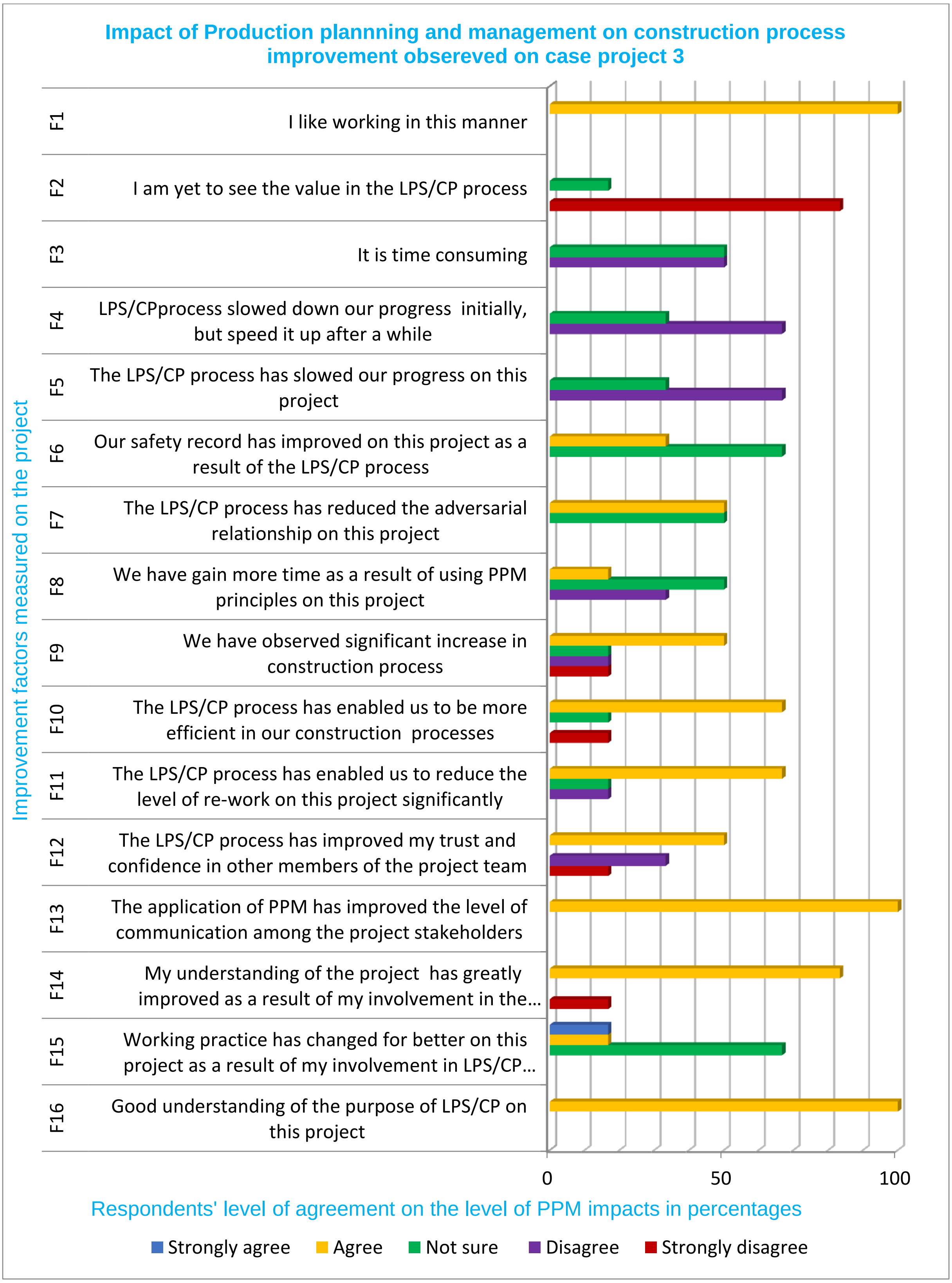

Figure 7.13: Last Planner/Collaborative planning impacts on construction process improvement on CSP03

7.5.4.2 Collaborative Working Practice, Communication, and Process Transparency

Figure 7.13 reveals that 83.3% of the respondents believed that their understanding of the project had greatly improved as a result of their involvement in the LPS/CP processes. However, 66.7% of the respondents claimed not to be sure if their working practices had changed for better as result of their involvement in the process. Furthermore, all the respondents indicated that the application of the LPS/CP principles on the project had improved the level of communication on the project. This was also confirmed in the interview as one of the respondents stated that:

> "*The more time you spend with each other in planning, the better. It has improved the relationship between us"* **[Subcontractor's, Contract Manager]**.

From the study, 50% of the respondents on CSP03 indicated that the implementation of LPS/CP principles had improved their trust and confidence in stakeholders on the project.

7.5.4.3 Impact on Re-work, Safety, Non-value Adding Activities, and General Process Improvement

Figure 7.13 reveals that majority of the respondents (66.7%) believed that the application of LPS/CP principles had reduced the level of re-work significantly on the project. This finding is further supported by the interview response. For example, the room activity programming that involves some form of *prototyping or First Run Studies* helps to reduce re-work and drives out non-value adding activities from the process. One of the respondents stated that:

> "*It helps us to check quality at each stage through the room fitting monitoring schedule developed collaboratively"* **[CSP03MM01, Build Manager].**

Furthermore, the study indicated that majority of the respondents (66.7%) agreed that the implementation of LPS/CP had made the team more efficient on the project, although 16.7% strongly disagreed.

In terms of its impact on safety, 66.7% of the respondents claimed not to be sure if their safety record had actually improved, while 33.3% agreed that the safety record had improved. However, from the interviews conducted, some of the respondents explained that since LPS/CP supports proper work sequencing and organisation, it makes the site tidy and supports safe working on the project. Again, with majority claiming not to be sure, it could mean the relationship between LPS/CP and safety had not been clearly understood by some of the respondents.

7.6 Cross Case Study Analysis and Discussion

The individual case studies and findings have been presented and partly discussed in sections 7.3, to 7.5. The focus of this section is to compare the findings across the cases and to discuss the implication of the findings in developing a strategy for the rapid and successful implementation of the LPS. The comparison focuses on the case study context, the LPS/CP practice observed, procurement practice, support required for implementation and the impact of the current practice on CPI. To simplify this section, the interview transcripts are not presented here as they have already been presented in the individual cases. The discussion focuses more on points that cut across the three case studies.

7.6.1 Case Study Context and Description of Case Study Projects

The aim of the cross case-study context comparison is to ensure the findings are properly interpreted in line with the context from which the data were obtained. Table 7.7 presents cross case comparison of the projects' attributes. The table shows that the case studies on which LPS/CP application was investigated cut across the major sectors of the UK construction industry. This suggests that the outcome of the study could offer wider lessons for the UK construction industry.

Table 7.7: Cross -case Comparison of Project Attributes

Project Attributes	CSP01	CSP02	CSP03
Nature of project	Highway and Infrastructure	Highways and Infrastructure	Building construction project
Location of project	North of Yorkshire, England	West of Yorkshire, England	West Midland, England
Nature of works	Upgrade to replace existing dual carriage way with three new lanes	Improvement of motorway to Smart motorway	Educational new build

Type of client	Public client	Public client	Public client
Mode of contractor selection	Framework agreement and ECI	Framework agreement	Framework agreement and ECI
Proposed project duration	30 months	24 months	30 months
Stage of project at end of the case study	57% completion	80% completion	85% completion
Procurement arrangement	D&B, joint venture	Traditional design bid and build, joint venture	D&B
Contract sum	£380 million	£120 million	£20 million
Current number of subcontractors on site	10	9	16
Point of application of LPS principles	Construction	Construction	Construction
LPS facilitation process	Internally facilitated	Internally facilitated	Internally facilitated

7.6.2 Demographic Information of Research Participants

In all, 28 semi-structured interviews were conducted across the three case studies as shown on Figure 7.14. The research participants interviewed comprise of 9 SM, 6 MM, 6 OM, and 7 SC. This shows all the key stakeholders were involved in the interviews, although the number interviewed varied across the projects. While CSP01 recorded the highest in the number of SM interviewed, the highest number of subcontractors interviewed was on CSP03. The variation in the number of respondents interviewed would further complement each other in the cross case analysis. It is worth stating that the reason for the variation has been offered in the individual case section. The high number of SC interviewed on CSP03 could be due to the high number SC on the project. Furthermore, the respondents' years of experience in the application of LPS/CP and in the UK construction sector is evenly distributed across the three cases, hence responses should be credible.

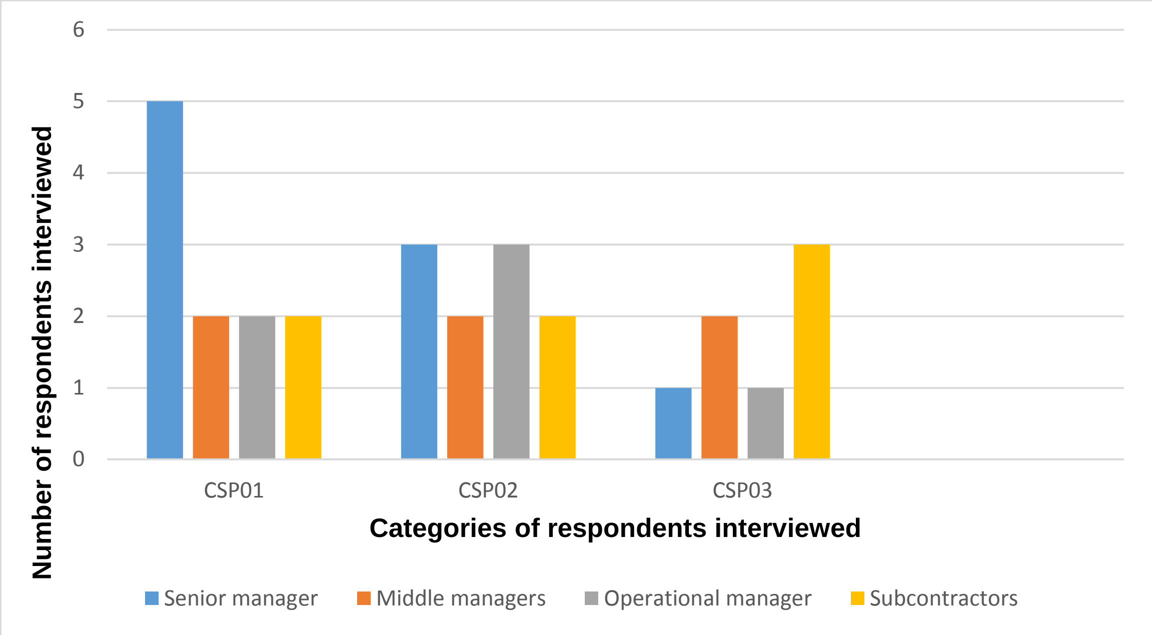

Figure 7.14: Cross Case-comparison of research participants

7.6.3 Cross-case Comparison of Last Planner/ Collaborative Planning Practice

Table 7.8 presents the Last Planner/Collaborative Planning practice as observed across the three case studies.

Table 7. 8: Cross-case Analysis of Last Planner System/Collaborative Planning

LPS Practice Observed	CSP01	CSP02	CSP03
Collaborative programming/phase planning	Implemented	Implemented	Implemented
6 Week look-ahead planning	Implemented	Implemented, but later reduced to 2 weeks at the tail end of the project	Implemented
Weekly Work Planning	Implemented, [13]daily huddle meeting was introduced later.	Implemented	Implemented, with daily huddle meeting
Constraint analysis and removal **(Make-ready process)**	Implemented, but lacked the rigour to remove constraints	Implemented, with partial strategy to remove constraints	Implemented, with partial strategy to remove constraints

[13] Daily huddle meeting was called daily stand up meeting on CSP01, and this was later introduced following some observation the researcher made to the facilitator in the course of the study.

Developing workable backlog	Not implemented	Not implemented	Not implemented
Prototyping/First Run Studies	Not implemented	Not implemented	Implemented
Average PPC	72.29%	90%	[14]90%
Recording of RNC	Recorded, with no much action on it	Recorded with some action	Recorded with some action
Learning	It occurred partially	Some level of learning occurred	Some level of learning occurred
Last Planner metrics measured			
PPC	Implemented	Implemented	Implemented
Task Make Ready	Not implemented	Not implemented	Not implemented
Task Anticipated	Not implemented	Not implemented	Not implemented
Frequency of plan failure	Not implemented	Not implemented	Not implemented

Table 7.8 shows that the LPS practice implemented across the three case studies include, phase planning, WWP, measurement of PPC and RNC. This finding is similar to those identified from the exploratory interviews and the structured observation presented in Chapter Six. The findings were further triangulated to confirm the earlier results from stage three of this study. The study shows that daily huddle meeting was held on CSP03 and later on CSP01, but was not done on CSP02. Although daily huddle meeting was not part of the initial element of LPS (Daniel *et al.*, 2015, Ballard *et al.*, 2009), its use in monitoring how the production system is performing on the day of production on site is on the increase (LCI, 2015; Daniel *et al.*, 2015; Salem *et al.*, 2006). This could be due to its potential in checking the production system on the day of production and to also re-plan in case of any deviation. For instance, it was not done on CSP01 initially, but it was later introduced.

Constraint analysis was observed on all the three case study projects, however only CSP03 developed partial strategy to remove the identified constraints. On CSP03,

[14] For confidential purpose the researcher is not allowed to published the PPC and RNC result on CSP03

constraints and action log were collaboratively developed by the team with actions assigned. However, the action log was only circulated via email to the distribution list at the end of the look-ahead planning meeting. It was also not published visually in the collaborative programming as expected. Publishing it visually not only improves process transparency but also keeps all the stakeholders on the project conscious of the actions required of them. On CSP01, constraints were only partially logged with no personnel given the clear action to address the identified constraints. Also, on CSP02, constraints were logged but not all the responsible persons for actions were usually available at the look-ahead planning session, especially the designers. Hence, another separate meeting had to be arranged with the team.

This show there is lack of discipline in the constraint removal process on the case study projects. Previous studies have also shown that there is lack of rigour in the implementation of more complex elements of the LPS such as the make-ready process (Daniel *et al.*, 2015; Dave *et al.*, 2015; Lindhard and Wandahl, 2014; Ballard *et al.*, 2009; Alarcon and Caldron, 2005). Furthermore, Table 7.8 reveals that CSP01 has the least PPC average of 72.29 %. Though this may seem good, however, going by the meaning and goal of PPC in showing workflow reliability (Ballard, 2000), this may not be true on CSP01. This is because it was observed from the interview that sometimes there were cases of over and under estimation of the amount work to be done by those doing the work. For example, Figure 7.1 shows PPC of 0% and 100% in some weeks on CSP01 which further attests to this fact. In some cases, PPC could be 100% with work still behind schedule when tasks are not properly made ready (Hamzeh, *et al.*, 2012).

Also, RNC were recorded on all the three case studies. The main causes of RNC on CSP01 were previous work not done and under estimation, while on CSP02 it was design changes and change of priority (see Figure 7.2 and 7.7). On CSP01, the lack of rigour in the make-ready or constraint removal process could have contributed to the frequent occurrence of previous work not been completed on the project and also the lack of honesty in making promises. Dishonesty and insincerity in promising was seen as barrier to LPS/CP implementation on the three case study projects.

The study reveals that among the many LPS metrics, only PPC was measured on the projects. Metrics such as Task Made Ready (TMR), Task Anticipated (TA), and frequency of plan failure were not measured on any of the projects (Ballard, 2015;

Ballard *et al.*, 2009). This could be due to the ignorance of the existence metrics and the level of maturity of the use of LPS. According to Hamzeh *et al.*, 2015; Ballard *et al.*, 2009, the above mentioned LPS metrics are less practiced even on projects that claim to use LPS, this implies the situation is not peculiar to the UK construction industry alone.

The study reveals that some form of learning occurs on all the projects, however, the amount of rigour required to actively translate the learning is inadequate. For instance, on CSP01, though RNC was recorded, one of the respondents stated that not much was done with it. Also, developing workable backlog was not done on any of the case study projects.

7.6.4 Cross-case Comparison and Discussion on Procurement and LPS/CP Practice

Table 7.9 presents the cross-case comparison from the three case study projects on procurement and LPS/CP implementation. This is discussed under two themes; procurement practice and procurement impact on LPS/CP implementation. Table 7.9 shows the summary of procurement practices and their impact on LPS/CP implementation on the three case studies. As shown in the table, it is clear that the procurement practice had influence on the implementation of the LPS/CP on the three case study projects. However, it is not the major determining success factor for the LPS/CP implementation. For instance, one respondent on CSP03 argued that, the success achieved in the LPS/CP implementation on the project will still be possible even if other forms of procurements was used. This shows procurement is not actually the gateway to LPS/CP implementation, rather, it is helpful in creating a collaborative working environment.

In some previous studies, it was perceived that the LPS could only work more effectively on D&B and on other collaborative contracts (Fuemana *et al.*, 2013). For example, Fuemana *et al.*, (2013.) in a New Zealand study that was based on perception of the respondents, opined that the full potentials of LPS implementation can be mostly realised on D&B and negotiated contract. However the study reported in this thesis provides empirical evidences that rebut such perceived narrow view, as the study reveals that the LPS/CP worked well on projects where DBB and D&B were adopted.

However, the role of using some form of collaborative approach in procuring projects alongside the use of LPS cannot be overlooked as all the three case study projects used some form of this. . For instance, on CSP02 where DBB was used, the subcontractors had been in a framework agreement for over five years. This supported the development of common understanding among the team and also the implementation of LPS/CP on the project. This suggests that the procurement approach to be used on a project should not be too rigid, but flexible to incorporate other collaborative practices.

Table 7.9: Cross-case Comparison of Procurement Practice

Procurement and LPS/CP	**CSP01**	**CSP02**	**CSP03**
Practice			
Procurement practice	**Joint venture, framework agreement, ECI**	**Joint venture, framework agreement**	**Framework agreement, ECI,**
Mode of contract	D & B	DBB	D&B
Impact			
Constructability issues	Regular Buildability/constructability	Frequent occurrence of constructability issues	Extensive constructability review at design stage
Design and scope changes	Less design changes observed, but design was lagging [15]behind	Frequent design and scope changes	Less design changes observed
Response to design issues	Just-in-time approach was used initially	Long lead time in receiving [16]response from design team	On-time response, but less design issues
Level of collaboration between construction and design team in LPS/CP meetings	**Strong,** the joint venture managed the design team	**Weak,** the joint venture had no power over the design team.	**Strong**, the main contractor managed the design team
Other impacts/strategy	Early involvement of the key [17]stakeholders who were not part of the production team	The expected response time from the design team was factored into the look-ahead planning process	Transfer of lessons learned by the team as a result of the framework

[15] Design was only at 50% completion before the commencement of construction work on CSP01.
[16] The design team on CSP02 do not attend the production planning meetings and it takes 9 days to receive feedback on design issues.
[17] Project governance bodies, such as the planning authority, local community, legal team etc were involved at the pre-construction stage.

Also, the use of LPS/CP on CSP02 alleviated other issues that could have occurred on the project considering the traditional mind-set the design team were adopting on the project. However, with the strategy of factoring in the design team's response time into the look-ahead and constraints removal process, the effects of their actions were minimised on the project. This is one of the key benefits of the LPS; it reveals bad news early which guides the team to plan better (Ballard, 2000; Mossman, 2014). Specifically, many months' worth of extra work as a result design and client changes, were completed within two months through the implementation of LPS/CP on CSP02 that used DBB.

7.6.5 Cross-case Comparison and Discussion on the nature of Support Required for LPS/CP Implementation.

Table 7.10 shows the nature of support required for the rapid and successful implementation of LPS/CP as gathered from the three case studies.

