


This item is held in Loughborough University's Institutional Repository (<https://dspace.lboro.ac.uk/>) and was harvested from the British Library's EThOS service (<http://www.ethos.bl.uk/>). It is made available under the following Creative Commons Licence conditions.




creative  
commons  
C O M M O N S D E E D


**Attribution-NonCommercial-NoDerivs 2.5**

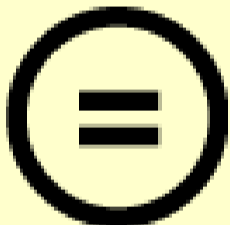
**You are free:**

- to copy, distribute, display, and perform the work

**Under the following conditions:**

 **BY:** **Attribution.** You must attribute the work in the manner specified by the author or licensor.


 **Noncommercial.** You may not use this work for commercial purposes.

 **No Derivative Works.** You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

**Your fair use and other rights are in no way affected by the above.**

This is a human-readable summary of the [Legal Code \(the full license\)](#).

[Disclaimer](#) 

For the full text of this licence, please go to:  
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

**BENCHMARKING AND READINESS  
ASSESSMENT FOR CONCURRENT  
ENGINEERING IN CONSTRUCTION (BEACON)**

**MALIK MANSOOR ALI KHALFAN**

A thesis submitted in partial fulfilment of the  
requirements of the Loughborough University  
for the Degree of Doctor of Philosophy.

**September 2001**

## **Abstract**

In the increasingly competitive business environment reduced project cost, improved time-to-market, better quality products, and customer involvement are becoming the key success factors for any product development process. Many organisations within different industries are now focusing on Concurrent Engineering (CE) to bring improvements to their product development process in order to keep pace with the competitive environment. The adoption of CE has shown positive effects on project quality, cost, lead time, schedule, and customer satisfaction. For a targeted and effective implementation, it is recommended to carry out a readiness assessment of an organisation prior to the adoption of CE. This thesis discusses the adoption of CE within the construction industry, reviews existing CE readiness assessment tools used in other industry sectors, and assesses their applicability to construction. It then presents a new developed CE readiness assessment tool for construction called the 'BEACON Model', its associated questionnaire, and an associated software. Description and results of CE readiness assessment case studies, which were conducted within five sectors of the construction industry, are then presented. At the end of the thesis, CE implementation strategies and considerations are presented based on the assessment results, followed by conclusions, recommendations and future work. The most important conclusion, which could be drawn from the research, is that the construction industry as a whole still needs improvements in most of the critical areas identified by the BEACON Model in order to adopt CE effectively.

## **Dedication**

To my father, Mansoor Ali Khalfan Hashim  
my mother, Rehmat Banoo Mansoor Ali  
my brother, Malik (Jr.), and his wife, Shahzmeen;

and

To almighty Allah,  
who has mercifully blessed me everything which I have,  
and to whom all praises should be done and all prays should be directed,  
and to his last prophet, Prophet Muhammed (SAS).

## **Acknowledgements**

I wish to express my sincere thanks to all those who have contributed to the successful completion of my PhD research.

To the ORS Award Committee and the Loughborough University's studentship, I express my appreciation for the provision of funds for the research.

The contribution of my supervisors, Prof. Chimay J. Anumba, and Dr. Patricia M. Carrillo, in providing guidance and various sources of information for the research is highly appreciated. My special thanks to Prof. Anumba for being instrumental in securing the funding for the research, for being a mentor, and for his constant inspiration and encouragement. I owe a deep debt of gratitude towards both of my supervisors.

I am also grateful to the following individuals who helped me in various aspects of my research throughout my research: Dr John M. Kamara (University of Newcastle upon Tyne), Dr Dino Bouchlaghem, Prof. Tony Thorpe, Prof. Andrew Baldwin, Prof. Andrew Price, Dr Alistair Gibb, Dr Onuegbu Ugwu, Mrs Jo Brewin, Mrs Jackie Palmer, Mrs Joy Hull, and Miss Fiona Wellby (Loughborough University).

To the organisations, which participated in the industry survey, and many individuals at conferences who were willing to discuss and clarify issues, relevant to the research, I am sincerely grateful. The contribution of my colleagues at the Department of Civil & Building Engineering, who provided encouragement and advice to me at various times, is deeply appreciated.

I am very much indebted to my father, Mansoor Ali, my mother Rehmat Banoo, my brother, Malik (Jr.) and his wife Shahzmeen, and my cousin Farida and her husband Farid Panjwani, for their patience, love, support, and encouragement.

And finally, my profound gratitude and praise go to Almighty Allah, who has enabled me to carry out this research, for sustaining me by His grace, and for using people to help me in times of need.

# Table of Contents

<b>Abstract .....</b>	<b>i</b>
<b>Dedication.....</b>	<b>ii</b>
<b>Acknowledgements.....</b>	<b>iii</b>
<b>List of Figures .....</b>	<b>viii</b>
<b>List of Tables.....</b>	<b>x</b>
<b>List of Abbreviations.....</b>	<b>xii</b>
<b>Chapter 1: Introduction.....</b>	<b>1</b>
1.1 Background.....	1
1.2 Guide to the Thesis .....	4
1.3 Project Aim and Objectives .....	6
1.3.1 Aim.....	6
1.3.2 Objectives.....	6
1.4 Justification for the Research.....	7
1.5 Research Methodology .....	8
1.6 Summary.....	10
<b>Chapter 2: Research Methodology .....</b>	<b>11</b>
2.1 Introduction.....	11
2.2 Research Methodologies.....	11
2.2.1 Qualitative Approach.....	11
2.2.2 Quantitative Method .....	12
2.2.3 The Triangulation Method .....	12
2.3 Research Methodology Adopted.....	12
2.3.1 Literature Review.....	14
2.3.2 Comparison of Readiness Assessment Tools and Models .....	14
2.3.3 Development of New Model and its Associated Questionnaire .....	14
2.3.4 Development of Assessment Methodology .....	16
2.3.5 Implementation of Prototype Software .....	16
2.3.6 Case Studies and their Results.....	17