Table 7.10: Summary of the nature support required for LPS/CP implementation from the Case Studies

Category of support required	CSP01	CSP02	CSP03
Support/process at organisational level	• Provision of training. • Inclusion of it in the contract. • Continuous mgt. support.	• Training support • Mandating in contract • Awareness • Use of collaborative form of contract	• Involvement of the commercial team in the process • Mandating it in contract • Use of collaborative form of contract
Support/process at project level	• Appointment of a facilitator. • Involvement of all required team. • Digitalisation of Post-It Note. • Provision of LPS/CP room on site. • Active involvement of construction manager. • Pre-plan before session	• Pre-plan before session • Discipline and transparency • Facilitation and appointment of champions • Involve all the required stakeholders	• Honesty and truth in promising • Pre-plan before session • Facilitation • Training • Engagement with all required at the site level
External support/process	• Development of standard metrics for LPS/CP implementation • Industry and	• Educational institution support • Process standardisation	• Education and training support • Standardisation of the process

	academic partnership		

As shown in Table 7.10, the support required is all encompassing; that is, at the organisational level, project level and also external support. The study reveals that the nature of support identified on each of the project studied are similar, even with different type of project and management structure. This shows that the requirement for the successful and rapid implementation of LPS on building projects would not be different from that of highways infrastructure, ship building, and rail projects among others. This supports the assertion that the LPS is applicable to any production system that requires the management of material and human resource (Mossman, 2014).

7.6.5.1 Support Required for LPS/CP Successful Implementation at the Organisation Level

At the organisational level, various supports were identified on the three case studies. The reoccurrence of some of these factors on all three case studies shows their importance in the successful implementation of the LPS/CP in construction projects. For instance, the inclusion of LPS/CP in the contract was mentioned on all the case studies. Doing this is essential as it makes it a formal process on the project, thus encouraging more commitment to the process. Also, it would ensure that all the required stakeholders get engaged in the process as expected. This is important, as it was observed in a previous study, that subcontractors were not involved in production planning meeting on a project managed with the LPS/CP (Pasquire *et al.*, 2015).

Furthermore construction is filled with many formal processes (Kadefors, 2004), which sometime may not even support the goal of the project. However, the goal of LPS is to engender collaboration among the project team, while also focusing the team to achieve the common goal of the project (Ballard and Howell, 2004). According to Kadefors (2004), formalisation of construction process should not be in relation to cost alone, but should include other practices that would support the actualisation of the project objectives. The LPS should be considered to be among such formal practices or processes too. As demonstrated on CSP02, LPS/CP could still be included in the contract even when a contract approach such as DBB is used.

Furthermore, the inclusion of the commercial arm of the business in the LPS implementation loop was considered to be essential to the organisation in LPS/CP implementation. The place of involving the commercial team in the process cannot be overemphasised, since every change in the programme from the LPS/CP meetings as a result of reliable promising has its own commercial imperative to the project. Hence, their involvement in the production planning meeting as and when required could reduce the time required in making decisions that relate to commercial matters (cost, contractual implication etc.) during the make-ready and look-ahead planning sessions. However, this must be done with caution, as it has been observed that when the production shifts too much attention, the production system could fail (Conte, 1998).

7.6.5.2 Support required for LPS/CP Successful Implementation at the Project Level

Comparing the number of support identified for each category, the support required at the project level is the highest numerically. This is no surprise as the LPS itself is a project production management method designed for construction (Daniel *et al.*, 2015; Ballard, 2000). This shows that much attention is required at the project level for the system to function effectively especially at the implementation stage. However, this cannot happen without both organisational and external supports.

At the project level, the need for a facilitator and the appointment of champions to drive the process was identified on the three case studies. This is crucial as the process would not progress if there are no capable and experienced personnel to manage the process. On all the case study projects, the process was internally facilitated. However, on CSP01, it was argued that after the initial facilitation, the process should be left with the team. As good as this may seem, it could lead to the abandonment of the entire process as each member of the team has a specific role to perform on the project. Leaving the process to the team to do it, means no one would be held accountable. However, on all the three projects, LPS/CP facilitation was the primary responsibility of the facilitators which yielded better results. Furthermore, the need for discipline, transparency, and truthfulness especially in conversation and making promises by the stakeholders in production planning sessions were considered as essential at the project level on all the three case studies. This underscores the importance of realistic expectations and promises. Macomber and

Howell, (2001) identified five elements in making a reliable promise among project stakeholders. These are: (1) understanding the condition for satisfaction (2) competency to perform the task (3) capacity to perform the task (4) sincerity and (5) commitment to clean the mess, if failing. This clearly suggests that in making promises during production planning sessions, the team must be transparent and sincere that the capacity required to deliver the task is available before making the promise. It is through reliable promising in the LPS that trust and confidence increases/develops among the project stakeholders (Macomber and Howell, 2001).

7.6.5.3 External Support Required for LPS/CP Successful Implementation

As shown in Table 7.10, the need to standardise the approach or process was identified on all the case studies. Again, this shows that there are variations in the current implementation of LPS principles on the projects investigated in the UK. Daniel *et al.*, (2016); Dave *et al.*, (2015); Koch, *et al.*, (2015) also observed variations in the implementation of LPS principles on construction projects in the UK. It is worth noting that the partial implementation of LPS is not only in UK construction, a Norwegian study (Kalsaas *et al*,. 2014); a Vietnamese study (Khanh and Kim, 2015) and a Danish study (Lindhard and Wandahl, 2014) all reported that not all the components of the LPS were implemented as expected.

These shows that external support is needed as it will be too simplistic to conclude that the LPS does not need improvement. Studies have shown that the LPS is dynamic and it is now being incorporated with BIM, Location based management, and Takt planning among others (Daniel *et al.*, 2015; Seppanen *et al.*, 2010; Sacks *et al.*, 2009). Also, it is interesting to note that the LPS is currently being benchmarked by Glenn Ballard with input from current practitioners, research institutes, consultants, and the academia to improve the initial framework on which it was developed (Ballard, 2015).

Furthermore, partnership between the construction industry and academic institutions on research, with focus on LPS was suggested as an external support required. This partnership is important, as academic institutions would be able to communicate recent developments on its application and principles to the industry practitioners. For example, in Brazil, it was reported that the active engagement between construction companies and academic institutions on LPS principle implementation on projects has yielded positive results and similarly in Chile (Alarcón *et al.*, 2005; Formoso *et al.*, 2002). In the UK, institutions such as Nottingham Trent University, University of Cardiff, University of Salford, Lean Construction Institute UK and Costain Plc among others are into such research partnership with Highways England (Highways Agency, 2014).

7.6.6 Cross-case Comparison and Discussion on the Impact of LPS/CP Implementation on Construction Improvement.

Figures 7.4, 7.5, 7.9, 7.10, 7.12 and 7.13 present the results of the interviews and the survey on the impact of LPS/CP implementation on construction process improvement from the three case studies conducted. LPS/CP implementation impacts on construction time and programme, collaborative working practice, rework and quality and safety are compared across the three case studies below.

7.6.6.1 Impact on Time and Programme.

The study reveals that on CSP01, all the respondents indicated that more time had been gained as a result of the use of LPS/CP, while on CSP02 and CSP03 50% indicated to have gained more time. This was further confirmed from the interviews as various time gained were identified on all three projects at various points. For example, on CSP02, a subcontractor reduced 80 weeks' programme to 50 weeks. Also, on CSP03, 8 months delay was reduced to 4 weeks as at the completion of this case study. The construction manager on CSP01 observed that the LPS/CP process had a positive impact on the project as things were always done on time as a result of the phase planning or collaborative programming.

This shows that majority of the respondents believed that the LPS/CP implementation helps in improving the construction time and programme, since it allowed the team to identify the right logic for activities. A realistic hand over date is also made possible in the phase planning or collaborative programming process. Previous case studies have also reported the impact of LPS implementation on construction time or programme reduction (Adamu and Howell, 2012; Leal and Alarcón, 2010; Alsehaimi, *et al.*, 2009).

7.6.6.2 Impact on Collaborative Working Practice

All the respondents on CSP01 and 85% on CSP02 indicated that their collaborative working practice had improved on the project as a result of the use of LPS/CP principles. However, the nature of relationship that develops in the LPS arises from the social conversation which supports the development of collaborative working relationships (Priven and Sacks, 2015; Daniel *et al.*, 2014; Mossman, 2014). This is opposed to the traditional approach of project management that uses technical conversation (Daniel *et al.*, 2014; Ballard, 1997).

However, on CSP03, 66.7% of the respondents claimed not to be sure if their working practice had improved for the better. This could mean that even with the use of LPS/CP on the project, the mind-set change had not fully occurred in some of the project members on CSP03. According to Liker (2004), the foundation for the implementation of lean principles is the mind-set change.

7.6.6.3 Impact on Rework and Quality

Looking at the impact of LPS/CP on re-work, the study reveals there was a positive substantial impact on all three case studies. For example, 85.7% of the respondents on CSP01, 75% on CSP02 and 66.7% on CSP03 agreed to have observed a significant reduction on the level of re-work on their project. This shows the potentials of the LPS in helping the stakeholders to understand all the intricacies in the construction processes, thus reducing re-work and non-value adding activities. This was further confirmed in the interview by a subcontractor:

> *"We become more efficient and we can drive the programme which we may not do normally, since issues get resolved early, you do not have to go back and do re-work"*.

Furthermore, on CSP03, the finishing schedule for the rooms was done using LPS/CP processes such as '*First Run Studies'* or '*Prototyping', collaborative programming/phase scheduling* which reduced rework and snagging. The level of reduction in rework observed on all the case studies could be due to the collaborative processes adopted and some level of consideration for work flow especially on CSP03. According to Ballard (2000), work flow reliability reduces waste and rework.

7.6.6.4 Impact on Safety

The survey results on the impact of LPS/CP implementation on safety revealed that the respondents were not sure if the process had an impact on the safety performance of the project. For example, on CSP01, 71.4% claimed not to be sure, on CSP02 and CSP03, 62.5% and 66.7% respectively claimed not to be sure. This shows that majority of the respondents were unaware of the impact of LPS/CP implementation on safety performance on the project. The results show that safety performance seems not to be the focus of the implementation of LPS/CP on those case studies.

7.7 Chapter Summary

This chapter presented the results from the multiple case studies which form phase 4 of this study. This includes; the analysis of the three case studies, cross-case comparison and discussion of the findings. The chapter identified the impact of procurement practice on LPS/CP implementation, the support/process required for successful and rapid implementation, the impact of LPS/CP practice on CPI and the current LPS/CP practices observed on the three case studies considered.

The chapter shows that procurement practice has an influence on the implementation of the LPS principles. However, the chapter established that procurement is not the gateway to effective and successful implementation of the LPS as empirically demonstrated on the three case studies investigated. This implies that the LPS process could still work or yield less result irrespective of the procurement route adopted. For instance, the study shows that there is no significant difference in the level of implementation of the core elements of the LPS in relation to the different procurement approach used. This suggests that irrespective of the procurement route used, a mind-set change towards collaboration is essential for it to work successfully. However, collaborative form of procurement creates a supportive platform for the implementation of the process compared to the traditional forms of procurement. The chapter demonstrates that creating a collaborative working environment is crucial to LPS/CP implementation.

Furthermore, the chapter identified and categorised the nature of support required for the rapid and successful implementation of LPS in construction. These are; support/process at the organisational level, support/process at the project level and external support. Various factors were considered under this categorisation and the chapter concludes that all the factors are the foundation that needs to be in place for the successful implementation of the LPS/CP.

The chapter demonstrates that LPS/CP implementation has a positive impact on construction process improvement with regard to improvement in activity scheduling and programme reduction, collaborative working practice, better understanding of project goal and task, better communication and relationship among project team, significant reduction in rework, and efficient working among others. The chapter demonstrates that LPS implementation has a positive impact on construction programming time reliability.

In comparing the LPS/CP principles practiced on the three case studies, there seems to be some level of improvement compared to practices observed in structured observation in stage 3. However, the more complex elements of the LPS are still partially implemented and in some case not implemented at all both stages. Based on the findings in this chapter, and previous chapters an approach to support construction stakeholders for successful implementation of LPS on construction project is now proposed and presented in the next chapter (Chapter Eight).

CHAPTER 8: DEVELOPMENT AND EVALUATION OF THE LAST PLANNER SYSTEM PATH CLEARING APPROACH

8.1 Introduction

The previous chapter (Chapter Seven) presented the findings from the three empirical case studies on the application of production planning and control principles. This chapter builds on those empirical findings and those from the exploratory and structured interviews in Chapter Six to propose an approach that supports construction stakeholders (clients, main contractors, and subcontractors) in the implementation of the LPS in construction. It also builds on the literature review conducted in phase one of this study. Section 8.2 presents the rationale for developing the proposed approach known as the "*Last Planner System Path Clearing Approach"* (LPS-PCA). The theoretical and the general overview of the approach are presented in section 8.3 and 8.4 respectively. The block and schematic diagrams of the proposed LPS-PCA are also presented in section 8.4 while the descriptions are provided in section 8.5. The chapter further presents the rationale for the evaluation and results of the evaluation in section 8.6. The chapter demonstrates that the proposed LPS-PCA has the potential to guide construction stakeholders in developing an understanding of what needs to be in place for the successful and rapid implementation of the LPS. The chapter summary is presented in section 8.7.

8.2 Rationale for the Last Planner System-Path Clearing Approach

The need for supporting the implementation of new techniques, and practices using some sets of guideline, framework, roadmap, and approach among others has been acknowledged in the literature (Nesensohn, 2014; Ogunbiyi, 2014, Sacks *et al.*, 2009, Ballard *et al.,* 2007). However, studies that have attempted to propose an approach for implementing specific lean techniques such as LPS in construction tend to focus more on the project level (Lindhard and Wandahl, 2014; Hamzeh, 2011; Hamzeh and Bergstrom (2010), Dombrowski *et al.*, 2010); with less focus on a holistic approach that would support construction stakeholders in the implementation process. This is despite the fact that, it has been suggested that the implementation of lean techniques should expand beyond project focus and include other organisational and human factors that could influence the process (Pevez and Alarcon, 2006). The dearth of holistic approach to support construction stakeholders in the implementation of the LPS informed the development of the LPS-PCA. The objectives of the proposed Last Planner System Path Clearing Approach (LPS-PCA) are as follows:

- To highlight the foundational factors or path levels that needs to be in place for the rapid and successful implementation of the LPS in construction.
- To offer a structured and holistic view for LPS of the implementation in construction.
- To offer an insight on how to sustain the implementation of the LPS in construction using a systemic view.

Among other things, the proposed approach would pay attention to the above mentioned objectives.

8.3 Theoretical Overview of the Proposed Approach

The proposed approach is built on various theories that have been used to explain the working of LPS in construction. It also reflected on the shift from an RCM approach in urban planning to CP and similar reflections on software design and development in the IT sector. Studies on planning in economics, collaborative working practice, and relational contract were also considered. Some of these theories have been explained in the literature review chapters.

These theories include: Transformation, Flow, Value theory (Koskela and Ballard, 2006); the language/action perspectives (Macomber and Howell, 2003; Flores, 1982); management-as-planning and management-as-organising (Johnston and Brennan, 1996); the shift from RCM to CP in urban planning (Gunton *et al*., 2003) and Hayek's, (1945) comment about the way knowledge needed for planning is dispersed among individuals. The proposed approach is also explained from a relational contracting theory perspective (Macneil, 1980). The theory posits that when parties to a contract have confidence or expect to work together in the future by the provision of the contract, this would further influence the behaviour of parties on the project (Macneil, 1980). The main components of the proposed approach are presented in the succeeding sections.

8.4 Background to the Last Planner System Path Clearing Approach

The Last Planner System Path Clearing Approach (LPS-PCA) development is supported by the extensive literature review conducted in phase one of this study as presented in Chapters Two to Five and the empirical data collected in the UK in phases two and three as presented in Chapters Six and Seven. Through the literature review, LPS implementation barriers, success factors, components implemented, and trends in implementation from previous implementations across the world were identified, and recent developments in the LPS were examined. This brings in a universal perspective into the current approach proposed.

The empirical data on production planning and control practice in construction was sourced from the major sectors of the UK construction industry through various methods. These methods include: the interviews, structured observed, and multiples case studies. Through this, data on the current LPS practice, its current drivers, current success factors, current benefits, current barriers, the nature of the support required for its successful implementation and its impact on construction process improvements among others were identified. In all, a total of 58 interviews were conducted. This supports the contextualisation of the proposed approach and also presents the current evidence from the industry.

8.4.1 The LPS Path Clearing Approach

The LPS-PCA is to guide construction stakeholders (client, main contractors, and subcontractors) in developing an understanding of what needs to be in place for the successful implementation of LPS and also in sustaining the implementation. The proposed approach consists of three major components:

- organisational level path clearing,
- project path clearing and
- external enabler

8.4.2 What the proposed Approach is not

The proposed approach is not prescriptive; it is only a guide or roadmap to help in developing an understanding of what needs to be in place (Path Clearing) for the implementation of LPS in construction. This means it is not rigid and could be adopted/adapted to various situations. Also, the proposed approach is not intended to provide a detailed description of the methodology for LPS implementation as this is available in various publications (Mossman, 2014; Ballard, 2000).

8.4.3 The Reason for Using LPS-PCA

It enables users (clients, main contractors, and subcontractors) to develop an understanding on what is required for the successful implementation of LPS in both process and behaviour wise. The proposed approach is presented diagrammatically in Figures 8.1 (basic diagram) and 8.2 (schematic diagram).

8.4.4 Basic Diagram of LPS Path Clearing Approach

Figure 8.1 presents the basic diagram of the *"LPS Path Clearing Approach"* (LPS-PCA). The basic diagram indicates how components in the proposed approach are closely integrated. For instance, the figure shows that the organisational level feeds into the pre-project activities, while pre-project activities contribute to implementation on the project. The external enabling factors on the other hand support all the operations as shown in Figure 8.1.

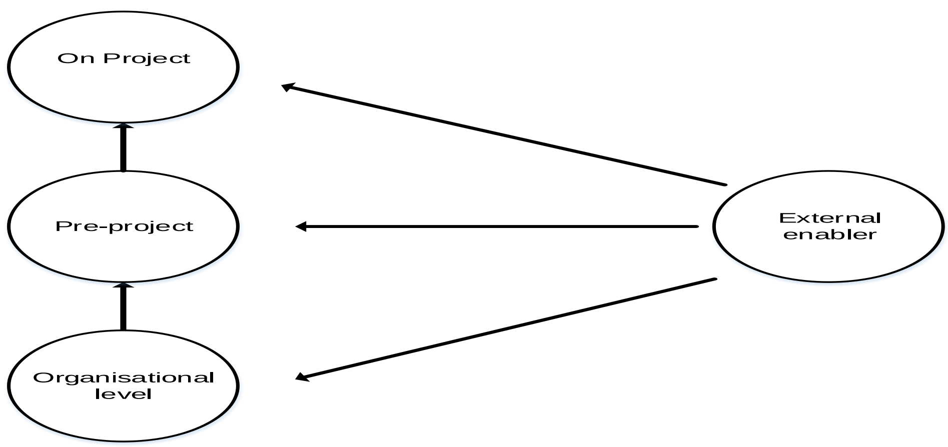

Figure 8.1: LPS Path Clearing Approach Block Diagram

Figure 8.1 shows that each part requires some form of input from other components for effective functioning. It is worth noting that both pre-project and project components fall under the project level i path clearing level as will be described later in Figure 8.2.

8.4.5 Schematic Diagram of LPS Path Clearing Approach

Figure 8.2 presents the schematic diagram of the LPS-PCA. It consists of:

- organisational level path clearing,
- project path clearing and
- external enabler

To improve understanding of the requirements at each path clearing levels, an industry guidance note was developed (see Appendix 11 for copy). This was done since the LPS-PCA focuses in supporting industry practitioners such as clients, main contractors, and subcontractors in corporate implementation of the LPS. However, in addition to this, a general description and definition of the components in Figure 8.2 are provided in this section, and each component is discussed in relation to previous studies. This was done to provide further insight into the theories that underpin the proposed approach.