2.3.7. Formulation of CE Implementation Strategies .....	17
2.4 Summary .....	17

**Chapter 3: Concurrent Engineering and Readiness Assessment .....19**

3.1 Introduction.....	19
3.2 Concurrent Engineering (CE) – Definition.....	20
3.2.1 Different Aspects of CE.....	21
3.2.2 Soft & Hard Factors of CE.....	22
3.2.3 Implementation related issues in CE .....	23
3.3 Critical Success Factors for CE Implementation in Other Industries .....	28
3.3.1 Introduction .....	28
3.3.2 Dynamic Phases of CE Implementation Process.....	28
3.3.3 Critical Success Factors for CE Implementation .....	30
3.3.4 Implementation of CSFs in the Construction Industry .....	33
3.3.5 Best Practice CE Environment .....	35
3.3.6 Benchmarking CE Best Practice.....	37
3.3.7 Benefits and Improvements .....	39
3.3.8 Bottlenecks in CE implementation.....	40
3.3.9 Summary & Conclusion .....	42
3.4 Concurrent Engineering in Construction .....	43
3.4.1 The Traditional Approach .....	43
3.4.2 The Application of CE to Construction.....	45
3.5 CE Readiness Assessment .....	49
3.5.1 Introduction .....	49
3.5.2 The Need for CE Readiness Assessment .....	50
3.5.3 Readiness Assessment Criteria .....	50
3.6 Readiness Assessment Tools and Models.....	53
3.6.1 An overview.....	53
3.6.2 Framework for Comparison .....	57
3.6.3 Findings .....	57
3.7 CE Readiness Assessment of the Construction Industry .....	60
3.7.1 The Need .....	60
3.7.2 Choice of an Assessment Model for Construction .....	61
3.8 Summary .....	63

**Chapter 4: Development of a CE Readiness Assessment Model for Construction.....65**

4.1 Background.....	65
4.2 The BEACON Model .....	68
4.3 BEACON Model’s Elements and Critical Factors .....	69
4.3.1 Process Element.....	70

4.3.2	<i>People Element</i> .....	73
4.3.3	<i>Project Element</i> .....	74
4.3.4	<i>Technology Element</i> .....	75
4.4	Maturity Levels.....	77
4.5	The BEACON Questionnaire .....	79
4.6	Discussion.....	80
4.7	Summary & Conclusions.....	81

## **Chapter 5: Development of the BEACON Software.....83**

5.1	Introduction.....	83
5.2	Objectives of the BEACON Software .....	83
5.3	System Architecture.....	84
5.4	Implementation Environment .....	85
5.5	Development of the BEACON Software within MS Access.....	86
5.6	Using the BEACON Software .....	90
5.7	Benefits .....	95
5.8	Summary .....	97

## **Chapter 6: CE Readiness Assessment of the Construction Supply**

### **Chain.....98**

6.1	Objectives of the Assessment .....	98
6.2	Methodology .....	99
6.3	Assessment of the Construction Supply Chain.....	104
6.3.1	<i>Client Organisations</i> .....	104
6.3.2	<i>Consulting Organisations</i> .....	110
6.3.3	<i>Contracting Organisations</i> .....	116
6.3.4	<i>Sub-Contracting Organisations</i> .....	123
6.3.5	<i>Material Suppliers and Manufacturers</i> .....	127
6.4	Comparative Studies of the Results of Construction Supply Chain .....	133
6.4.1	<i>Readiness of Clients</i> .....	133
6.4.2	<i>Readiness of Consultants</i> .....	135
6.4.3	<i>Readiness of Contractors</i> .....	137
6.4.4	<i>Readiness of Sub-contractors</i> .....	138
6.4.5	<i>Readiness of Material Suppliers and Manufacturers</i> .....	139
6.5	Discussion.....	141
6.6	Summary.....	144

## **Chapter 7: Formulation of Strategies for Concurrent Engineering**

### **Implementation.....146**



7.1	Importance of Strategy Formulation.....	146
7.2	CE Implementation Strategies and Considerations for Construction .....	146
7.2.1	<i>Background</i> .....	148
7.2.2	<i>Process Element</i> .....	149
7.2.3	<i>People Element</i> .....	154
7.2.4	<i>Project Element</i> .....	158
7.2.5	<i>Technology Element</i> .....	162
7.2.6	<i>Summary</i> .....	168
7.3	Towards Pilot CE Implementation.....	168
7.3.1	<i>Introduction</i> .....	168
7.3.2	<i>Key Issues</i> .....	170
7.3.3	<i>CE Champion and CE Steering Committee</i> .....	171
7.3.4	<i>CE Teams and CE Team Leader</i> .....	172
7.3.5	<i>Conclusions</i> .....	173
7.4	Summary.....	174

**Chapter 8: Summary and Conclusions .....176**

8.1	Summary.....	176
8.1.1	<i>Aim and Objectives of the Research</i> .....	176
8.1.2	<i>General Summary</i> .....	178
8.2	Conclusions.....	180
8.3	Limitations .....	182
8.4	Recommendations and Further Work .....	183
8.5	Closing Remarks .....	185

**References .....186**

**Bibliography.....199**

**Appendix 1 .....213**

**Appendix 2 .....236**

**Appendix 3 .....237**

## List of Figures

Figure 3.1: Characterisation of Concurrent Engineering	22
Figure 3.2: The improvement cycle	24
Figure 3.3: A comprehensive framework of organisational management and human factors for implementation of Concurrent Engineering	26
Figure 3.4: Four Dynamic Phases of CE Implementation Process	29
Figure 3.5: Camp's Model of Benchmarking	38
Figure 3.6: The over the wall approach	44
Figure 3.7: An integrated project team	45
Figure 3.8: The application of CE in Construction industry	46
Figure 3.9: Implementation Methodology for Concurrent Engineering	49
Figure 4.1: CERAMConstruct Model	67
Figure 4.2: BEACON Model	70
Figure 4.3: The Combination of Process, People, Project & Technology (P <sup>3</sup> T)	71
Figure 4.4: Typical Team Structure within a Virtual Construction Organisation	80
Figure 5.1: System architecture of the BEACON Model	85
Figure 5.2: Integration of Database and Spreadsheet in BEACON Software	89
Figure 5.3: Welcome Screen of the BEACON Model Software	91
Figure 5.4: Control Screen of the BEACON Model Software	92
Figure 5.5: A Typical Questionnaire Form for Critical Factors	93
Figure 5.6: Result Form for Critical Factors	94
Figure 5.7: Using BEACON Model Software	95
Figure 6.1: Integration Support Profile	100
Figure 6.2: Presentation of assessment result on BEACON Model Diagram	103
Figure 6.3: CE Readiness Assessment of Organisation A	106
Figure 6.4: CE Readiness Assessment of Organisation B	107
Figure 6.5: CE Readiness Assessment of Organisation C	108
Figure 6.6: CE Readiness Assessment of Organisation D	109

<b>Figure 6.7: CE Readiness Assessment of Organisation E</b>	<b>112</b>
<b>Figure 6.8: CE Readiness Assessment of Organisation F</b>	<b>113</b>
<b>Figure 6.9: CE Readiness Assessment of Organisation G</b>	<b>114</b>
<b>Figure 6.10: CE Readiness Assessment of Organisation H</b>	<b>115</b>
<b>Figure 6.11: CE Readiness Assessment of Organisation J</b>	<b>118</b>
<b>Figure 6.12: CE Readiness Assessment of Organisation K</b>	<b>119</b>
<b>Figure 6.13: CE Readiness Assessment of Organisation L</b>	<b>120</b>
<b>Figure 6.14: CE Readiness Assessment of Organisation M</b>	<b>121</b>
<b>Figure 6.15: CE Readiness Assessment of Organisation N</b>	<b>122</b>
<b>Figure 6.16: CE Readiness Assessment of Organisation P</b>	<b>125</b>
<b>Figure 6.17: CE Readiness Assessment of Organisation Q</b>	<b>126</b>
<b>Figure 6.18: CE Readiness Assessment of Organisation R</b>	<b>127</b>
<b>Figure 6.19: CE Readiness Assessment of Organisation S</b>	<b>129</b>
<b>Figure 6.20: CE Readiness Assessment of Organisation T</b>	<b>131</b>
<b>Figure 6.21: CE Readiness Assessment of Organisation U</b>	<b>132</b>
<b>Figure 6.22: CE Readiness of Clients</b>	<b>135</b>
<b>Figure 6.23: CE Readiness of Consultants</b>	<b>136</b>
<b>Figure 6.24: CE Readiness of Contractors</b>	<b>137</b>
<b>Figure 6.25: CE Readiness of Sub-contractors</b>	<b>139</b>
<b>Figure 6.26: CE Readiness of Material Suppliers and Manufacturers</b>	<b>140</b>

# List of Tables

Table 3.1: Potential Advantages of Using Concurrent Project Management	40
Table 3.2: Improving construction efficiency by concurrent construction strategies	47
Table 3.3: Readiness Assessment Criteria	51
Table 3.4: Comparison of CE Readiness Assessment & Related Models	58
Table 4.1: BEACON Model Maturity Levels (adopted from RACE model)	78
Table 5.1: Scores of the Responses	88
Table 6.1: A Summary of Readiness Assessment Results for Client Organisations	105
Table 6.2: A Summary of Readiness Assessment Results for Consulting Firms	111
Table 6.3: A Summary of Readiness Assessment Results for Contracting Organisations	116
Table 6.4: A Summary of Readiness Assessment Results for Sub-Contracting Organisations	124
Table 6.5: A Summary of Readiness Assessment Results for Material Suppliers and Manufacturers	128
Table 6.6: Summary of the Readiness Assessment Results	134
Table 7.1: Migration Path for Management Systems (Process Element)	149
Table 7.2: Migration Path for Process Focus (Process Element)	150
Table 7.3: Migration Path for Organisational Framework (Process Element)	151
Table 7.4 Migration Path for Strategy Deployment (Process Element)	152
Table 7.5 Migration Path for Agility (Process Element)	153
Table 7.6 Migration Path for Team Formation and Development (People Element)	155
Table 7.7 Migration Path for Team Leadership and Management (People Element)	156
Table 7.8 Migration Path for Discipline (People Element)	157
Table 7.9 Migration Path for Teams in an Organisation (People Element)	158
Table 7.10 Migration Path for Client Focus (Project Element)	159
Table 7.11 Migration Path for Quality Assurance (Project Element)	160
Table 7.12 Migration Path for Facility Design (Project Element)	161
Table 7.13 Migration Path for Communication Support (Technology Element)	162
Table 7.14 Migration Path for Co-ordination Support (Technology Element)	163