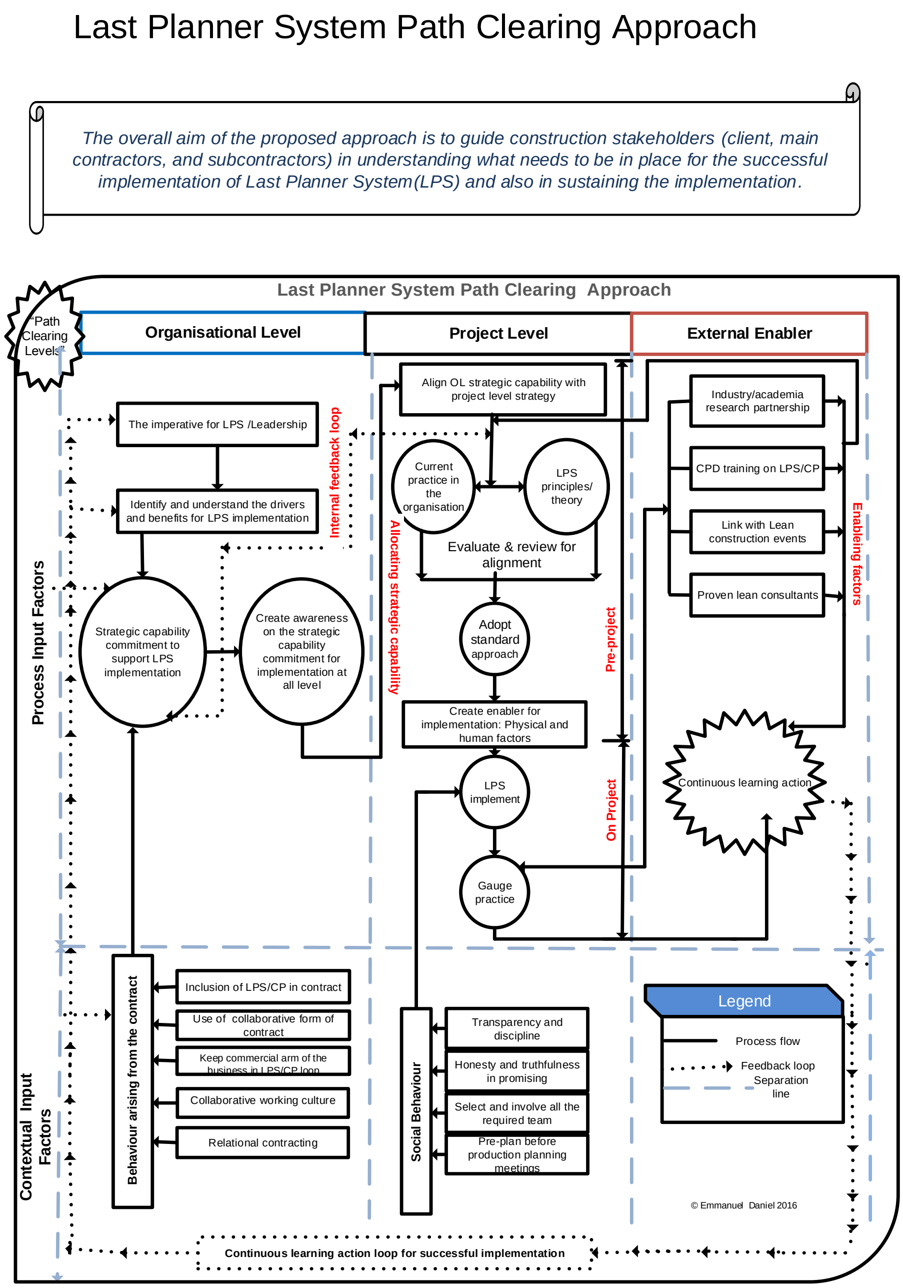

Figure 8.2: LPS Path Clearing Approach

8.4.6 Definitions of Key Components in the LPS-PCA

Path Clearing Levels: refers to the essential paths that need to be cleared for the rapid and successful implementation of LPS.

Organisational Level: this path identifies and defines what needs to be in place at the organisational level for LPS implementation. The organisational level factors also support the implementation of the LPS at the project level. It consists of the two input factors; the process input factor and the contextual input factor.

Process Input Factors: this refers to the processes that need to be created and practiced at the organisational and project levels to support the implementation of LPS.

Contextual Inputs Factors: behaviours that need to be in place both at the organisation and project levels to support the process inputs. This is part of the culture change required to implement LPS successfully.

Project Level: defines what needs to be in place at the project level for LPS implementation.

External Enablers: operates outside the organisational and project levels. They are strategically positioned to support the implementation of the LPS.

8.5 Description of the Composition of the LPS-PCA

The three path clearing levels and its associated components would be described in this section.

8.5.1 Organisational Level

Organisation plays a central role in the implementation of lean principles and techniques. The implementation of lean techniques has failed on projects in the past, because it was somehow disconnected from the organisation's vision and with too much focus on tools and methods (Pekkuri *et al.*, 2014). The conditions required at the organisational level (OL) for rapid and successful implementation of LPS as shown in Figure 8.2 are categorised into: (1) *organisational process input factors* (2) *organisational contextual input factors*. The process input factors are discussed below.

8.5.1.1 Organisational Level Process Input Factors

This refers to the processes that need to be created and practiced at the organisation level in the implementation of LPS. As it is called, it defines the processes that need to be in place at the organisational level (OL) for the LPS implementation. These include;

- identifying the imperative for LPS implementation/ leadership
- identifying and understanding the drivers for LPS implementation
- strategic capability commitment to support LPS implementation

- creating awareness on the strategic capability created across the business

a. The Imperative for LPS Implementation and Leadership

An organisation must identify the imperatives for the implementation of the LPS in its business. The imperative here is beyond having a goal of fulfilling an expectation from the client. For instance, in the UK, the demand from some public sector clients seems to be among the top imperative factors driving some supply chain companies in the implementation of the LPS. Such imperative factor or driver cannot sustain the implementation of the LPS, and indeed is a weak imperative factor.

Ideally, the imperative for LPS implementation should be based on the desire to become an active agent to support collaborative behaviour among employees. This implies that both the client and supply chain have a role in championing the LPS implementation. Also, it shows that the LPS implementation should not be championed by client companies alone, as perceived by some supply chain companies. Also, this imperative should be made explicit, as it has the potential of stimulating the top management in supporting the implementation. This could be on financial basis, time basis, risk or all three.

In addition to this, a high level leadership support is required to drive the process. Previous studies have shown that top management support and leadership are essential in the successful implementation of lean techniques such as the LPS (Drysdale, 2013; Hamzeh and Bergstrom 2010; Kim *et al.,* 2007). The expected leadership style is not just top down or bottom up; it is better described as 'empowered leadership' emanating within the team. It means each member of the team is empowered with the capacity to rise to the occasion when the need arises. Furthermore, the factors (drivers) that cause the imperative must be identified.

b. Identify and Understand the Drivers and Benefits for LPS Implementation

The specific drivers for the implementation of LPS should be identified. This is important as the drivers for LPS implementation in a client organisation could vary from that of a contracting organisation and even from one client or contracting organisation to another.

This implies each organisation must identify its own drivers as evidenced from this study. The drivers for LPS in clients' organisations could include:

- quest to overcome past failures
- quest for time compression and more realistic time
- cost saving and risk reduction
- price reduction from supply chains
- quest for better working relationship with supply chains and
- benefits from previous implementation.

Drivers for supply chain companies could include:

- client and public sector demand
- quest for time completion
- internal desire for continuous improvement
- project complexity
- time certainty and efficient working
- avoidance of time overrun that could lead to liquidation and damages
- quest for improved communication with team

The early identification of these drivers is an essential process input which should be in place, as it has the capacity to put pressure on organisations (client and supply chain companies) to create the needed change that could support the implementation. According to Ogunbiyi, (2014) identifying the drivers for lean implementation could support change in the organisation. Also, the benefits of LPS implementation should be explained to the top managers in the organisation as it would drive the management to develop strategic capability to support the implementation.

c. Strategic Capability Commitment to Support LPS Implementation

After identifying the imperatives and drivers for LPS implementation, it is important to develop a clear strategy and capability to support the implementation. Without a clear strategy, the LPS implementation cannot be sustained in the organisation. Both construction client and supply chain companies must create their own strategy.

This should focus on deliberate commitment to develop the required capability at the OL that would support the implementation. Findings from this study reveal that cultural issues were among the most reported barriers to the implementation of the LPS. This could be minimised through the development of the right strategy and creating policies that could influence the organisational culture in the implementation process.

This implies that the strategy should not be selected in isolation. Karim and Arif, (2013) observed that selection of the wrong strategy in the implementation of lean principles could lead to the disruption of the process it intends to improve. The strategy could include: provision of training for staff and the supply chains, supply chain assessment, changes to contract, and creation of lean business department among others. When there is clear strategy, the chances of hitting the targeted goal is high. In doing this, a clear contextual behaviour should be put in place at the OL to support the strategy.

d. Create Awareness on the Strategic Capability Commitment LPS

The identified strategic commitment capability for LPS implementation and the process created to formalise them at the organisational level must be communicated through training at all levels. This could entail the use of company intranet to communicate such an approach and information. The information guiding such an approach should be located in areas where it would be prominent and accessible. Also, workshops and training on the strategic capability commitment required should be organised at all levels. Specific avenues and approaches that could be used to create awareness on this include:

- company intranet, newsletters, updates from formal project meetings
- workshops, trainings, and
- monthly project briefing among others

This would enable all the departments within the business to understand what the organisation is doing, which would influence their own individual commitment to the strategic capability identified at the OL. The importance of creating awareness on company strategy at all levels has been emphasised in literature (Hodgkinson *et al.*, 2006; Elving; 2005). Elving, (2005) pointed out that creating awareness on the chosen strategy should be a fundamental consideration in the strategy development at the OL.

8.5.1.2 Contextual Inputs Factors (Behaviours arising from the contract)

Contextual input factors are the appropriate behaviours that should be in place at the OL to support the strategic capability commitments for LPS implementation. It focuses on the behaviours arising from the contract and its application in the process. It helps in formalising the strategic capability identified, thus, it should form the key components of the strategic capability commitment process. The behaviours arising from the contract include:

- the inclusion of LPS in the contract
- use of collaborative form of contract
- relational contracting
- collaborative working culture and
- keeping the business arm of the organisation in the LPS loop

a. Inclusion of LPS in the Contract

Findings from this research reveal that LPS practice was formally included in the contract agreement between the main contractor, client, and subcontractors on most of the projects investigated. The essence of its inclusion in the contract was to encourage all the required stakeholders to get involved and benefit from the process. This is necessary because of the numerous formal processes that dominate the construction industry. It has been suggested that formal process should not be in relation to cost alone, rather it should include other soft practices that contribute to the project's success (Kadefors, 2004). Undeniably, the LPS process is not an exception to this, and thus should be formalised.

b. Use of Collaborative Form of Contract

The use of collaborative form of contract is an essential element in the contractual behaviour that needs to be in place at the OL for LPS implementation. Empirical evidence from this study reveals that on most of the projects investigated, a collaborative form of contract was used. This include; framework agreement, ECI, D&B and joint venture. The study reveals that even when design bid build (DBB) is used on a project, and the supply chain has been in framework agreement, collaborative relationship still develops.

The contractual behaviour that occurs here could be better explained with relational contracting theory. According to Macneil, (1980) as parties to the contract have more and frequent conversation on the project, the relationship begins to develop. Also, the assurance of the possibility of securing a future job, for example, in a framework agreement, could motivate the team to get committed to each other on the project. Harper, (2014) asserted that when there is shared expectation between teams on a project, it would influence their behaviour on the project. This suggests that contractual behaviour has the potential of supporting collaborative behaviour on a project.

c. Inclusion of the Commercial Arm of the Business in the LPS Loop

Another contractual behaviour that should be keyed into the organisation's strategy is the inclusion of the commercial arm of the business in the LPS implementation loop. Although this was only mentioned on one project, it seems to be an essential pre-condition to be considered at the OL. Currently, the commercial arms on projects are less involved in the production planning meetings in the LPS process. The involvement of this business group in the production planning session could improve the make-ready process, as it could enable the team to make real time decision that requires commercial judgements.

This implies that commercial decisions may not necessarily need to be logged as constraints, thus reducing decision making time on the project. In addition to all the factors discussed above, it is important that a new approach or strategy to working should be communicated to other parts of the business from the organisational level.

8.5.2 Project Level

The project level (PL) factors are linked to the organisational level factors. The implication of this is that the strategic capability commitment for LPS implementation at the OL must be allocated appropriately at the project level. The PL is sub-divided into pre-project and project implementation activities as shown in Figure 8.2. Similar to the OL, the project level (PL) consists of the process input factor and contextual input factor.

8.5.2.1 Project Level Process Input Factors

This refers to the processes that need to be created and practised at the project level in the implementation of LPS. It defines the processes that need to be in place at the project level (PL) for LPS. This includes:

- Project level strategic capability commitment
- Identify and understand production planning practice on the project
- Evaluate practice with LPS principle and theory
- Adopt standard approach
- Create enabler for implementation

- Implement and gauge implementation

a. Align and Allocate Strategic Capability with Project Level Strategy

It is essential for a strategy to also be developed at the PL, and aligned with the OL strategy. This is important as the team on the project would be coming from different organisations. For example, an organisation can tell its employees it wants them to embrace a process and educate them on why. However, projects should develop their own identity due to the vast array of companies required to deliver a project.

In view of this, the project set-up; the companies involved including client, contractor, suppliers and designer should establish a joint strategy that considers the unique characteristics of the project. This should be aligned with the strategic support for LPS implementation.

b. Identify and Review Production Planning and Control Practice

At this point, it is essential for the production planning and control practice to be understood and streamlined to meet the strategic support allocated to the PL for the LPS implementation. To achieve this, the current production planning practice should be evaluated with an enhanced production planning and control principles such as the LPS principles.

c. Evaluate and Review Practice Using the LPS Principles

The LPS is a production planning and control method developed for the construction industry and it is among the most used lean techniques in construction. Thus, the production planning and control practice on the project should be evaluated and reviewed for alignment with the advocated principles/theory of the LPS (Ballard, 2000). The underlying theories of the LPS revolve around planning, execution, and control (Ballard *et al.*, 2009). The LPS is based on five principles which are to:

- ensure tasks are planned in increasing detail the closer the task execution approaches
- ensure tasks are planned with those who are to execute them
- identify constraints on the planned task to be removed by the team beforehand
- ensure promises made are secure and reliable and

- continuously learn from failures that occur when executing tasks to prevent future reoccurrence.

Evaluating the practice based on the LPS principles would enable the identification of areas that need improvement. The evaluation entails reviewing the practice with the six core components of the LPS (See section Chapter 5 for detail discussion of on LPS components). The evaluation should identify what is working well and the areas that need improvement. This is important as it has been observed by a notable management science theorist, Peter Drucker in one of his quotes as cited in Hasseberth, (2008) that: "what cannot be measured cannot be improved". A similar evaluation and review conducted showed high potential in revealing the level of alignment in the practice and identifying areas that need support/improvement (Priven and Sacks, 2015; Daniel *et al.*, 2016). This in no doubt would provide an understanding on the improved/standard approach to be adopted on the project.

d. Adoption of Standard Approach (Specific Capability commitments required)

Based on the evaluation and review, a standard LPS approach should be adopted. The absence of such typical approach could result into varied implementation of the process across projects executed in the same organisation. This means a project could be reinventing its own wheel which could hinder the intended benefits from the system. It is worth noting that the standard approach is not rigid, thus, it could be positioned to meet the reality on the project. However, since the LPS has 6 standard components (Mossman, 2014; Ballard, 2000), the team should develop the specific capability commitments required for the implementation of the components on the project.

e. Create Implementation Enablers for LPS implementation

For the adopted approach to work, implementation enabler should be created. The implementation enablers are grouped into two: physical and human factor enablers. The physical factors entail the allocation of designated room for production planning and control. This should include creating physical space such as co-location for working and visual production planning and control centre. Such location should be readily accessible to all the required stakeholders on the project including the subcontractors. Also, this needs to close to work stations to prevent non-value adding activities that could come from unnecessary movement. Furthermore, the board located in the room has the potential of communicating information visually to the team during and out of meeting time.

The human factor on the other hand is concerned with the appointment of facilitators and lean champions in driving the process on site. In the context of this study, all the research participants identified facilitation as an essential process that needs to be in place for the successful implementation of the process at the project level. It includes both external and internal facilitation. External facilitation such as the use of proven lean construction consultants could prove useful at the initial start. However, over reliance on consultants should be avoided. This is because it could make the team to view the process as an external initiative, thus reducing their commitment to the process. Previous studies have also identified the importance of facilitation and appointment of lean champions in LPS implementation (Mossman, 2015; BRE, 2006; Salem *et al*., 2005).

f. Gauge Practice

As the implementation process continues, it is important that the practice is constantly gauged using both internal and external mechanisms. To gauge the practice internally, the Planning Best Practice (PBP) guide should be used to access the level of implementation on the project (Bernades and Formoso, 2002; Priven and Sacks, 2015). The PBP guide is developed based on extensive research on the application of LPS principles in construction. These studies identified 15 LPS practices. The PBP has been used to assess the implementation of the LPS in different parts of world such as Brazil, Israel Chile, and UK among others (Bernades and Formoso, 2002; Priven and Sacks, 2015). However, a recent study identified two other practices that are considered to be essential to the practice of the LPS, which makes it 17 LPS practices (Daniel *et al.,* 2016).

In addition, the LPS implementation maturity guide could be used. The guide was originally developed by Gregory Howell in 2005, one of the inventors of the LPS (Lean Project Consulting, 2005). Through this, the efficacy of implementation could easily be assessed internally and areas that need improvement could be identified and addressed appropriately. Gauging of the practice also requires input from the external enabling factors.

8.5.2.2 Project Level Contextual Input Factors (Social Behaviour)

To successfully implement the adopted common approach, contextual input factors embedded as social behaviours are required at the project level. Social behaviours are those soft skill behaviours that need to be practiced by the team on the project for the successful implementation of the LPS at the PL. These factors include:

- transparency and discipline,
- honesty, trust and truthfulness in promising,
- selection and involvement of all the required team,
- pre-planning before production planning, and
- proactive involvement of the construction manager and subcontractors

These are among the social behaviours that should be in place at the PL for the rapid and successful implementation of the LPS. The need to be cautious about lack of honesty and poor promising in the implementation of the LPS has been explained theoretically from the Language/action perspective theory (Macomber and Howell, 2001). Practically, it entails making promises that are realistic and achievable within the timeframe. This suggests that no stakeholder on the project should be pressurised into making undue commitments. The five conditions for making reliable promise should be adhered to in LPS implementation (Macomber and Howell, 2001). These are:

- understand the condition of satisfaction (CoS)
- access competency before making promise
- ensure capacity available and allocated
- empower the team to say YES OR NO (sincerely)
- accept responsibility for failure and re-review the process for learning

The action expected here is informed by social information exchange (conversation) (Gonzalez *et al*., 2015; Macomber and Howell, 2003) as opposed to the technical information exchange that dominates traditional project management (Ballard and Howell, 1997). In such social conversations, as advocated in the LPS, every stakeholder is empowered to make promises which could be YES! or NO!.. It has been observed empirically that where such social network of conversation exists on a project, the LPS works in managing the production on site effectively (Priven and Sacks, 2015).

Also, reliable promising supports workflow and programme reliability which is the core focus of the LPS (Macomber and Howell, 2001). This shows the importance of social behaviour in the implementation of LPS at the project level. Furthermore, all the required team members should be involved in the process including the subcontractors. The proactive involvement of the construction manager in production planning also increases the buy-in of other stakeholders on the project.

8.5.3 External Enablers

External enablers can help in gauging practice, and can bring in new strategies and innovations to improve current practice both at PL and OL as shown in Figure 8.2.These external enablers include:

- research partnership between the industry and the academia
- CPD training courses on LPS
- engagement with proven lean construction consultants, and
- Lean Construction Institute events.

Also, there is need to deliberately engage with the identified external enabling factors presented above. This is essential as it has been observed that the LPS is dynamic and it always uses various avenues to improve practice, for example, its use of theory to explain practice (Daniel *et al.,* 2015). Such external forum and partnership could be an avenue for communicating and learning about improvements or findings. Research partnership with the industry and facilitation of the process supports the implementation of the LPS. Previous studies have also shown that research partnership with the industry and facilitation of the process proven facilitators could support the success of the LPS implementation in construction (Mossman, 2015; Alarcón *et al*., 2005; Formoso *et al*., 2002).

8.5.4 Continual Learning Action and Feedback Loop

The continual learning action is the loop that sustains the implementation of the LPS. It focuses on learning and taking action at each level. The continual action learning advocated occurs at every point in the process as shown in Figure 8.2. This implies that learning does not just occur at the end of the entire process only, since there is an internal feedback loop. As shown in Figure 8.2, there is an internal feedback loop between the OL and PL; this is done to ensure issues that need addressing are attended to before the process is rolled out completely.

For instance, with the roll out of a set of strategies, unintended consequences may occur and it is helpful to understand these sooner than later. This shows the importance of creating internal feedback loop as shown in Figure 8.2. In the implementation of the LPS “bad news early could be said to be good news”.

To sustain the implementation of lean techniques, the organisation must be positioned to be a learning organisation (Henrich *et al.,* 2006). This implies that individuals within the organisation should not only learn, but should be willing to change from the old ways of working. According to Mohd-Zainal *et al.,* (2013) organisations do not learn, it is only the individuals in the organisation that learn. This further show the important role people play in the sustenance of LPS implementation. An inference could then be drawn thus that; the more individuals in the organisation learn, the more the organisation learns, and the higher the chances of sustaining lean practice. Mohd-Zainal *et al.,* (2013) asserted that there is a strong relationship between organisational learning and sustaining of lean practice. Renowned researchers in lean such as Jeffrey Liker also recognised the relationship between lean implementation and organisation learning (Liker, 2004).

Furthermore, all the learning actions feedback into the entire system to support the internal feedback loop as the system continues. For effective learning, action data should be captured and a formal strategy should be developed to act on them to support continual learning. New ideas and innovations emerging from the implementation process should feedback into the system for improvement as shown in Figure 8.2.

8.6 Evaluation and Refinement of the LPS-PCA

8.6.1 Rationale for Evaluation of the Proposed Approach

The LPS-PCA was evaluated to achieve the following specific objectives:

- To confirm if the three path clearing levels categorised in the proposed approach should be the core areas to focus on in LPS implementation.

- To assess the adequacy of the content of each of the path clearing levels identified.
- To evaluate the usefulness of the proposed approach in supporting construction stakeholders in the implementation of LPS.
- To identify areas that need to be removed, included, or improved.

8.6.2 LPS-PCA Evaluation Method

The importance of validating research outcomes from research participants and other stakeholders which the research output could benefit cannot be over emphasised. Bazeley, (2013) described respondent validation or member checking as a process of arriving at an agreement between those that participated in the study and/ or did not participate in the study to comment on the output from the study. Such approach has been identified as a good strategy to guide the quality of the research outcome and in the interpretation of the data (Bazeley, 2013; Silverman, 2011; Cresswell, 2007). In evaluating and validating the proposed LPS-PCA approach, expert opinion was sought from lean construction practitioners through semi-structured open ended interview and survey. It has been suggested that complex and non-quantitative models could be validated using qualitative interviews and surveys (Smith 1983).

Lean construction practitioners were used in evaluating and validating the LPS-PCA. The lean construction practitioners were categorised into two: the original study participants (SP) and the non-study participants (NSP). This was done to understand the level of difference in the perception of those who participated in the study and those who did not participate in the study on the proposed approach. The feedback from those that participated in the study provides internal validity, while those from non-research participants support external validity. Silverman, (2011) stated that verifying research outcomes with the research participants further increases the confidence in the credibility of research results. However, Bazeley, (2013) cautioned that the feedback from the research participants only may not necessarily be final, as there could be possibility that the researchers conclusion could differ from the respondents' views.

Twelve questions were developed (see Appendix 9) to evaluate the LPS-PCA. The questions were structured and open-ended to enable the respondents' air their views appropriately as required. The evaluators were drawn from the UK, US and

Australia; this was done to bring a wider perspective on the approach. However, majority of the respondents were from the UK, this is because the study was conducted in the UK. The results of the evaluation are presented and discussed below.

8.6.3 Demographic Information of Participants used in the Evaluation

The respondents that participated in the evaluation of the "Last Planner System Path Clearing Approach" (LPS-PCA) are in two categories: those that participated in the study are denoted with a code (SP) and the non-study participants denoted with a code (NSP). However, all have some level of experience in the use of production planning and control principles based on the LPS in construction as shown in Table 8.1. The respondents were drawn from client, main contracting, subcontracting, and consulting organisations. This shows that the evaluation results would sufficiently represent the view of key practitioners the proposed approach is targeted at. Also, all the respondents have sufficient experience in the use of LPS which means their view could be relied on.

Table 8. 1: Background Information of the Participant used for the evaluation

Participant code	**Position**	**Country of Operation**	**Years of exp. in LPS**	**Years of const. exp.**
SP01	Senior Excellence manager	UK	15	20
SP02	Production planning manager	UK	3	18
SP03	Programme manager	UK	6	40
SP04	Senior consultant	UK	3	7
NSP05	Assistant operation manager	UK	1	1
NSP01	Lean process deployment manager	Australia	10	30+
NSP02	Lean Advisor	US	1	3
NSP03	Continuous Process improvement manager	UK	1	1
NSP04	Senior consultant	UK	4	11
NSP05	Senior Planner	UK	1	18

However, those with low number of years' of experience in the use of LPS were purposively included in the sample to show how easy the proposed approach would be to new users. Table 8.1 shows that the respondents were drawn across different countries. This enabled the study to demonstrate the possibility of adopting/adapting the approach in other parts of the world outside the United Kingdom where the original study was conducted.

8.6.4 Discussion of the Evaluation Results

Table 8.2 presents the mean responses from the two categories of the respondents (SN and NSP) that participated in the evaluation of LPS-PCA. The response was measured on Likert scale 1 to 4 (where 1= Very low coverage, 2 = low coverage, 3 = high coverage and 4 = very high coverage). The results indicate that there is no significant difference in their responses on the key aspects of the LPS-PCA evaluated.

Table 8. 2: Results of LPS-PCA Evaluation

	Aspect of LPS Path Clearing Approach Evaluated				
Participant Code	Appropriateness of the identified three path clearing levels	Level of completeness of factors considered at the OL	Level of completeness of the factors considered at the PL	Level of completeness of factors considered as eternal enabler	Usefulness of the approach in LPS implementation
Study participants response					
SP01	3	2	3	4	Yes
SP02	4	4	4	3	Yes
SP03	2	3	3	3	Yes
SP04	3	3	2	4	Yes
SP05	3	3	3	3	Yes
Mean response	**3**	**3**	**3**	**3.4**	
Non study participants responses					
NSP01	4	3	3	3	Yes
NSP02	3	3	2	3	Yes
NSP03	4	3	3	3	Yes
NSP04	4	3	3	3	Yes
NSP05	4	3	3	3	Yes
Mean response	**3.8**	**3**	**2.75**	**3**	
Overall mean response	**3.4**	**3**	**2.89**	**3.2**	Yes

For example, the mean responses for the completeness of the factors consider at the OL by the SP and the NSP is 3. This shows that there is no significant variation in their responses in relation to the LPS-PCA. It also implies that both those that participated in the study and those who did not, believed that the factors considered at the OL are comprehensive in relation to LPS implementation. This finding reinforces the internal and external validity of the proposed approach. Furthermore, Table 8.2 revealed that the consistency is not just across the two groups only, but within the groups also.

8.6.4.1 Completeness of Components and Contents of the Proposed Approach

The evaluation results reveal that both the SP and NSP believed that the three path clearing levels considered in the LPS-PCA are essential areas to focus on in LPS implementation with a total mean response of 3.4. Majority of the respondents also agreed that the factors considered in each path clearing level have a high coverage. For example, the total mean response for OL is 3, PL is 2.89 and external enabler is 3.2. This shows that the key factors that would enable clients, main contractors, and subcontractors to develop an understanding of what needs to be in place for the successful implementation of the LPS are adequately considered in the proposed approach. One of the respondents stated that: "*All was covered sufficiently*" **[NSP05, UK]**

However, the level of coverage of the content at the project level seems to shows the least response from the research participants, with a total mean response of 2.98. This could be due to the high expectation of the respondents on this, since LPS is a project based production management system. For instance, some of the respondents suggested a step by step guide for LPS implementation on a project. However, this is not the aim of the proposed approach, since such steps have already been published (see Mossman, 2014; Ballard, 2000). Nevertheless, in response to this, an industry guide was developed to enable the stakeholders understand the step actions required at each path clearing levels (see Appendix 11 for a copy). Also, the results in Table 8.2 indicate that both the SP and NSP believed that the factors considered as external enablers are comprehensive with an average mean response of 3.4 and 3 respectively.

8.6.4.2 Application and Usefulness of the Proposed Approach

All the respondents agreed that the proposed approach would definitely support the implementation of the LPS in construction. Since this question was open-ended the respondents were able to air their views on the usefulness of the LPS-PCA. Some of the respondents stated that:

> *"Yes, as it gives structured approach to planning with the project team including the supply chains, it helps draw upon a vast amount of knowledge and experience"* **[SP02, Production Planning Manager- UK].** *"Yes, it gives more clarity and structure"* **[NSP01, Lean Process Deployment Manager- Australia].** *"Yes, having a framework/guide to clearing path for implementation would help"* **[NSP04, Senior Consultant- UK].** *"Yes, a structured approach is essential"* **[SP03, Programme Manager- UK].** *"Yes, it will provide a high level strategy path for implementation across our business"* [**NSP05, Senior Planner-UK]**

The above statements clearly show that the proposed approach would be useful to construction stakeholders in the implementation of the LPS in construction. However, some of the respondents recommended that the proposed approach should be used with the support of an experienced coach for maximum benefit. Here are some of the comments:

> *"The approach should be used with support of a facilitator/lean champion"* **[NSP01, Lean Process Deployment Manager- Australia].** *"The approach should be used with the support of an industry experienced coach"* **[SP03, Programme Manager- UK] "***As it stands, I would recommend that the proposed approach should be used with some form of consultation with experts" "* **[NSP04, Senior Consultant- UK].**

The above statements show the need for engaging experienced facilitators and lean champions in using the approach. A previous study has highlighted the importance of facilitation in the implementation of the LPS (Mossman, 2015). Furthermore, majority of the respondents indicated that the proposed approach can be adopted/adapted in any part of the world. Some of the respondents stated that:

> *"I am sure it could be adapted anywhere, as the overall objective is the same"* **[SP03, Programme Manager- UK]**. "*My view is that the proposed*

approach could be adopted on any construction project irrespective of the location" **[NSP02, Lean Advisor- US].**

This shows that the usefulness of the proposed approach is not just limited to the UK construction industry where the study was originally conducted. Since this assertion is also supported by other research participants drawn from the US and Australia. However, some of the respondents suggested that the proposed approach should be rolled out to the senior management team first. Some of them stated that: *"The approach should be rolled to the senior management team first, then cascaded down to project and site level"* **[NSP05, Senior planner-UK]**. Again, this further confirms that the way in which the LPS-PCA is structured is appropriate.

8.6.4.3 Refinements to LPS-PCA Following Evaluation Feedbacks

One of the objectives of the evaluations is to identify areas that need improvements in the proposed approach. Some of the respondents suggested that an industry tailored guidance note should be developed to supplement the proposed approach. Some of the respondents stated that: "*It needs to be supported with accompanying notes for the site team*" **[SP02, Production Planning Manager- UK]**. "*Guidance note that explains each component should be provided"* **[SP01, Senior Excellence Manager- UK].**

In response to this feedback on the need for a guidance note to support construction practitioners in the use LPS-PCA, a 25 page industry tailored guidance that describes each component and the step actions required at each stage was developed. Please see Appendix 10 and 11 for an A3 copy of LPS-PCA and an industry guidance note. Some further evaluation was done using the guidance with those that participated in the initial evaluation. They agreed that the guidance has further improved their understanding on the use of the LPS-PCA.

8.6.4.4 Emerging Influence of the LPS-PCA and the Pilot Implementation

It is worth mentioning that piloting the LPS-PCA on a live project is not part of the objectives of this study. This is due to the limited time frame of the study and the methodology adopted for this study which is exploratory and descriptive rather than an action research. However, during the evaluation process, some of the respondents indicated an interest to pilot it on some live project. One of the clients stated that: *"I would recommend the use of the approach; my team would pilot it in our* *organisation*" **[SP03, Programme Manager- UK].** This shows the proposed approach is already in the process of influencing the implementation of the LPS in construction. It could also imply that there is not a set process such as LPS-PCA at the moment.

8.6.4.4 Feedback on Pilot Implementation LPS-PCA in a Client Organisation

It is interesting to note a client has commenced the pilot implementation of LPS-PCA in its organisation and this process is still on-going. The focus of the implementation at the moment has been on *"the organisation path clearing level* and the engagement with some "*external enablers"* as proposed in the approach. For example, the Continuous Process Improvement Manager for the client has had some engagement with some Lean Construction Institute affiliate bodies and lean construction researchers in the academia.

Following these engagements, various presentations on LPS were made and the imperative for the use LPS was made to the company management team. This presentation and the business case for LPS supported the management buy-in. At present, an experienced lean construction professional has been employed by the client through an academic and industry partnership to implement the approach on its projects. Again, this empirically shows that management support and engagement with external enabler is important to the process.

Currently, an experienced lean construction professional employed by the client uses the LPS-PCA in LPS implementation in the organisation without any influence from the researcher. Again, this does not only demonstrate the functionality of the LPS-PCA but also reduces bias that usually occurs when such implementation is done by the researcher. Training and workshops is being organised and they are now in the process of establishing the strategic capability required to support the implementation at the organisation level.

This preliminary finding indicates that the proposed LPS-PCA support construction stakeholders in the implementation of the LPS. Since the process is still on-going, a follow up to see how the piloting process progresses would be done, and this will be reported in future publications.

8.7 Chapter Summary

This chapter focused on answering one of the research questions set out in this study that states that: *how can construction stakeholders be supported to successfully implement the LPS?* The chapter established the rationale for developing a structured approach that would support the implementation of the LPS in construction. The chapter shows that previous approaches developed or proposed to support the implementation of the LPS in construction seem to focus more on the project level, with less attention to other factors. To address this gap, the Last Planner System Path Clearing Approach (LPS-PCA) was proposed. The aim of the LPS-PCA is to enable construction stakeholders (clients, main contractors, and subcontractors) to develop an understanding of what needs to be in place for the rapid and successful implementation of the LPS. The LPS-PCA comprises of three path clearing levels, these are: organisational, project and external enablers.

The chapter shows that these path clearing levels are essential areas to focus on in the LPS implementation. The chapter also highlighted the necessary step actions to follow in adopting the proposed approach in the implementation of the LPS at each path clearing level. The step actions required at each path clearing level were classified into process input and contextual input factors. The chapter demonstrates that the proposed LPS-PCA would support the implementation of production planning and control in construction. This is based on the feedback received from the evaluation of the proposed approach. To further support this, it was suggested that an industry guide be developed to assist practitioners in using the LPS-PCA, thus, a full guidance was developed and a copy is available in Appendix 11.

The evaluation results indicate that the issues covered in the proposed approach are adequate to support and guide construction stakeholders in understanding what needs to be in place for the successful implementation of the LPS. It is worth mentioning that a client is currently piloting the proposed approach in its organisation and preliminary findings indicate that the approach supports LPS implementation. This further demonstrates the potential and practical application of the proposed approach in supporting the application of the LPS in construction. The chapter shows that the approach could easily be adopted/adapted anywhere in managing project production based on the LPS. The next chapter presents the conclusion to the study.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

This final chapter captures the main conclusions and recommendations from this study. The chapter commences with the re-statement of the research aim and objectives and goes further to presents the summary of the main findings. The chapter also presents the conclusions on each research objective and the research questions. The original contribution of the study to knowledge and the implication of the research findings for industry are identified. Finally, the chapter identifies the study limitations and makes recommendations for further research and the industry.

9.2 Re-statement of Research Aim, Objectives and Process

The aim this research is to know how the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK from a production planning and control perspective aligns with the advocated principles and theories of the Last Planner System (LPS). In addition to this, to finally, propose an approach that would support construction stakeholders (Client, Main contractors and Subcontractors) for rapid and successful implementation of the Last Planner system for construction process. To achieve this aim, six objectives were identified as presented in Chapter One and in section 9.4.

Empirical data on the current application of CP for delivering construction projects in the UK from production planning and control based on the LPS perspective were aggregated. These data were obtained from the major sectors (building, road, and rail) of the UK construction industry through various methods. These methods include: interviews, structured survey, and case studies. In all, a total of 58 interviews were conducted, 15 projects observed, 3 in-depth case studies conducted and 10 survey responses. The summary of findings is presented in the next section.

9.3 Summary of Research Findings

The summary of the research findings from stages 1 to 4 are presented below:

- The literature review established that there is dearth in empirical study on the relationship between collaborative planning practice for construction delivery projects from a production planning and control perspective in the UK and the advocated principles of the LPS of production control.
- Findings from the literature also indicate that previous frameworks proposed to support the implementation of the LPS tend to focus more on the project level.
- The study reveals that the LPS has shown its potential to improve construction project management practice, evidenced within many published examples from across the major continents of the world.
- The study reveals that Collaborative Planning and Last Planner are used interchangeably to describe the application of production planning and control principles in the UK on most of the projects evaluated.
- Collaborative programming/phase planning, WWP meetings and the measurement of PPC were done on most of the projects evaluated.
- Practices such as the make-ready process, look-ahead planning, consideration for work flow, and acting on reasons for non-completion of tasks among others were only partially implemented.
- The study established that the current practice of CP in the UK construction industry aligns partially with the LPS principles.
- The study shows that client demand and the desire for continuous improvement are among the major drivers for implementing production planning and control practice based on the LPS in the UK construction industry.
- Currently, LPS is mostly used as an intervention measure within the UK construction industry rather than for transformation.
- The study further reveals that cultural issues, dishonesty, “old thinking”, “poor promising”, and lack of trust are among the major barriers to LPS implementation in the UK.
- The study identified and categorised the nature of support required for the rapid and successful implementation of LPS in construction. These are; support/process at the organisational level, support at the project level and external enablers.

- Study reveals that the batching (reduced batch sizing) of the highways infrastructure projects support the implementation of the LPS on highways projects.
- The study confirms that the LPS can be implemented with any form of procurement method.
- The study reveals that the formal inclusion of the LPS in the contract clause influences the commitment of the supply chain to the process.
- The study also confirms that the use of collaborative form of contract and long term relationship influences the implementation of the LPS.
- The study developed an approach to support construction stakeholders (clients, main contractors & subcontractors) in developing an understanding of what needs to be in place for the successful implementation of the LPS.
- The evaluation and pilot implementation results indicate that the proposed approach supports the application of production planning and control practice in construction.
- The study reveals that LPS implementation has a positive impact on construction process improvement with regard to improvement in activity scheduling and programme reduction, collaborative working practice, and better understanding of project goal and task among others.