Table 7.15 Migration Path for Information Sharing (Technology Element)	164
Table 7.16 Migration Path for Integration Support (Technology Element)	165
Table 7.17 Migration Path for Task Support (Technology Element)	166
Table 7.18 Step-by-step Migration Path from Ad-hoc to Optimising Maturity Levels	167

## List of Abbreviations

CAD	Computer Aided Design
CC	Concurrent Construction
CE	Concurrent Engineering
CERAMConstruct	Concurrent Engineering Readiness Assessment Model for Construction
CERC	Concurrent Engineering Research Centre (West Virginia University)
CESD	Centre of Entrepreneurial Studies & Development, Inc, (West Virginia University)
CMM	Capability Maturity Model
DBMS	Database Management System
KBMS	Knowledge-based Management System
LAN	Local Area Network
PDP	Project Development Process
PDT	Project Development Team
PMO	The Process Model of Organisation
QFD	Quality Function Deployment
RA	Readiness Assessment
RACE	Readiness Assessment for Concurrent Engineering
SISD	Swedish Institute for System Development
SPICE	Standardised Process Improvement for Construction Enterprise
TQM	Total Quality Management

## **Chapter 1: Introduction**

This chapter presents the introduction to the research topic, and the aim and objectives of the research. It also presents the justification, methodology, and sources of data for the research. A guide to the thesis chapters is also included.

### **1.1 Background**

There is a growing awareness of the need for changes within the construction industry in its current practices and processes of project development which include design, procurement, construction, project delivery etc. This is mainly caused by the following:

1. The dramatically decreasing construction costs through standardisation of construction processes (CIRIA Report,1999);
2. The increasing demand and sophistication of clients (de Graaf et al., 1996);
3. The rising requirements for project functionality through growing competition;
4. The rapid developments in communication and information technologies; and
5. The recommendations in UK Government-initiated reports such as the Latham Report (1994) and the Egan Report (1998).

Many construction companies are responding to this increasing importance of project development processes by incorporating concurrent engineering practices to improve their project development capability (de Graaf and Sol, 1994).

Not only the construction industry, but also other industries are increasingly challenged with growing competition, reduced product life cycle, and changing market and customer demands. To meet these demands, organisations within these industries are forced to develop new products, which have to be cheaper, delivered faster and provide greater functionality. The product development process in many organisations, however, presents many problems with respect to the required product quality, time-to-market, and costs. To achieve a better performance level, a new or better configuration of processes and technology, consisting of people and means, is needed. Concurrent Engineering is considered to offer a solution to the problems encountered. The practice of Concurrent Engineering is known to combine high quality, low cost and a short time to market (de Graaf et al., 1996). Other possible effects of implementation of CE could be a good product development practice, which includes innovation and organisational learning (Bergman and Ohlund, 1995).

In the manufacturing sector, a great improvement in performance and productivity has been achieved through the application of Concurrent Engineering (CE). This application refers to a design process where all life cycle stages of a product are considered simultaneously, from the conceptual stage through the detailed design stage to construction, operation, and eventual disposal of a facility (Tummala, 1996). The CE approach to manufacturing aims to increase product quality and reduce cost and development time, by integrating diverse specialities into a unified development process. The CE approach to product development seeks continuous process improvement. This includes increased organisational effectiveness and efficiency, the elimination of non-value added activities that is waste, and continuous optimisation or



refinement of the entire system which includes design, manufacturing, production and marketing for an improved productivity and quality (Love and Gunasekaran, 1997). The popularity in CE use is, no doubt, a result of the associated benefits in adopting its principles. These includes (de Graaf et al., 1996; Tummala, 1996; Kamara et al., 1997):

- A reduction in product development time and time to market;
- An overall cost saving;
- Products that match customers needs;
- Assured quality; and
- Low service cost throughout the life of the product.

These improvements in productivity, through the use of CE in manufacturing, provide a basis for the adoption of its principles in other industries such as construction. Due to the similarities between the construction and manufacturing industries, developments in manufacturing processes that have led to improvements in the productivity can also be used in the construction processes. These similarities include fulfilling the customers/clients requirements, delivering assured product/project, minimum lead time, cost saving etc. (Kamara et al., 1997). Furthermore, the changing environment within which the construction industry operates, and the growing demand for more units of construction for fewer units of expenditure, are similar to some of the challenges which led to the adoption of the concurrent engineering in the manufacturing industry. It is therefore, argued that, concurrent engineering can provide a suitable framework to improve the construction process. However, while there are similarities, there are also marked differences between manufacturing and construction which should be taken into

consideration if CE is to be effectively implemented in the construction industry and its processes (Kamara et al., 1997).

While Concurrent Engineering (CE) is gaining acceptance, some implementation efforts have not realised their full potential for reducing costs and improving time-to-market for product development efforts. This is due in part to weak planning to support the implementation (Componation and Byrd, 1996). One method that has been used successfully to improve planning is to conduct a readiness assessment of an organisation prior to the introduction of CE. Some studies have been conducted in manufacturing and software organisations using a range of techniques. No similar studies have been conducted in the construction industry. The project will not only focus on the development of CE readiness assessment model for the construction industry but will also come up with CE implementation strategies within the industry.