9.4 Conclusions on Research Objectives

Table 9.1 presents the identified six objectives of the study and how they were achieved in this study. The conclusions on each research objectives are subsequently discussed.

Table 9. 1: Research Objectives and How they were Achieved

No	Research Objectives	Method Used	Chapter
1	To critically review the need for construction process improvement (CPI) and the development of production planning and control practice in the UK construction industry.	Review the extant literature on CPI initiatives and the development of production planning control practice in the UK construction industry.	Chapter Two
2	To critically evaluate the development of collaboration in design, planning and execution of work in other fields and identify the implication for construction planning theory and practice.	Review the extant literature on collaboration and collaborative working and the development of collaboration in urban planning and software development.	Chapter Three

3	To critically evaluate the applications and developments in the Last Planner System in managing project production system in the construction industry globally.	Review extant literature on LPS implementation case studies, theories publications and recent developments	Chapter Four
4	To investigate the current understanding and application of production planning and control practice in the UK construction and its alignment with the LPS	Conducted 30 exploratory interviews and a structured observation of 15 projects.	Chapter Six
5	To determine the nature of support needed for rapid and successful implementation of the LPS and to identify the impacts of LPS on CPI.	Three in-depth case studies were conducted and data was collected via interviews, document analysis and physical observation.	Chapter Seven
6	To propose and validate an approach that would support construction stakeholders in implementing the LPS.	Development of Last Planner Path Clearing (LPS-PCA) approach based on the findings from Stages 1 to 4 of the study. LPS-PCA was evaluated with research participants and non-research participants	Chapter Eight

9.4.1 Objective 1

To understand the need for construction process improvement and the development of Production Planning and Control Practice in UK Construction

The aim of objective one was to explore the need for construction process improvement (CPI) and the development of production planning and control practice in the UK construction industry. The review established that the demand for construction process improvement is not limited to the UK construction industry alone; rather it is a global call across the world. More importantly, the review shows that the demand for construction process improvement was hinged on collaboration in the design, planning and in the execution of the planned task, especially as detailed in the UK construction industry reports. However, the lack of genuine framework for CPI has retarded its application in the industry.

The review shows that the earliest application of production planning and control principles under the name “Last Planner System” for delivering construction projects in the UK was on the Heathrow T4 coaching gate, T4 Arrival phase 2, and T1 International Arrivals projects in 1999. It was then fully implemented on Heathrow T5 project in 2001 by the BAA. LPS was piloted on a building project by research team at Northumbria University in 2003. This was followed by the Lean Construction Improvement Programme (CLIP) under the term “Collaborative

Planning" (CP) which was implemented on demonstration projects. The review shows that the reported practice of CP in the demonstration project has some resemblance with the LPS, while other elements of the LPS were not reported. However, this could not be fully substantiated from the review as empirical data from the industry is required for authentication. This became the knowledge gap which informed the overall research question for the study.

9.4.2 Objective 2

To Evaluate the Development of Collaboration in Planning in Urban Planning and Software Engineering Development and the implication for Construction Planning

This objective was motivated by the quest to appreciate the development of collaboration in design, planning, and execution of work in other fields and identify learning and implications for construction planning theory and practice.

The review reveals that the dissatisfaction with the non-collaborative approach used in the fields of urban planning (UP) and software engineering development informed their eventual journey towards more collaborative approaches. The study established that the paradigm shift in these fields have implications for construction planning practice and theory. The study shows that the Rational Comprehensive Model (RCM) and the waterfall process model that previously formed the basis of planning decisions in UP and in software development lack the capacity to support collaboration in planning. This has also been established to form the basis of planning practice in the construction industry as seen in the CPM. However, with the realisation of the negative impact of these approaches to planning decisions, both UP and software engineering design opted for a more collaborative model.

The successful adoption of collaborative approaches in these knowledge areas shows that the construction industry could also move from its current technical approach to a more social approach that encourages collaboration. This entails focusing on system thinking rather than the current functional 'activity to activity' thinking that dominates the industry. The review shows that the application of the current theory of project planning alone, that is, 'management-as-planning' (the *Transformation* view), lacks the capacity to develop collaborative relationships among project stakeholders. To overcome this, construction planning and management should include the concept of management-as-organising that supports the 'Flow' and

'Value' view for smooth running of the production (construction) system as demonstrated in Scrum and the LPS.

9.4.3 Objective 3

To understand the Application and Developments in the Last Planner System in managing production planning and control

This objective aims to develop an understanding on the application and developments in the Last Planner System in managing project production in the construction industry globally. General and systematic review of publications on the LPS was conducted, including the review of IGLC publications between 1993 and 2014. The review established that the LPS is a production planning and control methodology for managing project production in construction, which was developed by Ballard and Howell from research in the industrial construction sector.

The review demonstrates that the LPS has developed in terms of its level of implementation, and theory, and is now used as a vehicle to improve construction management practice in different parts of the world. In fact, it is one of the most implemented lean construction techniques. The study indicates that it has been implemented across 16 countries which cut across the major continents of the world and with significant impacts. The study shows that the LPS is not static, but has evolved greatly in managing production in construction. This is demonstrated in its integration with other emerging concepts such as BIM, and vplanner. Also, the trend in the implementation of its elements, progress on LPS research, and its building practice on sound theory among others attest to its development. The LPS is currently being benchmarked by Glenn Ballard with input from across the world; the participants are drawn from both industry and academia. The intention of this is to reflect on the initial framework and to correlate that with current practice in the industry in order to strengthen its application and influence.

9.4.4 Objective 4

To investigate how the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK from a Production Planning and control perspective align with the advocated principles and theories of the Last Planner System (LPS)

The aim of this objective is to identify how *Collaborative Planning* (CP) for delivering construction projects from the production planning and control perspective in the UK construction industry aligns with the advocated principles of the LPS. To achieve this objective, 30 construction professionals drawn from the major sectors (Building, road, and rail) of the UK construction industry were interviewed. In addition to this, 15 projects from these sectors were observed and findings were triangulated to obtain a wider perspective.

The study established that the current practice of CP as observed in the major sectors of the UK construction industry align partially with some of the generally advocated principles of the LPS acknowledged in the literature. The study reveals that the current practice of CP in the UK has not explored all components of the LPS. The depth of application of the more complex attributes contained in the LPS is weak or missing. This situation inhibits the extent of benefit that can be realised and even the enhancement of industry performance.

9.4.5 Objective 5

To identify the nature of support needed for rapid and successful implementation of the LPS and to identify the current impacts of production planning and control practice on construction process improvement.

To achieve this objective, three in-depth case studies drawn from building and highways infrastructure projects were conducted. Evidence was obtained from interviews, document analysis, and observations. The study identified and categorised the nature of support/process required for the rapid and successful implementation of LPS in construction into three. These are; support required at the organisational level, support required at the project level and the external enablers. Various factors were considered under this categorisation and the study concludes that all the factors are the foundation that needs to be in place for the successful implementation of the LPS.

The study demonstrated that the LPS implementation has a positive impact on construction process improvement with regard to improvement in activity scheduling and programme reduction, collaborative working practice, better understanding of project goal and task, better communication and relationship among project team, significant reduction in rework, and efficient working among others. However, its impact on safety was not clear, as it was not measured in relation to LPS/CP implementation on the case studies.

9.4.6 Objective 6

To propose and validate an approach that would support construction stakeholders in implementing the LPS.

The aim of this objective is to develop an approach that would support construction stakeholders (clients, main contractors, subcontractors) in the implementation of the LPS. To achieve this objective, 3 in-depth case studies were conducted over a 12 month period. A non-prescriptive approach known as "*Last Planner System Path Clearing Approach" (LPS-PCA)* was developed and validated using 10 construction industry professionals. Previous approaches developed or proposed to support the implementation of the LPS in construction seemed to focus more on the project level, with less attention on other factors. The LPS-PCA developed in this study comprises of three path clearing levels, these are: organisational, project and external enablers. A guidance note that highlights the necessary step actions to follow in the implementation of LPS using the LPS-PCA was developed, see Appendix 11.

The evaluation and pilot implementation results reveal that the proposed LPS-PCA has the potential to support stakeholders in the implementation of the LPS in construction. This is based on the feedback received from the evaluators and the pilot implementation. The evaluation results indicate that the issues covered in the proposed approach are adequate to support and guide construction stakeholders in understanding what needs to be in place for the successful implementation of the LPS. It is worth mentioning that the pilot implementation is still on-going.

9.5 Conclusion on Research Questions

Two overarching research questions informed this research:

3. How does the current understanding and application of "Collaborative Planning" (CP) for delivering construction projects in the UK from a Production Planning and Management perspective align with the advocated principles of the LPS?
4. How can construction stakeholders (client, main contractors, and subcontractors) be supported for rapid and successful implementation of the LPS?

The above research questions were answered through the achievements of the six study objectives. Specifically, it emerged from the study that the current practice of CP in the UK construction industry only aligns partially with the advocated principles of the LPS. The second research question was answered through the achieved aim of developing an approach called LPS-PCA that was proved to have the potential to support construction stakeholders in the implementation of the LPS in construction.

9.6 Original Contribution of Research to Knowledge

The Nottingham Trent University Research Degree Regulations states that PhD research should generate "*the creation and interpretation of new knowledge and / or the invention and generation of ideas through original research in an academic discipline.*" Accordingly, this research has made a number of original contributions to the existing body of knowledge in construction project management, lean project management and in particular to the future application of production planning and control principles in construction. The original contribution of this thesis to knowledge is itemised under; (1) contribution to theory and (2) contribution to practice.

9.6.1 Contribution to Theory.

The original contribution to theory is evidenced in these points:

- it identifies the mismatches in the current practice of collaborative planning for delivering construction projects from a production planning and control perspective in the UK construction industry by exposing and exploring the current practice across the major sector of the UK construction industry. It also generates new insights into the prevailing application of production planning and control principles through the lens of the Last Planner System.
- the development of a non-prescriptive but all-inclusive approach for supporting construction stakeholders (client, main contractors and subcontractors) in the implementation of the LPS in construction known as "Last Planner System Path Clearing Approach" that includes organisational and external path clearing levels. This expands previous approaches to the implementation of the LPS in construction which focused more on the project level.
- a contribution to the limited literature and theory on collaboration in construction planning. This by providing evidence through a critical evaluation of extant literature in urban planning, software engineering and

construction management on planning that construction project management could also move from its current technical approach in planning to a more social approach that encourages collaboration.

9.6.2 Contribution to Practice

The practical contribution of the research to construction project management and lean construction practice are itemised below:

- The practical application of the developed LPS-PCA enables construction stakeholders (clients, main contractors, and subcontractor) to understand what needs to be in place for the successful implementation of the LPS, especially intending stakeholders. Thus, enabling them to make the right decision with regard to process and behaviour in the LPS implementation process.
- The provision of evidence on the impact of LPS on construction process improvement in the UK construction industry addresses a problem of initiating change without evidence.
- It identified the need for path clearing in full Last Planner System implementations. The identification of the three “path clearing levels” (organisational, project and external enabler) provides a focal point for construction practitioners to focus on in the implementation of production planning and control principles based on the LPS in construction
- The clear identification of the elements of the current practice of CP compared to the components of the LPS and the mapping out of the identified matches and mismatches guide the future practice of the LPS among construction practitioners in the construction industry.

9.6 Research Publications

As part of the contribution of this research to lean construction and construction project management body of knowledge, the following papers have been developed and published from this research.

9.6.3 Conference papers

1. Daniel, E.I., Pasquire, C., and Dickens, G. (2016). “Exploring the factors that influence the implementation of the Last Planner System on joint venture infrastructure projects: A case study approach.” In: *Proc. 24th Ann. Conf. of*

the Int'l. Group for Lean Construction, Boston, MA, USA, pp. xx–xx. Available at: <www.iglc.net>.

2. Daniel, E.I., Pasquire, C. and Dickens, G. (2015), "Exploring the Implementation of the Last Planner® System Through IGLC Community: Twenty One Years of Experience". In:, Seppänen, O., González, V.A. & Arroyo, P., *23rd Annual Conference of the International Group for Lean Construction.* Perth, Australia, 29-31 Jul 2015. pp 153-162
3. Daniel, E. I, Pasquire, C and Dickens, G (2015b). "Assessing the practice and impact of production planning and management in UK construction based on the Last Planner® System". *2nd School of Architecture Design and Built environment Doctoral Conference, 8-9* June, 2015, NTU, Nottingham UK
4. Daniel, E. I, Pasquire, C and Dickens, G., (2014). "Social perspective of planning in construction: The UK experience *In: Raiden, A B and Aboagye-Nimo, E (Eds) Procs 30th Annual ARCOM Conference, 1-3 September 2014, Portsmouth, UK, Association of Researchers in Construction Management, 1355- 1365*

9.6.4 Journal Publications

1. Daniel, E .I, Pasquire, C Dickens, G. and Ballard, G. (2016). The relationship between the Last Planner® System and collaborative planning practice in UK construction. *Engineering , Construction and Architectural management (2016)*
2. Daniel, E .I, Pasquire, C., and Dickens, G. (under review) Collaboration in planning in other fields and its implication for construction project management. *Journal of Construction Economics and Management*.

9.6.5 Future Publication Plan

1. Framework for supporting construction stakeholders in the implementation of the Last Planner System in the construction industry
2. An identification of the nature of support for the rapid and successful implementation of the Last Planner System in Construction
3. The influence of procurement on the implementation of the Last Planner System in construction

4. Assessing the impact of Last Planner System on construction process improvement: The UK experience

9.7 Research Limitations

Every research has its limitations and this not an exception. The main limitations to this research are itemised as follows:

- The empirical data aggregated for this research are mainly on the construction phase. This implies that the application of production planning and control principles based on the LPS explored did not capture the practice in the design phase sufficiently. In addition, views from design practitioners are not fully represented; future studies should include this.
- Although, a client is currently piloting the validated LPS-PCA on a live project in its organisation, evidence of this is only partially reported in this thesis due to the time required to generate such evidences. Implementing the approach on a project over a long period would offer further improvement to the proposed approach. Future work should consider this.
- While effort was made to draw LPS-PCA evaluators from across globe to reflect a wider perspective, majority of those that eventually participated are largely practitioners from Europe, North America, and Australia. Since they are all Westerners, the Western culture could influence their judgement.

9.8 Recommendations

This study has explored the practice of production planning and control based on the LPS in construction and has developed an approach to support construction stakeholders in implementing the LPS in construction. There is opportunity for future study to build on the work reported in this thesis and also recommendation for industry practitioners for better benefit realisation. Recommendation is therefore made for industry practitioners and researchers.

9.8.1 Recommendation for Industry Practitioners

Based on the outcome of this study, the following recommendations are made for construction industry practitioners and stakeholders:

- Key practices associated with the LPS such as the make-ready process, look-ahead planning, full consideration for workflow, strategy to act on RNC, and communication of results to subcontractors among others that are currently only partially implemented should be done fully.
- The “make-ready process” and the development of a workable backlog should be fully integrated into the look-ahead planning. Commitment to this is essential and the project team should acknowledge the importance of releasing only sound tasks into the production system.
- The “Planning Best Practice” (PBP) checklist should be used by the project team to evaluate the level of LPS principles on the project.
- Initially, the developed LPS-PCA should be used in consultation with an experienced lean construction practitioner.
- Lean champions and facilitators should be appointed both at the project and organisation levels to drive the implementation of the LPS on the project and in the organisation as a whole.
- Project managers and facilitators should endeavour to select and ensure all the required stakeholders are present at the production planning meetings.
- For smooth implementation of the LPS at the project level, the step actions identified at organisational level and the external enablers should be deployed as appropriate.
- Organisations should develop a long-term strategic plan for LPS implementation and integrate such plan into their business delivery model for better benefits.

9.8.2 Recommendation for Further Research

There are various scopes for future study to build on from the outcome this research, some of these are itemised below:

- This study has successfully explored and identified the mismatches in the current practice of the LPS in the UK and developed an approach (LPS-PCA) to support construction stakeholders for successful implementation. However, this approach has not been fully tested on any live project to measure its impacts in supporting LPS implementation. Future studies should consider using action research method to implement the LPS-PCA on live projects.

This would provide empirical evidence that could be used to improve the approach as appropriate.

- It emerged from this study that “poor promising” is among the major barriers in the implementation of production planning and control practice based on the LPS on the projects. Future studies should investigate the fundamental principles and apparatus that support effective commitment/promising among construction stakeholders on projects so as to grow trust within the project team.
- Also, considering the increasing report on the use of the LPS in the design phase in other parts of the world, future studies should explore the application of the LPS at the design phase in the UK construction industry and compare such findings with this study. The study should then extend the LPS-PCA and integrate the design phase into it.
- Considering the increasing call by the Government for the use of BIM in delivering construction projects the UK, future studies should examine how LPS and BIM could be used to manage project production planning and control using a case study approach.

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APPENDICES

Appendix 1: Sample of Semi –structured interview guide

An Exploratory study on Last Planner System (LPS) and Collaborative Planning (CP) Practice in the UK Construction Industry

(**Open-ended Interview Guide**)

Background information of respondent:

A Planning practices

1. How do you plan and execute work on this project or in your organisation?
2. Could you please describe the key process involved in your planning and execution process and what do you call this approach?
3. For how long do you plan your work ahead of time and how has it help so far on this project?
4. How do you measure the reliability of your planning?

B Impact, benefit and drivers of planning approach

5. What do you think has helped in your planning process with other stakeholders on your project?
6. From your experience what are the major benefits you have achieved from your planning approach?
7. Based on your experience how has the following construction projects stakeholders benefited from the approach used in planning and execution of work? Clients, Contractors, Consultants, Subcontractors and Foremen and site operatives
8. What other factors do you think could encourage your subcontractors or supply chain to get commitment to the way you plan and execute your work?
9. How do you hope to sustain this planning approach in your organisation and down to your supply chain say tier 3, 4 &5 **C**

C Barriers

10. Based on your experience what are the barriers have you observed from the implementation of this planning approach, in term of organisational, contextual and cultural issues and others; how can they be overcome?
11. How has your procurement methods influenced or affected the use of this planning approach on this project with other stakeholders? (e.g. subcontracting options)

12. What do you suggest should be done to support your organisation and other construction organisations such as medium and large construction organisation in using this approach effectively (academia, Government, client, contractors etc)

D Intellectual origins

13. How do you personally learn about this planning approach
14. What motivated your organisation to adopt this planning approach and what form of support have you received from internal and external consultant in implementing this planning approach.
15. Which of these describe your planning approach ? Collaborative Planning [ ] Last Planner System [ ] Critical Path Method [ ] Line of Balance [ ] Gantt Chart [ ] Takt time Planning [ ] Location based Planning[ ] Others, please specify………………………………………

    For how long have you been using it…………………………….

Appendix 2: Approval Letter from College Ethical Committee

19/05/2015 JICEC Checklist - Daniel, Emmanuel 2013 (PGR)

JICEC Checklist

Dossor, Sarah <sarah.dossor@ntu.ac.uk>

Tue 20/01/2015 15:16

Inbox

To: Daniel, Emmanuel 2013 (PGR) <emmanuel.daniel2013@my.ntu.ac.uk>;

Dear Emmanuel

Thank you for your recent submission to the Joint Inter- College Research Ethics Committee (JICEC) on 24 December 2014 requesting ethical clearance for the project entitled: An Exploratory Study into the use of the Last Planner System and Collaborative Planning for Construction Process Improvement in the UK. I am pleased to inform you that this has now been approved and signed off by the Chair.

Yours sincerely

Sarah Dossor
Research Office Team Leader
Maudslay 312
College of Art, Design and Built Environment
Nottingham Trent University
Burton Street
Nottingham NG1 4BU
Tel: 0115 848 2393
Fax: 0115 848 4298
Email: sarah.dossor@ntu.ac.uk
www.ntu.ac.uk

Appendix 3: Sample of Interview Invitation/Consent Letter Issued

NOTTINGHAM TRENT UNIVERSITY

Invitation to participate in research study

Research Project:

Exploratory study into the use of Last Planner® System and collaborative planning for construction process improvement in the UK

Researcher:	**Supervisory team:**
Emmanuel I. Daniel	Professor, Christine Pasquire
	Dr. Graham Dickens

You are being invited to take part in a research study. Before you decide, it is important that you understand why the research is being undertaken and what it involves. Please take time to read the following information. Ask us if there is anything that is not clear, or if you would like more information. Finally, take time to decide if you want to take part or not.

Purpose of the study:
The aim of this case study is to gather knowledge for the purpose of understanding how the Last Planner System and collaborative planning is currently understood and applied in the UK construction industry and how construction organisations can be supported for successful implementation. The research will develop a methodology to assist a rapid and successful implementation of the Last Planner System for construction process improvement. It is expected that the study will reveal the current LPS and CP practices from across construction organisations in the UK.

Must I participate?
No. It is up to you to decide whether or not to take part. If you do, you will be asked to sign a consent form. You are still free to withdraw at any time without giving a reason.

What happens, if I participate?
You will be involved in an interview, which will take not more than 45 minutes

- The interview may be voice recorded
- The results will be used in the creation of the proposed pre-disposition
- The data will be treated with anonymity and confidentiality

Are there any risks / benefits involved?
There are NO risks or monetary benefit involved in participating in this study.
However, copy of the thesis or a summary of the major findings can be made available. Please provide an email if interested……………………………………………………………

Will my taking part in the study be kept confidential?
All data will be coded and anonymised so that no individual can be identified in future publications.
Please sign below and retain a copy of this and the consent form and do not hesitate to contact us if you need further clarification on this. xxxxxxxxxxxxxxxxxxxxxxxxxxx
Yours faithfully,

Emmanuel I Daniel
Doctoral Researcher
Nottingham Trent University
emmanuel.daniel2013@my.ntu.ac.uk

Appendix 4: Transcribed Interview Sample

Position of interviewee: Programme Manager

Code:

RH= Researcher

SM = interviewee

RH - What are the key issues with construction planning?

SM03 – Generally speaking it is coping with change

RH – How was the planning done on this project?

SM01 – At the initial phase we develop the tender programme with limited information because of the commercial nature to enable us hit the target price. Very limited information is required at the tender stage

RH – Do you involve the subcontractor at this stage?

SM – We only consult the key subcontractors. Some time we use preferred contractors which we did on this project. The programme drawn up at this point is one man view on how the work would be done. As far as I am concern they is no wrong or right programme, it is a view. When contract is awarded, when we get the work we go into detail discussion in the CP session with key subcontractors, material suppliers, etc. we bring them into a strategically at the early stage. Then they say is better done this way or perhaps this way

RH - How do you develop the collaborative programme?

SM- We uses the contract programme as the module to work around to develop the collaborative programme. You could end working in a different sequence. We define change and the effect of the change in the CP session. We review the programme, the CP session did not necessarily improve the programme, it might identify some flaws in the programme which could lead to extension. It is not always good news. It is a live document and cannot be rigid because of uncertainties. The software monitors changes. It is very fluid we match reality with the base programme.

RH – Do you plan for entire duration of the project?

SM – No we plan in phases, if we try to do for all you will be there for days. We do six weeks lookahead. We started with six weeks lookahead, but as things get critical we went down to 4 weeks lookahead. Now we are doing 2 week lookahead. The frequency of the meeting or shortness is due to the volume of work.

RH – How do you measure the reliability of your programme?

SM01 – What we do every month we send turn around documents which take a snapshot of the programme. We record progress on day to day basis. The software usually pick this up. It shows the actual start and finish date. I can let you have a copy of the turnaround document. We put progress against what has been proposed to be achieved, with any comments. Like on this project we are doing very well above the programme. We measure and report this every month.

RH – How do you incorporate this into the weekly work plan?

SM 01– The team does the day to day planning at the weekly level, they are aware of the overall programme. They do their programme to meet it or beat it. I look at the overall programme and tell the team if they are deviating from it.

RH – How do you define CP?

SM01 – CP introduces lean process into the programme, as good as one can possibly make it. It takes the whole programme and betters it by working together rather than individual subcontractors working separately. It makes the programme sleek and as quick as possible.

RH – what motivate the team into doing CP?

SM – Because 9 out 10 subcontractors would want to be on site as short as possible. The quicker you finish the job, the quicker you get on your new job. The quicker the subcontractors complete the job, the more the profit. The lesser time on the project the lesser risk of financial loss. The subcontractor would want to work efficiently and effectively while on site. We work together as a team everyone fully integrated.

RH – Is the idea that of the joint venture?

SM – No, it is the client initiative but to be fair outside of the tis project we do some CP . But, not on grounded scale as this, not as formal as this.

RH – What is your own definition of CP

SM – Is about getting the key players to the room to go through ultimately the contract programme to look at where conflict are arising in the activities. It brings the us together as one team. Without CP will have many down time due to conflicts. It helps to organise and decide activity to deliver the programme. It is an opportunity to flag up any constraint. We talk on technical issues and design query.

RH - What do you think has made CP to work on this project?

SM – what helped is the formalisation of the CP process on this project, it is not an ad hoc thing. It is a serious process. It gets everybody's mind thinking in the right direction. It helps as the planner to get better insight on how the various teams can work together so I take that benefit to the next scheme.

Now, the HA are tasking the team to deliver the project 50% ahead of the programme. The only way that can be achieved is through CP. The idea is not about the physical building of the job, but CP should be applied to the approval system, the design also. It should be applied to the system. It would be beneficial for the subcontractor, main contractor to sit with the designer as [he is] doing the design. It should be applied to all aspects of the scheme. To me 50% saving can easily come in if CP is used in the approval system and in the production of the design. The major saving is in the design.

RH – Challenges of the scheme.

SM – the biggest problem we have got is to have a client who does not know what he wants, his always changing things. The problem is how to manage those changes. On this scheme the client has introduced 300 weeks of work, if it is added end to end, it will take another four years to build. We have been asked to finish in two months as addition to the contract time, this is how big an issue it is, that is why CP came in.

It reduces any potential delay.

RH – Benefits of CP

SM – one thing about CP; people are entitled to voice their opinion about safety. A subcontractor could say hang on a minute, the safety barrier has been removed, we will not work in such area.

You remember the guy said during the meeting, he can't do it, the safety guard has been removed. Safety is a big thing. It gives the benefit to know what is going on other people's mind. It is a two way thing.

RH – Who benefits more.

SM – No one benefit more. I think everyone benefits from the process. But the main contractor may benefit more because their work supersedes other people on the project. But it is a team thing. Initially, we use to have the client rep in the meeting. If all the team benefit, it means the whole process benefits.

RH – Is there CPI

SM – it is a mindset thing. The more you talk to each other the more you learn. People will grow up to see how to improve the process. It is a mindset thing. We have daily and weekly meetings with the team.

RH - What do see as the challenge to the implementation of the process on this project?

SM - There are subcontractors employed directly by the client, which we do not pay but have to manage them. They tend to be stock in the old ways. For example, if we have an outside 3rd party employed, the client, this operation originally is 12 weeks, let's see if we can do it in a shorter time, they would say no, it is 12 weeks, 12 weeks must be 12 weeks. Some organisations like working in the old way. The contractors employed by the client tend to be stock in their own ways.

RH – Do you think CP will work more is it is done by direct labour?

SM – No, if we have people working for us directly, by the nature of who they are, they would be put to work by our foreman, the foremen will be the one that will be invited into the CP meeting. The reason we invite much people is because they have specialist subcontractor. For example, people that put barriers, the drainage, earthwork are all specialist. If we are to do it all ourselves, we will be master of our own destiny and there is very little collaboration you can do with yourself. The main positive feature of the collaboration in my view is that it gives the subcontractors, anyone else invited the confidence, reassurance that their opinion, views are being listened to and taken on board. Not you will do it in my own way.

RH - In term of facilitation, do you think the facilitation process has actually helps in the implementation?

SM – Yes, it is a learning process, when we started, it was a paper more crude and we use the post-it note, but most time they fall off. We invite too many people in, if we feel we should invite representatives only. When we first started, we had outside facilitators coming in. some of us have received training and we are now doing it on our own.

We started off with the CP, to me the biggest thing in the CP session is to have the planner present in the session, because if he is not there he can't get first-hand information on what people say. The planner also draws the attention of the team to what needs to be done on the programme. The other problem with the CP is at the initial time when we ask the subcontractors, how long will you do this? They will say no, no, I won't say it. But with time, they gain confidence in the process and they are now contributing.

RH – what do you see as the barrier to the process?

SM - …em, one of the biggest things during the CP sessions is people not telling the truth, you've got to be honest with yourself and the rest members of the team. It is no use to say I will finish that work today while you know you still need 3 or more days. It is no good to say I will do it next week and you know you have not got men to do it. This makes mockery of the whole process. People need to be absolutely honest with themselves and with each other. If people are not telling the truth CP is a complete waste of time.

RH – How has the procurement method actually helped in the CP process?

SM – As earlier mentioned, we take the view s on our previous project M62, we talk to a number of subcontractors on the CP. A subcontractor who is not interested in CP may not be engaged.

The designers are employed by the client and it does not affect the collaborative planning, we only have liaison meeting with the designer rather than CP to try and focus on the priority, but it does not help. The best way to control somebody is when you are paying them. if you are paying somebody, they listen more than when someone else is paying them. it is not as it used to be initially, they try to listen a bit. The designers have little appreciation of the commercial implications of what they do and they don't do. It is very difficult but we have to manage it.

RH – Client support

SM – So we have several workshops where we have done presentation to members of staff, the client, the head of the scheme and designers to express their views. To me it is not the main crux, the main crux is the collaborative planning. The HA project manager has also supported, without it, we will not be where we are now. The support of the project manager does help, some project managers use to choose to stay in the office.

RH – how about training?

SM – Training has helped. It is very difficult to stand out there to hold CP session without any training. Without the training, the facilitation wouldn't progress. We receive both internal and external training sessions.

RH – Does this include the subcontractors?

SM – As far as I am aware, it only involves the internal team. I am not aware of subcontractors that are invited for the training.

RH – Do you think it will work differently on a building project?

SM – No, no. All it does is turning it from this way to that way, it is the same principle. The benefit will still be the same if it is used in house building, in ship building, highway, aeroplane. It gets everybody working together as a team. It is not just restricted to linear scheme.

RH – What form of support can be provided for effective implementation?

SM – A facilitator is needed to promote the benefits of collaborative planning. Internal facilitation of CP session, for the 1-4 sessions, provision of training course for internal members.

RH – Support from the organisation?

SM – appointment of lean managers to promote the practice across the business. High profile members of staff to promote the idea. Lean managers, senior management staff.

RH – What change is required?

SM – You can't force change on anyone, the best way is to talk to them, explain and demonstrate the benefits of what you do. For example if I am to be on another scheme, I would say the benefit of CP is that we were able to do 3 years' worth of additional work in 2 months. This is the only way to sell with physical evidence.

RH – How do you hope to sustain the practice?

SM – On some of the schemes, it would be part of the criteria for awarding the schemes. To sustain is to spread the benefit across the organisation, provision of training for people to become lean managers.

RH – External factor

SM – The main understanding is the sense of belief that it is achievable, it is the realistic nature of the approach.

Appendix 5: Last Planner System Practice Evaluation Instrument

Centre for Lean Projects
NOTTINGHAM TRENT UNIVERSITY

Evaluation Production Planning and Control practices based on the Last Planner System in the UK

Structured Interview

1. organisation name: Nature of organisation

Tier 1 – 2 – 3 - 4

2. Interviewee Position in organisation

How long in the industry Yrs. of experience- LPS

Production Planning and Control Evaluation Criteria

S/N0	Practices	Weighting
1	Planning and control process standardization	
2	Formalized collaborative programming or phase planning	
3	Analysis of constraints	
4	Programming Workable backlog	
5	Analysis of physical flow	
6	Detailed specification of task	
7	Formalization of short-term planning (WWP)	
8	Formalized Shared decision making process	
9	Measurement of programme reliability (PPC)	
10	Recording reasons for non-completion of task	
11	Formal meeting to take action on reasons for non-completion of task	
12	Taking a formal action for early completion task	
13	Formal communication of results using visual devices	
14	Constant evaluation and learning	
15	Use of prototyping or First Run studies	
16	Development of workable backlog	
17	Lookahead planning	

1.0	Full implementation
0.5	Partial implementation
0.0	No evidence of implementation

Appendix 6: Sample of Case Study Consent Letter Issued

NOTTINGHAM
TRENT UNIVERSITY

Case Study Consent Form

Research Project:
Exploratory study into the use of Last Planner® System and collaborative planning for construction process improvement in the UK

Case Study Project:

Note: This consent form is to be retained by you and the researcher . At the completion of the research it should be disposed in a secure fashion.

Relevant data will be collected via:

- Documentary evidence
- Observation
- Interviews

I agree to participate in the study
I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way.

I understand that details of the material discussed are confidential and agree not to disclose any of the information given to any other party.

I agree to the interview being audio recorded for the interviewer's reference only.

I agree to the use of anonymised quotes in this thesis and other academic publications

Participant's name:xxxxxxxxxxxxxxxxx

Signature:xxxxxxxx

Date:xxxxxxxxxxxxxxx

Researcher:
Emmanuel I Daniel
Doctoral Researcher
Nottingham Trent University
emmanuel.daniel2013@my.ntu.ac.uk

Supervisory team:
Professor, Christine Pasquire
Dr. Graham Dickens

Appendix 7: Case Study Interview Guide

Centre for Lean Projects
NOTTINGHAM TRENT UNIVERSITY

Project:

An exploratory study into the use of Last Planner® System and collaborative planning for construction process improvement

Target populations and sample

- Senior level managers
- Middle level managers
- Bottom level managers

Underlying philosophy of the study:

The aim of this case study is to gather knowledge for the purpose of understanding how the Last Planner System and collaborative planning is currently understood and applied in the UK construction industry and how construction organisations can be supported for successful implementation. The case study is to enable the researcher obtain information that will aid the development of a methodology to create a pre-disposition within project teams to enable a rapid and successful implementation of the Last Planner System for construction process improvement. It is expected that the study will reveal the current LPS and CP practices from across construction organisations in the UK.

Section 1:

This section attempts to obtain background information on the organisation and respondents participating in the study.
Nature of organisation………………………………….. Nature of project………..…………..................
Position in organisation……………………………….Professional membership attained…………….
Years of experience in LPS and CP…………………..…Years of experience in construction…………...

Section 2: Construction planning and the Last Planner System

This section attempts to explore issues with construction planning, and determine how mature the LPS and CP implementation are in the organisation.

1. Based on your experience, what are the issues with planning in the construction industry?
2. How do you plan and execute work on this project or in your organisation?
3. Can you please describe the key processes involved in your planning and execution of work on this project and what the approach is called?
4. How long do you plan ahead of time and how has it helped in meeting your targets?
5. How do you measure the reliability of your planning?
6. What is your own definition of CP and the LPS? Do you think they are there to achieve the same goal on the project?
7. What motivated you or your organisation in adopting LPS and CP, and for how long?

Section 3: Benefits and drivers

This section examines the impacts of LPS and CP on construction process improvement and also attempts to identify the core drivers for implementing the process.

8. From your experience, what do you see as the major benefits of using LPS and CP on this project? How do the following stakeholders benefit from the process? Clients, Contractors, subcontractors, foremen and site operatives
9. Can you please identify (if any) the construction process improvement (CPI) you have observed on your projects since the use of LPS and CP?
10. What do you see as the major relationships between LPS and CP implementation and CPI
11. What are the factors that have helped in using this planning approach with other stakeholders on the project?
12. What do see as the core drivers for implementing LPS and CP in construction?
13. How does LPS and CP facilitation process impact the success of the implementation on this project? Is continual external facilitation a disadvantage?

Section 4: Barriers and success factors

This section seeks to identify and categorise the barriers and success factors for LPS and CP implementations.

14. Based on your experience, what are the barriers and challenges observed during implementation in terms of people, process, organisation, cost, culture, technology etc. How do you overcome these barriers and challenges?
15. How has the procurement method used on this project contributed to the success or failure of the implementation process?
16. Based on your experience what are the major success factors you have observed over this time? Please can you categorise these success factors?
17. What nature of support or training have you and your team received on LPS and CP? Who are those involved in the training, is this beneficial to the implementation? How does the site team react to this approach of working? Are they satisfied?
18. Please share your view. Do you think LPS and CP works effectively on road projects than building? Why?

Section 5: Support for effective implementation

This section explores and seeks to understand factors that support rapid implementation of LPS and CP for construction organisations.

19. What form of support do you think is required for rapid implementation of the LPS and CP in construction?
20. Can you please classify these supports? E.g. at organisational level, project level, Client, contractor, academia, and Government among others
21. What further support do you think should be given to SME’s since 70% of these work packages are executed by them?
22. Based on your experience, can you suggest some changes that need to be put in place at organisational level, project level, by the SME contractors and clients to support rapid implementation?
23. What factors do you think could motivate and sustain this planning approach down the supply chain?
24. Based on your experience, what do you see as the key enablers for LPS and CP implementation in construction?

Please add further comments you feel will contribute to the aim of this study..

Thank you

Appendix 8: Post Case Study Survey Instrument

Case Study Post Implementation Evaluation Survey

Section 1: Background information

1. Nature of organisation: Main contractor [ ] Subcontractor [ ] Client [ ] Others please specify……… 2. Position in organisation…………………………….
Nature of project……………………………….

3. Years of experience in collaborative planning …………. Years of experience construction………

4. Professional body membership status…………………………………………………………..

Section 2: Specific question on collaborative planning/Last Planner System

Based on your experience on this project kindly indicate your view on the following based on 5 point Likert scale

S/N0	Collaborative planning practice	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
1	I have a good understanding of the purpose of collaborative planning on this project?					
2	I feel my working practice has changed for better on this project as a result of my involvement in the collaborative planning meetings					
3	My understanding of the project has greatly improved as a result of my involvement in the collaborative planning meetings					
4	The application of collaborative planning has improved the level of communication among the project stakeholders					

5	The collaborative planning process has improved my trust and confidence in other members of the project team					
6	The collaborative planning process has enabled us to be more efficient in our construction processes					
7	The collaborative planning process has enabled us to reduce the level of re-work on this project significantly					
8	We have observed significant increase in construction process improvement on this project as a result of the collaborative planning process					
8	The collaborative planning process has reduced the adversarial relationship on this project					
9	Our safety record has improved on this project as a result of the collaborative planning process					
10	The collaborative planning process has slowed our progress on this project					
11	Collaborative planning process slowed down our progress initially, but speed it up after a while					
12	It is time consuming					
13	I am yet to see the value in the collaborative planning process					
14	Do you like working in this manner?					

2. Who do you think benefit more from the collaborative planning process as implemented on this project?

The client [ ] the subcontractor[ ] the main contractor[ ] site workers and supervisors[ ] All the stakeholders on the project [ ] Others please specify………………………………………..

Please share briefly the reason for your answer in question 2 above…………………………………
……..
……..
……..

3. Based on your experience kindly suggest what is needed or can be done to support the rapid and successful implementation of collaborative planning on construction projects

- …….
- …….
- ……..
- ……..
- …….
- …….
- …….
- …….

Please share something of your experience on the use of this new approach on this project……………………..………..

Appendix 9: Last Planner Path Clearing Approach Evaluation Survey Guide

Centre for Lean Projects
NOTTINGHAM TRENT UNIVERSITY

Structured and Semi-structured Survey to Evaluate, Refine, and Validate Last Planner System Path Clearing Approach.