## **1.2 Guide to the Thesis**

The first chapter is an introductory chapter, which provides an overview of the research, introduces the subject matters, aims and objectives of the project, justification for the research, a brief account of the research methodology, sources of data and a guide to the first year report.

The second chapter gives details of the research methodology adopted for this project and provides a justification for its selection.

The third chapter presents a literature review on Concurrent Engineering (CE), CE Readiness Assessment, the implementation of CE within construction and other industries (e.g. manufacturing, software engineering etc.). It also provides a comparison among existing readiness assessment tools and models, and checks briefly its appropriateness for construction industry.

Chapter four presents the modified new readiness assessment model, called the BEACON Model for the construction, its derivation from existing tool, status of that existing tool, and the description of the stages in the new model. It also describes the main criteria of the questionnaire, which was developed for the new readiness assessment model for the construction industry. Later, this chapter discusses the assessment methodology and result generation techniques and methods.

Chapter five describes the development of a software programme for the BEACON Model. This includes the objectives of the software, its system architecture, its implementation environment, and its actual development. This chapter also presents how to use the software, and its benefits.

Chapter six presents and discusses the results of the CE Readiness Assessment case studies, carried out within the UK construction industry using the BEACON Model.

Chapter seven discusses strategies and considerations for CE implementation based on the CE readiness assessment results presented in chapter six.

The last chapter, chapter eight summarises the whole project, evaluate it against the original aims and objectives, presents the conclusions drawn from the research, outlines recommendations for the companies, and identifies the limitations of the research. It also covers areas for future work, which could be carried out by another researcher, and which was out of the scope of this project.

### **1.3 Project Aim and Objectives**

#### *1.3.1 Aim*

This research project aims to explore the development of a tool which could be used to investigate the readiness of the construction industry to improve its project delivery process through the implementation of Concurrent Engineering (CE), and formulate strategies for the effective implementation of CE within the industry.

#### *1.3.2 Objectives*

The specific objectives of the research project are as follows:

- a) To review the implementation of CE in other industry sectors (e.g. manufacturing, shipbuilding, offshore, software engineering, etc.) with a view to identifying the critical success factors, best practice, the technical and socio-cultural barriers, and generic cross-sectoral benefits;
- b) To investigate existing tools and metrics for assessing the readiness assessment of organisations for CE implementation. These tools will include CMM, RACE, PMO-

RACE, PRODEVO, etc., with the best available tool being selected and, if necessary, modified for use in assessing the construction industry;

- c) To assess the readiness of the construction industry for CE implementation by using the tool resulting from objective b). This will cover key sectors of the supply chain – clients, designers, contractors, and material suppliers/manufacturers. It will identify the barriers, enablers, and critical success factors that will affect the implementation of concurrent engineering in the construction industry; and
- d) To develop strategies and considerations for enhancing the construction industry's efficiency and competitiveness through the implementation of CE. This will be based on the lessons learnt from other industry sectors, and the results of the readiness assessment.

#### **1.4 Justification for the Research**

There is growing interest in the adoption of Concurrent Engineering in the construction industry. Concurrent Engineering has the potential to make construction projects less fragmented, improve product quality, reduce time-to-market and reduce total project cost (Tummala, 1996). It is evident that by adopting Concurrent Engineering (CE), the software and manufacturing industries have significantly improved in the areas mentioned earlier in section 1.1. To facilitate the adoption of Concurrent Engineering in Construction, it is necessary to review CE implementation efforts within other industries and assess the extent to which firms in construction industry are ready for the adoption of CE, and develop guidelines in the form of CE implementation strategies, which would facilitate CE adoption within the industry. This assessment could be done with

the help of CE Readiness Assessment Tools but the existing tools were made particularly for the software and manufacturing industries and may require modification for use in the construction industry. So there is an urgent need for a readiness assessment model, specifically designed for the construction industry, which could focus on the construction industry's practices and assess its readiness for the adoption of CE. On the other hand, there is also a need for a paradigm shift within the construction industry in order to overcome the fragmentation within the industry and CE has potential to overcome this problem (Evbuomwan and Anumba, 1998). However, this cannot be accomplished until CE implementation strategies for the industry are developed and defined.

## **1.5 Research Methodology**

The Triangulation Method, a combination of both Qualitative and Quantitative Research Methods (Denzin, 1978), is used for the research project. A review of the existing literature, written on CE, its implementation within construction and other industries and readiness assessment tools for CE, is based on personal document analysis method. A comparison of the readiness assessment tools and models is also carried out through the qualitative method. The action research method is used to identify problems in the existing tools, which prevent them to be used in the construction industry. The method is then used to develop a solution in form of a model, which is applicable and appropriate to the construction industry through the modification of existing tools.

Development of a readiness assessment model and its associated questionnaire is based on personal document analysis method. Recommendations on using and evaluating questionnaires, presentation of results, and plotting result on the new model are carried out through qualitative review of literature on these topics and through personal document analysis method. MS Office software was used to develop an associated software for the model.

Case studies, their evaluation and presentation of data were carried out through quantitative research method. The development of CE implementation strategies would be based on results from the readiness assessment and a qualitative review of existing literature. The research methodology is described in detail in the next chapter.

Many books have been written in the last fifteen years on Concurrent Engineering and regarding its application in the software and manufacturing industries. The current research activities in academic institutions have also contributed towards the Concurrent Engineering concept, its application to new industries such as construction, readiness assessment tools and models for assessing organisation's readiness for the adoption of Concurrent Engineering, CE implementation strategies etc. These institutions include Concurrent Engineering Research Centre (CERC), West Virginia University; Swedish Institute for System Development; some British Universities including Salford, Loughborough, etc. and others. These research activities and their results are being published in the form of research papers, journal articles and Internet web-sites.