(Please note: The LPS is also known as Collaborative Planning (CP) by some practitioners in the United Kingdom)

Overall aim of the proposed approach.
The overall aim of the proposed approach is to guide construction stakeholders (client, main contractors, and subcontractors) in understanding what needs to be in place for the successful implementation of LPS/CP and also in sustaining the implementation.

Background of research participants:

1. Background: Academia **[ ]** Industry **[ ]**

2. Years of experience in LPS/CP… …… Years of experience in construction……………

3. Country: …………… Highest educational qualification……………………….

Evaluation Question:
Having studied the proposed approach for LPS/CP implementation(attached). Please rate the following questions regarding the approach on scale of 1 to 4. Indicate your response by inserting the appropriate number in the box provided and comments as appropriate.

Description of scale: 1 = Very low coverage 2 = Low coverage 3 = High coverage 4 = Very high coverage

4. Based on your experience how would you rate or describe the appropriateness of the three structural levels identified to be essential areas of focus for LPS/CP implementation in the proposed approach **[ ]** ***N.B:*** *Substructural levels in the proposed approach refers to the essential phases where the supports required for LPS/CP implementation should be focused.*

Please insert comments if any:

5. Based your experience, please rate the level of completeness of the issues considered at the organisational sub-structural level: **[ ]**

Please insert comments if any:

6. Based your experience please rate the level of completeness of the issues considered in the project sub-structural level: **[ ]**

Please insert comments if any:

7. Based your experience kindly rate the level of completeness of the issues considered in the external sub-structural level: **[ ]**

Please insert comments if any:

8. How easily can the proposed approach be understood (please use the scale below)
[ ]
1= Very difficult to understand 2 = Difficult to understand 3 = Easy to understand
4 = Very easy to understand.

Please insert comments if any:

9. Do you think the proposed approach would in any way support the implementation of LPS/CP in construction?

Please give reasons for your comment:

10. Do you think the proposed approach could be adopted/adapted in your country?

Please give reasons for your response :

11. Would you recommend the use of this proposed approach for LPS/CP implementation?

Please give reasons for your response:

12. How would you recommend the use of the proposed approach?

Please insert comments:

12. Please suggest further improvements that can be considered in this proposed approach that aims to guide construction stakeholders (client, main contractors, and subcontractors) in understanding what needs to be in place for the successful implementation of LPS/CP?

Please insert comments:

Thank you for your contribution to this study.

Appendix 10: Last Planner System Path Clearing Approach A3 Size

Last Planner System Path Clearing Approach

The overall aim of the proposed approach is to guide construction stakeholders (client, main contractors, and subcontractors) in understanding what needs to be in place for the successful implementation of Last Planner System (LPS) and also in sustaining the implementation.

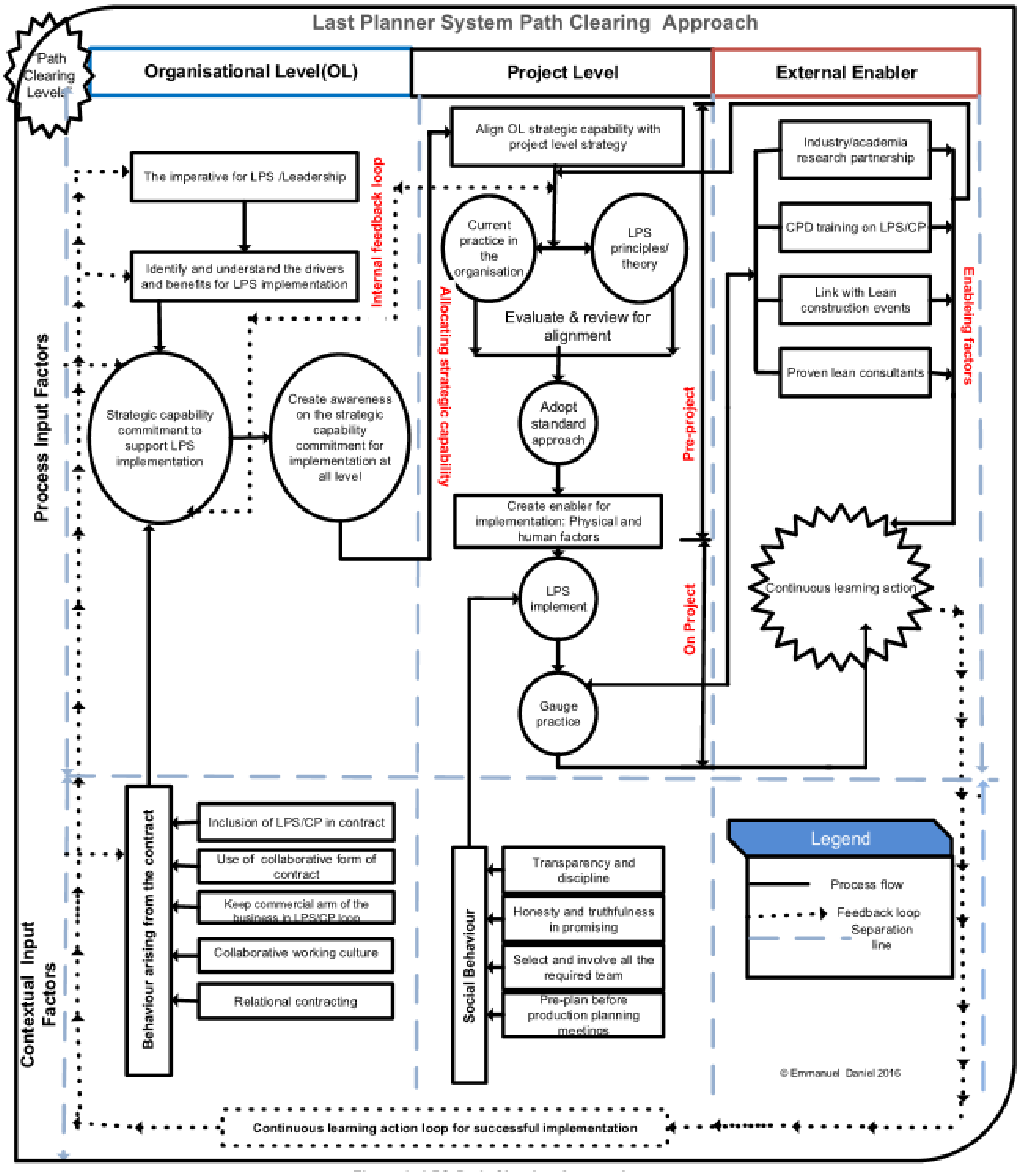

Figure 8.2 Last Planner Path Clearing Approach

Appendix 11: Last Planner System Path Clearing Approach Industry Guide

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

"Last Planner System path clearing Approach"

(Proposed approach and guidance notes)

Emmanuel Itodo Daniel

July, 2016

CONTENTS

Contents 1
Glossary of terms in the proposed "Last Planner® path clearing Approach" 2
1.0 Introduction 2
1.1 Why is LPS Path Clearing Approach needed? 2
1.2 What is the LPS Path Clearing Approach? 3
1.3 What the proposed Approach is not 3
1.4 Why should I use it? 3
1.5 How should I use it? 3
2.0 Last Planner system Path Clearing Approach 3
2.1 Block Diagram of LPS Path Clearing Approach 3
2.2 Schematic Diagram of LPS Path Clearing Approach 4
3.0 LPS-PCA Guidance Note: STEPS FOR ACTIONS 5
3.1 Organisational Level 5
3.1.1 Step Actions at the Organisational Level 6
Step Action #1: The Imperative for LPS implementation and Leadership 6
Step Action #2: Identify and Understand the Drivers and benefits for LPS Implementation 6
Step Action #3: Strategic Capability commitment to Support LPS Implementation 7
Step Action #4: Behaviour Arising from the Contract 8
Step Action #5: Create Awareness on the Strategic Capability Commitment LPS 8
3.2 Project Level 8
3.2.1 Step Actions at the Project Level 9
Step Action #1: Align and Allocate strategic capability commitment from OL with the PL strategy 9
Step Action #2: Identify and review Production Planning and Control Practice 9
Step Action #3: Evaluate and Review Practice Using the LPS Principles 9
Step Action #4: Adoption of Standard Approach (Specific Capability commitments required) 10
Step Action #5: Create Enablers for LPS Implementation 12
Step Action #7: Gauge Practice 13
Step Action #8: Gauging LPS implementation with implementation assessment question 14
3.3 External Enabler 16
Step Action#1: Engage with the external enabling factors 16
Step Action #2: Continuous Learning Action and Feedback Loop 16

1

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

GLOSSARY OF TERMS IN THE PROPOSED "LAST PLANNER® PATH CLEARING APPROACH"

Last Planner System: is an integrated and comprehensive production planning and control approach developed for the construction industry that creates predictability and reliability of delivery. It is the widely used name for the application of production planning and control principles in construction.

Collaborative Planning: is a commonly used name for describing an application of production planning and control approach by practitioners in the UK construction industry.

Path Clearing Level: refers to the essential paths that need to be in place for the rapid and successful implementation of the LPS. They are three, namely; organisational level, project level and external enabler.

Organisational Level: It is one of the path clearing levels in the proposed approach. It identifies and defines what needs to be in place at the organisational level for LPS implementation. The organisational level factors also support the implementation of the LPS at the project level. It consists of the two input factors; the process input factor and the contextual input factor.

> **Process Input Factors:** this refers to the processes that need to be created and practiced at the path clearing levels in the implementation of LPS.
>
> **Contextual Inputs Factors**: this refers to behaviours that need to be in place both at the organisation and project levels that are capable of influencing the established process input factors positively. Its focus is to bring about social norm at these levels and to lubricate the process input factors in achieving the expected goals of the implementation.

Project Level: It is among the path clearing levels in the proposed approach. It identifies and defines what needs to be in place at the project level for LPS implementation. It also consists of the two input factors; the process input factors and the contextual input factors as described above.

External enablers: these factors operate outside the organisational and project levels. They are strategically positioned to support the implementation of the LPS.

1.0 INTRODUCTION

The implementation of the Last Planner System (LPS) is growing. The LPS is also known as Collaborative Planning (CP) in the UK. The Last Planner System implementation approach developed here is called *"Last Planner System Path Clearing Approach"* (LPS-PCA). The approach is based on an empirical study conducted in the UK, which spans a three year period. The proposed approach consists of three major components. These includes; organisational level path clearing, project path clearing and external enabler. For better understanding of the requirements at each level, this guidance note has been developed to support the proposed approach. The proposed approach, an overview and guidance notes are presented.

1.1 Why is LPS Path Clearing Approach needed?

The current practice of LPS in different parts of the world is largely stalled at some specific elements of the LPS. This has hindered the full realisation of the benefits from the implementation of the approach as intended. For instance, in the United Kingdom, the implementation of the LPS is stalled at collaborative programming or phase planning and the lack of rigour in committing to the key elements of the LPS such as the make-ready process. In addition to this, there is narrow view in the current application of the system. For instance, some construction stakeholders see the process as avenue to control the activities of other stakeholders on the project, rather than a mutual platform for communication and development of collaborative relationship. This implies that, resistance is subtly embedded within implemented practices. This shows the essential need for '*path clearing*', so as to achieve rapid and successful implementation of the LPS. It is believed that the proposed approach would support and guide practitioners in LPS implementation.

1.2 What is the LPS Path Clearing Approach?

It is an approach to guide construction stakeholders (client, main contractors, and subcontractors) in developing an understanding of what needs to be in place for the successful implementation of LPS and also in sustaining the implementation.

1.3 What the proposed Approach is not

The proposed approach is not prescriptive; it is only a guide or roadmap to help in developing an understanding of what needs to be in place (Path Clearing) for the implementation of LPS in construction. This implies it is not rigid and could be adopted/adapted to various situations. Also, the proposed approach is not intended to provide a detailed description of the methodology for LPS implementation as this is available in various publications.

1.4 Why should I use it?

It will enable you to develop an understanding to make decisions as a client, main contractor or subcontractor on what is required for the successful implementation of LPS in both process and behavioural wise.

1.5 How should I use it?

The proposed approach as presented in Figures 1 and 2 on subsequent pages should be used alongside the guidance note provided for better and quicker understanding.

2.0 LAST PLANNER SYSTEM PATH CLEARING APPROACH

2.1 Block Diagram of LPS Path Clearing Approach

Figure 1 presents the basic diagram of the *"LPS Path Clearing Approach"* (LPS-PCA). The block diagram indicates how components in the proposed approach are closely integrated. For instance, Figure 1 shows that the organisational level feed into the pre-project activities, while the pre-project activities contribute to the implementation on the project. The external enabling factors on the other hand support all the operations as shown in Figure 1.

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

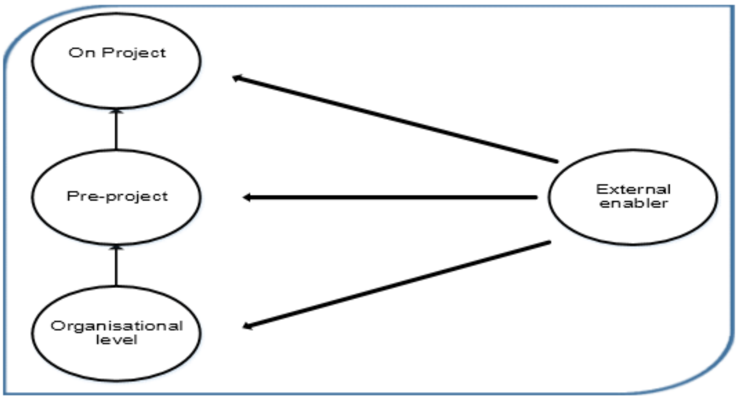

Figure 1: LPS Path Clearing Approach Block Diagram

This shows that each part requires some form of input from other components for effective functioning. It is worth noting that both pre-project and project components fall under the project level in the path clearing levels as will be described later in Figure 2. Figure 2 presents the schematic diagram of the proposed LPS-PCA.

2.2 Schematic Diagram of LPS Path Clearing Approach

As earlier stated the overall aim of the LPS-PCA is to guide construction stakeholders (client, main contractors, and subcontractors) in developing an understanding of what needs to be in place for the successful implementation of the LPS and also in sustaining the implementation. The LPS-PCA comprises of three path clearing levels as shown in Figure 2. Path clearing levels are essential paths that need to be in place for the rapid and successful implementation of the LPS. They are three namely; organisational level, project level and external enabler. These paths and its associated components are described in the guidance notes in details to enhance the usage of LPS-PCA by construction practitioner.

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

Last Planner System Path Clearing Approach

The overall aim of the proposed approach is to guide construction stakeholders (client, main contractors, and subcontractors) in understanding what needs to be in place for the successful implementation of Last Planner System(LPS) and also in sustaining the implementation.

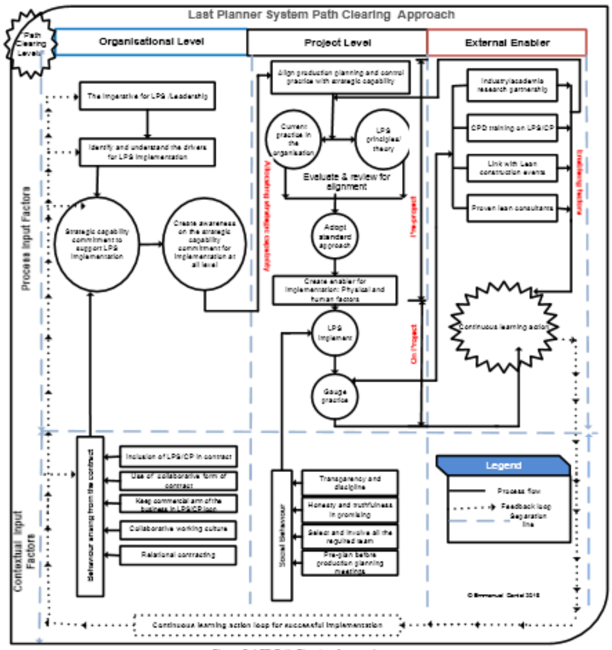

Figure 2: LPS Path Clearing Approach

3.0 LPS-PCA GUIDANCE NOTE: STEPS FOR ACTIONS

The aim of the guidance note is to provide further explanations on each of the components (steps for action) presented in Figure 2. The guidance note is structured under the three path clearing levels. These include; the organisational level, the project level and the external enabler. It is worth noting that the guidance note presented is not prescriptive, rather it gives a general overview of what could be expected or considered at each stage in preparing for the LPS implementation.

3.1 Organisational Level

Organisations play a central role in the implementation of lean principles and techniques. The implementation of lean techniques has been hindered in the past because it was somewhat disconnected from the organisation's vision and the absence of a clear strategy. The

5

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

organisational path clearing level consists of two input factors; the process input factors and the contextual input factors.

Organisational Process Input Factors: this refers to the processes that need to be created and practised at the organisation level in the implementation of LPS. As it is called, it defines the processes that need to be place at the organisational level (OL) for LPS. This includes;

- identifying the imperative for LPS implementation/ leadership
- identifying and understanding the drivers for LPS implementation
- Strategic capability commitment to support LPS implementation
- Creating awareness on the strategic capability created across the business.

Construction clients and supply chain companies have an important role to play at this level. Commitment to this process input factors is essential for both the construction client and the supply chain companies at this level. This is important because it has great influence in determining the success of the implementation at the project level. However, this cannot be achieved in isolation, thus, the OL input process factors are fed by the contextual input factors.

Contextual Inputs Factors: this refers to behaviours that need to be in place at the OL that are capable of influencing the established process input factors. Its focus is to bring about social norm at the OL and lubricate the process input factors especially the strategic capability commitment to support LPS implementation. At the OL, the contextual input factors are known as 'behaviour arising from contract'. This will be further explained under 'behaviour arising from contract'. Again, this shows that the process input factor and the contextual input factors at the OL are interlinked. The step actions at the OL are now described.

3.1.1 Step Actions at the Organisational Level

Five key step actions would be described at the organisation path clearing level.

Step Action #1: The Imperative for LPS implementation and Leadership

An organisation must identify the imperative for the implementation of the LPS in its business. The imperative here is beyond having a goal of fulfilling an expectation from the client. For instance, in the UK, the demand from the public sector client seems to be among the top imperative factors driving some supply chain companies in the implementation of the LPS. Such imperative factors or drivers cannot sustain the implementation of the LPS, indeed it is a weak imperative factor.

Ideally, the imperative for LPS implementation should be based on the desire to become an active agent to support collaborative behaviour among employees. This implies that both the client and supply chain have a role in championing the LPS implementation. Also, it shows that the LPS implementation should not be championed by client companies alone, as perceived by some supply chain companies. This imperative should be made explicit, as it has the potential of stimulating the top management in supporting the implementation.

In addition to this, a high level leadership support is required to drive the process. The expected leadership style is not just bottom-top or top-bottom, it is better described as 'empowered leadership' from within the team. It means each member of the team is empowered with the capacity to rise to the occasion when the need arises. Furthermore, the factors (drivers) that cause the imperative must be identified.

Step Action #2: Identify and Understand the Drivers and benefits for LPS Implementation

The specific drivers for the implementation of LPS should be identified. This is important as the drivers for LPS implementation in a client organisation could vary from that of a contracting organisation and even from one client or contracting organisation to another.

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

This implies each organisation must identify its own drivers. The drivers for LPS in clients' organisations could include:

- quest to overcome past failures
- quest for time compression
- quest for better working relationship with supply chains
- benefits from previous implementation, and

While for supply chain companies, the drivers could include:

- Client and public sector demand, quest for time completion
- internal desire for continuous improvement
- project complexity
- Time certainty and efficient working
- avoidance of time overrun that could lead to liquidation and damages
- quest for improved communication with team

The early identification of these drivers is an essential process input which should be in place, as it has the capacity to put pressure on organisations (Client and supply chain companies) to create the needed change that could support the implementation. Also, the benefits of LPS implementation should be explained to the organisation as it would drive the management to develop strategic capability to support the implementation.