Conferences are being held such as the ISPE International Conference on Concurrent Engineering, which takes place every year and others, to present research work and discuss issues related to Concurrent Engineering. International Conferences on “Concurrent Engineering in Construction” are also being organised, which focus on CE application particularly within the construction industry. Hence, all the above mentioned sources of data are used for the research project.

Readiness assessment data is collected with the help of a questionnaire associated with new readiness assessment model from various construction-related organisations throughout the UK.

## **1.6 Summary**

This chapter gave an introduction to the subject matter, a guide to the thesis, the aim and objectives of the project, justification for the research, a brief research methodology and the sources of data for the research project. The next chapter will elaborate on the research methodology adopted for this project.



## **Chapter 2: Research Methodology**

This chapter gives an introduction to general research methodologies, presents and justifies the methodology adopted throughout various stages of the research project.

### **2.1 Introduction**

The Research Methodology means the entire process of the study (Creswell, 1994). The purpose of describing the research methodology is to let people know about the research methods employed for any project. Research approaches could be based on either Qualitative methods or Quantitative methods or the combination of both called the triangulation method (Denzin, 1978).

### **2.2 Research Methodologies**

As mentioned above, research methodologies could be broadly categorised as either qualitative methods or quantitative procedures or the combination of both of them, termed as the triangulation method. The qualitative, quantitative, and triangulation methods are briefly described below.

#### ***2.2.1 Qualitative Approach***

According to the Creswell (1994), a qualitative methodology is a procedure for a qualitative study that includes advancing the assumptions of qualitative designs,

indicating the specific type of design, reflecting on the researcher's role, discussing data collection, developing data recording procedures, identifying data analysis procedures, specifying verification steps, and presenting the narrative outcomes of the study.

### *2.2.2 Quantitative Method*

The quantitative method seeks to gather factual data in order to study relationships between facts, and how these relationships accord with finding and theories of previous studies and research. Therefore, for this purpose, scientific techniques are used to obtain quantified data which are evaluated in the light of existing knowledge (Bryman & Cramer, 1990).

### *2.2.3 The Triangulation Method*

A combination of qualitative and quantitative methods is termed as the triangulation method, where theories can be developed qualitatively and tested quantitatively. It allows the researchers to gain insights and results to assist in making inferences and in drawing conclusions (Denzin, 1978).

## **2.3 Research Methodology Adopted**

The research methodology adopted is based on detailed surveys and case studies involving the UK construction industry. Use is made of established survey techniques

such as structured questionnaires and readiness assessment metrics and techniques such as CMM, RACE etc., which have been specially developed for use within a Concurrent Engineering context. These models have been used successfully in the manufacturing and software engineering industries to analyse all the key aspects of an organisation and have well-defined metrics for measuring the readiness of organisations for the adoption of Concurrent Engineering (CE). The implementation of CE in these other industry sectors has also be investigated with a view to identifying lessons learnt, best practice, and pitfalls to avoid. The results of the study will be utilised in the later stage of the research to formulate strategies for the effective implementation of CE in the construction industry.

The triangulation method was used for the research presentation in this project. Since the aim of the project was not only to develop a new readiness assessment model and its application within the construction industry by carrying out case studies, but also to develop with CE implementation strategies for the industry. Therefore, the triangulation method was the most appropriate method for this purpose because it combines both qualitative and quantitative methods. Qualitative methods are used for the development of a new model and its associated questionnaire, and formation of CE implementation strategies, whereas quantitative methods are used for carrying out case studies and their results.

### *2.3.1. Literature Review*

The review of the existing literature, written on Readiness Assessment Tools for Concurrent Engineering (CE), was based on personal document analysis, a procedure used to carry out qualitative research by reviewing and analysing current theories and literature (Dainty et al., 1997; Keppel, 1991). The existing material on Concurrent Engineering, and particularly on its readiness assessment and its implementation within other industries, was collected and reviewed and a referenced summary was prepared, which is presented in the next chapter. This includes books, journal articles, conference papers, and material available on the Internet.

### *2.3.2. Comparison of Readiness Assessment Tools and Models*

A comparison of the readiness assessment tools and models was carried out using a qualitative method, and is covered in chapter three. A pre-defined set of criteria was developed and used for the comparison. The comparison was based on the CE aspects covered in the tools and models. The sources of the data were the model themselves and the associated questionnaires.

### *2.3.3. Development of New Model and its Associated Questionnaire*

The action research method was used to identify deficiencies in the existing tools, which make them unsuitable for use in the construction industry. The method is also used to

devise solutions in the form of modifications to existing tools so as to make them applicable to construction. The action research method is a method, which is used to carry out qualitative research by improving current practices and developing solutions to the current problems and deficiencies (Tesch, 1990; Keppel, 1991). In order to develop a new CE readiness assessment model for the construction industry, the Readiness Assessment for Concurrent Engineering (RACE) tool was used and modified according to the requirements of the construction industry. The current processes, and practices within the industry were also taken into account for this purpose and aspects that were irrelevant to the construction industry were deleted from the existing model.

The development of the questionnaire for the new model was based on personal document analysis. The new questionnaire was based on modification of the issues covered in the existing RACE model. All the questions in the new model are in the form of statements unlike the RACE model questionnaire where it is in the form of questions. The new Model also has a five-point assessment scale and comment space unlike the 'Yes' and 'No' answers in the RACE model. The choice of assessment scale and the statement questionnaire were based on the comments and feedback on RACE model (RACE Report, 1993), when it was applied within other industries.