Step Action #3: Strategic Capability commitment to Support LPS Implementation

Having identified the imperatives and drivers for LPS implementation, it is important to develop a clear strategy and capability to support the implementation. Without a clear strategy, the LPS implementation cannot be sustained in the organisation. Both construction client and supply chain companies must create their own strategy. This should focus on deliberate commitment to develop the required capability at the OL that would support the implementation. It includes commitment to training and retraining of team to achieve the required competence.

Furthermore, the strategy should be connected to the organisation's culture and appropriate policy should be created to support the strategy. Cultural issues (people) are among the most reported barriers to the implementation of the LPS. This could be minimised through the development of the right strategy and creating the policy that could influence the organisational culture in the implementation process. This implies that selecting the strategy should not be done in isolation. At this point, it important that the supply chain companies and the construction client identify the specific strategy that best suit the implementation in their organisation. In construction client organisations this may include:

- provision of internal training for staff
- routine supply chain development programme
- routine supply chain assessment programme, and
- creation of lean business department

For supply chain companies it may include:

- start up and refresher workshops
- internal training for staffs
- training programme for subcontractors, and
- lean academy for staff

7

"LAST PLANNER SYSTEM PATH CLEARING APPROACH"

When there is a clear strategic capability commitment to support the LPS implementation, the chance of hitting the targeted goal is high. In doing this, a clear contextual behaviour should be put in place at the OL to support the strategy.

Step Action #4: Behaviour Arising from the Contract

Contractual behaviours are the appropriate behaviour that should be in place at the OL to support the strategic capability commitments for LPS implementation. It focuses on the behaviour arising from the contract and its application in the process. It helps in formalising the strategic capability identified, thus, it should form the key components of the strategic capability commitment process. These contractual behaviours include:

- the inclusion of LPS/CP in the contract
- use of collaborative form of contract
- relational contracting
- collaborative working culture and
- keeping the business arm of the business in the LPS loop.

All of this applies to both construction client and the supply chain companies. It is worth noting that in most cases the choice of procurement route at the higher level is largely determined by the construction client, though this could be an exception. However, whenever the client chooses to use a non-collaborative form of contract, the main contractor could still use other forms of collaborative approach such as going into framework with its subcontractors and supply chains. This implies that the inclusion of the LPS in the contract should not be viewed as the client's responsibility only. The expectation is that the contract should be viewed as a relationship rather than a mere transaction as seen in traction economics. This is important as it has the potential of supporting the development of collaborative working culture.

People would tend to work more collaboratively when there is hope of future transaction, this is strongly supported in collaborative and relational form of contract. For instance, a main contractor included the use of LPS in the contract with its subcontractors and it supported collaborative working behaviour on the project. Irrespective of the procurement approach employed, the LPS would work when the strategy for it use is clear and communicated appropriately. The essence of its inclusion in the contract is to encourage all the required stakeholders to get involved and benefit from the process.

Step Action #5: Create Awareness on the Strategic Capability Commitment LPS

The identified strategic commitment capability for LPS implementation and the process created to formalise them at the organisational level must be communicated at all levels. This could entail the use of company intranet to communicate such an approach and information. The information guiding such an approach should be located in areas where it could be easily accessed. Also, workshops and trainings on the strategic capability commitment required should be organised at all levels. Specific avenues and approach that could be used to create awareness on this include:

- company intranet, newsletters,
- workshops, trainings, and
- monthly project briefing among others

This would enable all the business departments to understand what the organisation is doing, which would influence their own individual commitment to the strategic capability identified at the OL.

3.2 Project Level

The project level (PL) factors are linked to the organisational level factors. The implication of this is that the strategic capability commitment for LPS implementation at the OL must be allocated appropriately at the project level. The PL is sub-divided into pre-project and project implementation activities as shown in Figure 2. Similar to the OL, the project level (PL) also consists of the process input factor and contextual input factor.

Project Process Input Factors: this refers to the processes that need to be created and practised at the project level in the implementation of LPS. It defines the processes that need to be in place at the project level (PL) for LPS. This includes:

- Project level strategic capability commitment
- Identify and understand production planning practice on the project
- Evaluate practice with LPS principle and theory
- Adopt standard approach
- Create enabler for implementation
- Implement and gauge implementation

***Project level Contextual Inputs Factors**:* this refers to behaviours that need to be in place at the PL that are capable of influencing the established process input factors. Its focus is to bring about social norm at the PL and lubricate the process input factors at the PL. These contextual factors are known as 'social behaviours' at the PL. They include:

- Transparency and discipline
- Honesty and truthfulness in promising
- Selection and involvement of all the required team
- Pre-planning before production planning meetings

These factors would be described in the step actions in the PL.

3.2.1 Step Actions at the Project Level

The 8 core step actions for LPS implementation at the project level are now discussed.

Step Action #1: Align and Allocate strategic capability commitment from OL with the PL strategy

It is essential for a strategy to also be developed at the PL, however, this should be aligned with the OL strategic capability commitment. This is important as the team on the project would be coming from different organisations. For example, an organisation can tell its employees that it wants them to embrace a process and educate them on why. However, projects could develop their own identity due to the vast array of companies required to deliver a project. In view of this, the project set-up; the companies involved including client, contractor, suppliers and designer should establish a joint strategy that considers the unique characteristics of the project. This should be aligned with strategic capability commitments so as to avoid conflict. Also, the strategic capability commitment should be allocated and the strategy for actualising it should be made explicit to the team at the project level.

Step Action #2: Identify and review Production Planning and Control Practice

At this point, it is essential for the production planning and control practice to be understood and streamlined to meet the strategic capability commitment and the strategy at the PL allocated for the LPS implementation. To achieve this, the current production planning practice should be evaluated with an enhanced production planning and control principle such as the LPS principles.

Step Action #3: Evaluate and Review Practice Using the LPS Principles

The LPS is a production planning and control method developed for the construction industry and it is among the most used lean techniques in construction. Thus, the production planning and control practice on the project should be evaluated and reviewed for alignment with the advocated principles/theory of the LPS. The underlying theories of the LPS revolve around planning, execution, and control. The LPS is based on five principles which are to:

- ensure tasks are planned in increasing detail the closer the task execution approaches.
- ensure tasks are planned with those who are to execute them
- identify constraints on the planned task to be removed by the team beforehand
- ensure promises made are secure and reliable and
- continuously learn from failures that occur when executing tasks to prevent future reoccurrence.

Evaluating the practice based on the LPS principles would enable the identification of areas that needs improvement. The evaluation entails reviewing the practice with the six core components of the LPS (described in the next section). The evaluation should identify what is working well and the areas that need improvement. This is important as it has been observed that what cannot be measured cannot be improved. Similar evaluation and review conducted showed high potential in revealing the level of alignment in the practice and identifying areas that need support/improvement. This in no doubt would provide an understanding on the improved/standard approach to be adopted on the project.

Step Action #4: Adoption of Standard Approach (Specific Capability commitments required)

Based on the evaluation and review, a standard LPS approach should be adopted. The absence of such typical approach could result into varied implementation of the process across projects executed in the same organisation. This means a project could be inventing its own wheel which could hinder the intended benefits from the system. It is worth noting that the standard approach is not rigid, thus it could be positioned to meet the reality on the project. However, since the LPS has 6 standard components, the team should therefore develop the specific capability commitments required for the implementation of the components on the project.

The six LPS standard core components are:

(1) milestone planning

(2) collaborative programming or phases planning

(3) look-ahead planning

(4) make-ready process

(5) weekly work planning

(6) measurement and learning.

These components will be discussed briefly to gain understanding on the specific capability required on each component.

The master plan or milestone planning

The master plan or milestone planning captures the entire task to be executed throughout the project and at the same time shows the length of time required for each activity to be completed. It identifies the project milestones and initiates the means for achieving them .It forms the basis for the development of the collaborative programme or phase planning.

Collaborative programming or phase planning

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Collaborative programming is a process used in developing a reliable construction programme from the master or contract programme by direct involvement of the subcontractors, contractors, suppliers, designers and other stakeholders on the project including the client. It is worth noting that this process is commonly called collaborative planning or programming by practitioners in the UK, while phase scheduling is the common name used for it in the Lean Construction Institute literature.

Look-ahead planning

The look-ahead planning is a medium term plan for project activities and is developed from the collaborative programme considering the work to the next level of detail. Usually, tasks that will occur within four to six weeks in the look-ahead window are screened for constraints in all eight flows. These include the seven process flows such as information, permissions, resources, space, material, previous work, worker, equipment and the plus one soft flow 'common understanding' However, in the traditional way of managing projects, the look-ahead plan (master programme) only provides advance notice of the start date of an activity and does not consider the complex network of flows, their sequence, matching work flow with capacity, or maintaining a backlog of workable activities.

Make-ready process

The make-ready process is used to eradicate the constraints or blockers to planned activities identified in the look-ahead programme before they are passed into production on site through a constraints analysis process. Now, work needs to be considered in a greater detail as the make-ready process focuses on matching the available resources for work with the present realities on the construction site, so as to ensure production can proceed at an optimum level. The purpose of the make-ready process is to prepare for flow – all seven resource flows plus one soft flow need to be considered to enable the constraints to be removed and the resources and capacity balanced to enable successful production.

Weekly Work Planning

Weekly Work Plan (WWP) is done to review the task planned in the previous week in order to plan for the week ahead collaboratively with the team. At this point, only tasks that meet the four criteria of production are entered onto the WWP. These criteria require that work must be 1. well defined (detailed task breakdown), 2. sound (can be done), 3. sequenced (interdependencies assessed) and 4. properly sized (load matches capacity). Tasks meeting the four criteria but not entered onto the WWP are held in readiness as a "workable backlog" or Plan B tasks. The workable backlog enables the workforce to drop onto these tasks if for any reason they are unable to complete work on the WWP. '*Daily huddle*' meetings are used to monitor how activities planned for the week are performing each day. Its focus is to guide the planned production from deviation and to re-plan when such is envisaged. It is also called daily stand-up meeting in the UK.

Measurement, learning and Action

The key metrics measured in the LPS implementation are; the Percentage of Promises (or planned) Completed (PPC), the Reason for Non-Completion (RNC) and a developing Reliability Index using metrics from Tasks Made Ready (TMR) and Tasks Anticipated (TA) In practice, PPC measurement, and recording of RNC are the most commonly used. PPC measurement not only encourages learning but also provides a clear indication of productivity. PPC is a percentage of the activities achieved against those planned for the week. In measuring the PPC, RNC of completion of activities are also populated using charts and the 5-WHY is used to identify the root cause analysis for task not completed. The PPC, RNC and 5-WHY are usually reported using standard sheets, and they support learning.

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Evaluation and learning within a lean construction system is tightly coupled to action. In this way, the production planning becomes agile and responsive to uncertainty and risk in problem solving generating action in the moment – it is not enough to leave evaluation and learning until project closure. A systematic adoption of the described process could support a common and improved implementation of LPS across projects or organisation.

Step Action #5: Create Enablers for LPS Implementation

For the adopted approach to work, implementation enabler must be created. The implementation enablers are grouped into two: physical factor and human factor enablers. The physical factors entail the allocation of designated room for production planning and control. This should include creating physical space such as co-location for working and visual production planning and control centre. Such location should be readily accessible to all the required stakeholders on the project including the subcontractors. It should also be located close to work station to prevent non-value adding activities that could come from unnecessary movement. Furthermore, the board located in the room has the potential of communicating information visually to the team during and out of meeting time.

The human factor on the other hand is concerned with the appointment of facilitator and lean champions in driving the process on site. In the context of this study, all the research participants identified facilitation as an essential process that needs to be in place for the successful implementation of the process at the project level. It includes both external and internal facilitation. External facilitation such as the use of proven lean construction consultants could prove useful at the initial start. However, over reliance on consultant should be avoided. This is because it could make the team to view the process as an external initiative, thus reducing their commitment to the process.

Step Action #6: Social Behaviour

To successfully implement the adopted common approach, contextual input factors embedded as social behaviour are required at the project level. Social behaviours are those soft skill behaviours that need to be practiced by the team on the project for the successful implementation of the LPS at the PL. These factors include:

- transparency and discipline,
- honesty and truthfulness in promising,
- selection and involvement of all the required team,
- pre-planning before production planning, and
- proactive involvement of the construction manager.

These are among the social behaviours that should be in place at the PL for the rapid and successful implementation of the LPS. The need to be cautious about lack of honesty and poor promising in the implementation of the LPS has been explained theoretically from the Language/action perspective theory. Practically, it entails making promises that are realistic and achievable within the time frame. This suggests that no stakeholder on the project should be pressured into making undue commitment. The five rules for making reliable promising should be adhered to in LPS implementation. These are:

- Understand the condition for satisfaction (COS)
- Access competency before making promise
- Ensure capacity available and allocated
- Empower the team to say YES OR NO (sincerity)
- Accept responsibility for failure and re-review the process for learning

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The action expected here is informed by social information exchange (conversation) as opposed to the technical information exchange that dominates the traditional project management .In such social conversations as advocated in the LPS, every stakeholder is empowered to make promises which could be YES! or NO! It has been observed empirically that where such social network of conversation exists on a project, the LPS works in managing the production on site effectively. Also, reliable promising supports workflow and programme reliability which is the core focus of the LPS. This shows the importance of social behaviour in the implementation of LPS at the project level. Furthermore, all the required team members should be involved in the process including the subcontractors. The proactive involvement of the construction manager in production planning also increases the buy-in of other stakeholders on the project.

Step Action #7: Gauge Practice

As the implementation process continues, it is important that the practice is constantly gauged using both internal and external mechanisms. To gauge the practice internally, the Planning Best Practice (PBP) guide as presented in Table 1 should be used to access the level of implementation on the project. The PBP guide is developed based on extensive research on the application of LPS principles in construction. In addition, the LPS implementation maturity guide as shown in Table 2 should be used. The guide was originally developed by Gregory Howell; one of the inventors of the LPS. Through this, the efficacy of implementation could easily be assessed internally and areas that need improvement could be identified and addressed appropriately. Gauging of the practice also requires input from the external enabling factors.

The Planning Best Practice was identified based on previous studies on the implementation of the LPS in construction. These studies identified 15 LPS practices. The PBP has been used to assess the implementation of the LPS in different parts of world such as Brazil, Israel Chile, and UK among others. However, a recent study identified two other practices that are considered to be essential practices of the LPS, which makes it 17 LPS practices are presented in Table 1.

Table 1 Production planning and control practice (Planning Best Practice)

		Level of implementation			
S/NO	LPS Practice	**F**	**P**	**N**	**Level of implementation in percentage (%)**
1	Initial collaborative programming/phase planning meeting				
2	Formalisation of Weekly Work Plan (WWP)				
3	Measurement of Percentage Plan Completed (PPC)				
4	Planning and control process standardisation				
5	Involvement of subcontractors in planning and decision process				
6	Formalised shared decision making process				
7	Lookahead Planning				

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8	Detail specification of task				
9	Recording reasons for non-completion of task				
10	Formal system to take action on reasons for non-completion of task				
11	Analysis of physical flow				
12	Make Ready and analysis of constraints				
13	Use of prototyping/First Run Studies				
14	Constant evaluation and learning				
15	Formal communication of result to supply chain using visual device				
16	Detail consideration for flow				
17	Programming workable backlog				

Key:	**Weighting:**
F= full implementation	F= 1.0
P= partial implementation	P= 0.5
N= no evidence of implementation	N= 0.0

Using the information provided above, the level of implementation on projects can be ascertained over a period of time.

Step Action #8: Gauging LPS implementation with implementation assessment question

Table 2 presents standard questions used in assessing the implementation of LPS in construction developed by Lean Project Consulting. The repeated assessment of LPS implementation based on these questions supports learning and improvement in the implementation process. This structured questionnaire should access the implementation progresses.

Table 2: LPS implementation assessment questions

	LPS implementation assessment questions	**Yes**	**NO**
1	Are key milestones and budget established and shared with the team?		
2	Have those targets been reviewed with the team within the last 30 days?		
3	Is the team confident the targets can be met?		
4	Was a pull plan produced for the current phase within the last 120 days?		

14

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5	Has a pull plan been developed for any phase that is anticipated to start within the next 45 days?		
6	Was the pull plan (phase planning) developed by designers, client representatives, consultants, specialty contractors and the contractor working together?		
7	If there were key players missing, were they invited?		
7b	If no above, did the team cope with their absence effectively?		
8	Is the status of the phase plan discussed in the project leadership meeting?		
9	Are the team confident the work on pull plan can be completed within the current milestone?		
10	Is the project being managed with a 6-week look-ahead plan (LAP)?		
11	Are constraints identified and promises secured to remove them?		
12	Is the project coordinated using the LAP at the site level?		
13	Are performers raising constraints throughout the six week interval?		
14	Are constraints identified on the LAP and are they discussed in the production planning meeting?		
15	Do the team promise to remove constraints for which they are responsible?		
16	Are the team confident the work on that LAP can be started and completed as shown?		
17	Are all tasks shown to be constraint-free on the LAP really ready for work -- lacking only the application of labour and prerequisite tasks?		
18	Has workable backlog been established for each performing group?		
19	Are design teams and crews using a weekly work plan (WWP)?		
20	Is only ready work promised?		
21	Are daily completions identified and accepted as promises kept?		
22	Are daily stand-up meetings held for managing promises?		
23	Are completions reported publicly on a daily basis?		
24	Are the completions recorded daily along with the		

15

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	reasons for incompletion?		
25	Is PPC charted and on an improving trend?		
26	Are reasons for failure accumulated on a Pareto chart?		
27	Are reasons for failure discussed regularly by the team and ideas developed to improve performance – eliminating underlying causes?		
28	Has an assignment been rejected because it wasn't ready?		
29	Does the project team have a mood of ambition and determination?		
30	Are performers adjusting their actions during the week to help others?		

***Source**: Lean Project Consulting, 2005*

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3.3 External Enabler

The external enablers do not only help in gauging the practice, it also brings in new strategies and innovations to improve the current practice both at the PL and OL as shown in Figure 2. Unlike the OL and PL, external enablers have only the process input factors embedded as external enabling factors. These include:

- research partnership between the industry and the academia,
- CPD training courses on LPS
- engagement with proven lean construction consultants, and
- Lean construction Institute events

Step Action#1: Engage with the external enabling factors
There is need to deliberately engage with the identified external enabling factors presented above. This is essential as it has been observed that the LPS is dynamic and it always uses various avenues to improve practice, for example, its use of theory to explain practice. Such external forum and partnership could be an avenue for communicating and learning about such improvement or findings. Research partnership with the industry and facilitation of the process supports the implementation of the LPS. For instance, external facilitation from proven lean construction practitioner is important especially in staring and setting out the process.

Step Action #2: Continuous Learning Action and Feedback Loop

The continuous learning action is the loop that sustains the implementation of the LPS. It focuses on learning and taking action at each level. The continuous action learning advocated occurs at every point in the process as shown in Figure 2. This implies that learning does not just occur at the end of the entire process only since there is an internal feedback loop. As shown in Figure 2, there is an internal feedback look between the OL and PL; this is done to ensure issues that need addressing are attended to before the process is rolled out completely. For instance, with the roll out of a set of strategies, unintended consequences may occur and it is helpful to understand these sooner than later. This shows the importance of creating internal feedback loop. In the implementation of the LPS "bad news early could be said to be good news".

Also, there is an in-built feedback mechanism at the project level to assess the implementation to enable appropriate actions. These include the Planning Best Practice and the 30 LPS structured questionnaire. This instrument has the potential of revealing areas that needs improvement while the process is still on-going.

Furthermore, all the learning actions are feedback into the entire system to further support the internal feedback loop as the system continues. For effective learning, action data should be captured and a formal strategy should be developed to act on them to support continuous learning. New ideas and innovations emerging from the implementation process should feedback into the system for better improvement.