A pilot study was also carried out for the questionnaire, which resulted in its further refinement. The purpose of the study was to validate the questionnaire, check its applicability and effectiveness, and obtain feedback in order to improve the questionnaire. Academia, research associates and managers in the construction organisations were given the questionnaire for this purpose and their feedback was

taken into account for the development of the statements and the assessment scale. This resulted in development of the 'BEACON Model'.

#### *2.3.4. Development of Assessment Methodology*

Personal document analysis method was adopted for a qualitative review of literature (Tesch, 1990). The review helped in developing the recommendations on using and evaluating the questionnaire, presentation of results, and plotting the result of the new model. The scoring, and evaluation of the questionnaire and plotting of the scores on the model were based on previous work carried out by other researchers such as Componation and Byrd (1996) etc. in this field.

#### *2.3.5. Implementation of Prototype Software*

A computer version of the questionnaire was also development called the BEACON Software by using rapid prototype method, which assists in automatic results generation. The software is developed as a Microsoft Access application, and designed to facilitate responsiveness and quick processing. Microsoft Excel is also used in the development of the software and used to produce a graphical representation of the results.

### ***2.3.6. Case Studies and their Results***

Case studies were carried out within the UK construction industry using the new model and its associated questionnaire. The results are evaluated and presented with the help of quantitative research methods. The method of selecting the companies was random, and questionnaires were sent out and completed questionnaires were received by post. The assessment was then based on developed assessment methodology.

### ***2.3.7. Formulation of CE Implementation Strategies***

The development of CE implementation strategy was based on the readiness assessment results and a qualitative review of literature in this area within other industries. Therefore, generic CE implementation strategies were presented along with recommendations, which would vary from company to company.

## **2.4 Summary**

This chapter has described the triangulation method, comprises of both quantitative and quantitative procedures and methods, which was adopted to carry out this research project. The chapter has also described the methodology adopted in detail for each task carried out during the project. This includes literature review on Concurrent Engineering (CE), comparison of CE Readiness Assessment tools and models, development of the BEACON Model and its associated questionnaire, and prototype

software, assessment methodology, case studies and results, and development of CE implementation strategies.



## **Chapter 3: Concurrent Engineering and Readiness Assessment**

This chapter provides literature review on Concurrent Engineering (CE), CE in the construction industry, CE readiness assessment, tools available for carrying out the assessment, and a comparative study of the tools in order to find out the most appropriate model for the construction industry.

### **3.1 Introduction**

Ongoing research and development into the implementation of Concurrent Engineering (CE) within the construction industry have made researchers think how to make CE implementation better, more effective, and more efficient. This has led researchers to investigate CE implementation efforts within other industry sectors, which suggest carrying out a CE readiness assessment of a construction organisation. This should be done before the adoption of some CE aspects within the construction industry, which have facilitated the CE adoption in other industries. The problem is that there is no model or tool available, which will help in assessing the readiness of the organisation. However, there is not only a need to have a CE readiness assessment model for the construction industry, but also to have CE implementation strategies for the industry. Therefore, this chapter includes literature reviews on CE and its application to the construction industry, and a comparative review of existing readiness assessment tools and models that have been specifically developed and successfully used in the manufacturing and IT sectors. The chapter argues that the readiness assessment of a construction organisation is a necessity for the implementation of CE in construction and investigates the applicability of existing tools and models to the construction industry.

### **3.2 Concurrent Engineering (CE) – Definition**

The UK Government initiated reports such as the Latham Report (1994) and the Egan Report (1998) have recommended the improvement of the construction industry's business performance. The need for greater co-ordination and integration within the industry has led to the adoption of various concepts from other industries. One of these, which offers major scope for effective co-ordination and integration within the industry, is Concurrent Engineering (Kamara et al., 2000).

Concurrent Engineering, sometimes called simultaneous engineering, or parallel engineering has been defined in several ways by different authors. The most popular one is that by Winner et al. (1988), who state that concurrent engineering "...is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements." Another definition is by Broughton (1990) who defines simultaneous (concurrent) engineering as "...an attempt to optimise the design of the product and manufacturing process to achieve reduced lead times and improved quality and cost by the integration of design and manufacturing activities and by maximising parallelism in working practices."

### *3.2.1 Different Aspects of CE*

There are eight basic elements of CE, which are divided into two aspects as follows (Bergman and Ohlund, 1995; Chen, 1996, Componation and Byrd, 1996; de Graaf and Sol, 1994; Khalfan and Anumba, 2000c; Prasad, 1997):

#### *Managerial and human aspect*

Managerial and human aspect covers team development, leadership, and organisational philosophy. It includes:

- The use of cross-functional, multidisciplinary teams to integrate the design of products and their related processes;
- The adoption of a process-based organisational philosophy;
- Committed leadership and support for this philosophy; and
- Empowered teams to execute the philosophy.

#### *Technological aspects*

This includes use of technology for design and manufacturing, communication, co-ordination, and developing standards. It covers:

- The use of computer aided design, manufacturing and simulation methods to support design integration through shared product and process models and databases;
- The use of various methods to optimise a product's design and its manufacturing and support process;
- The use of information sharing, communication and co-ordination systems; and

- The development and/or adoption of common protocols, standards, and terms within the supply chain.

### 3.2.2 Soft & Hard Factors of CE

CE encompasses a number of business method, which comprises a series of interconnecting practices relating to people, processes, computer-based support tools, and formal method (see Figure 3.1). Broadly speaking, the model can be divided into those ‘soft’ or psychological aspects of CE such as team working and team leadership, and those ‘hard’ factors or systems of CE such as formalised methods, e.g. QFD, FMEA and computer-based support tools (Dann et al., 1996).

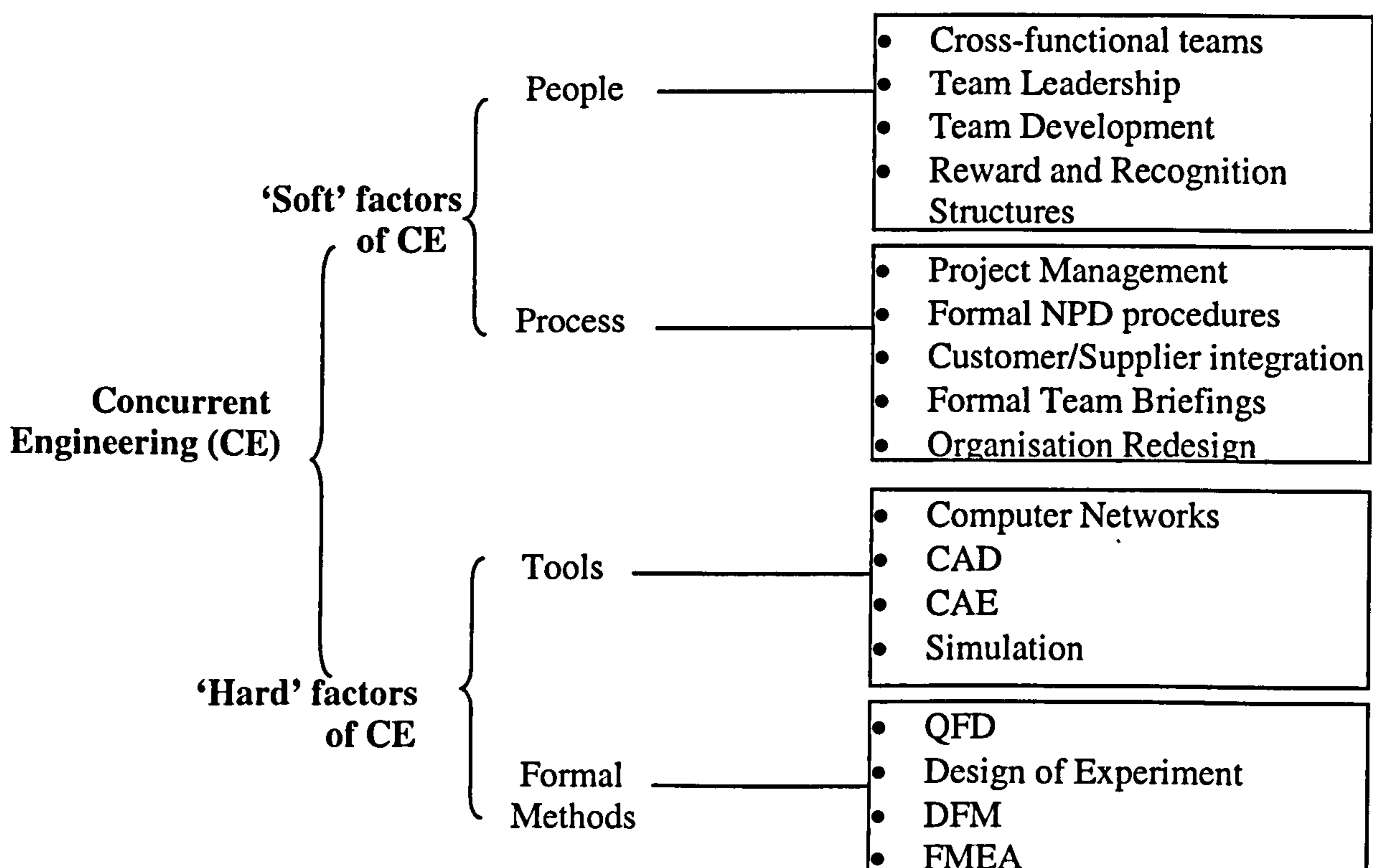


Figure 3.1: Characterisation of Concurrent Engineering (Dann et al., 1996)

### *3.2.3 Implementation related issues in CE*

In order to compete and cut down the lead-time for introducing new products, many of the large automotive industries in the western world are adopting this integrated approach to product development. The theory of simultaneous engineering is simple, the implementation however has proved to be a difficult task. Attempts to implement simultaneous engineering can result in restructuring and reorganisation of a company. The major issue involved with implementation can be summarised as follows (Sya, 1997):

- a) Senior management commitment;
- b) People management;
- c) Product costing;
- d) Monitoring, feedback and control; and
- e) Financial Justification.

Implementing Concurrent Engineering, however, is not straightforward, but requires well-designed improvement cycles. In Figure 3.2 the four successive stages in an improvement cycle are depicted. These stages are awareness, readiness, deployment and improvement. In the awareness stage, the potential benefits of Concurrent engineering are becoming known. In the readiness stage, the company is measured with respect to certain performance criteria. These measurements lead to decisions concerning adaptation to the organisation, the technology and the process, composing the product development process. In the deployment

stage, specific improvement plans are made and implemented. In the improvement stage, the progress is measured and the improvement cycle is closed by re-entering the readiness stage for further improvement (de Graaf et al., 1996).

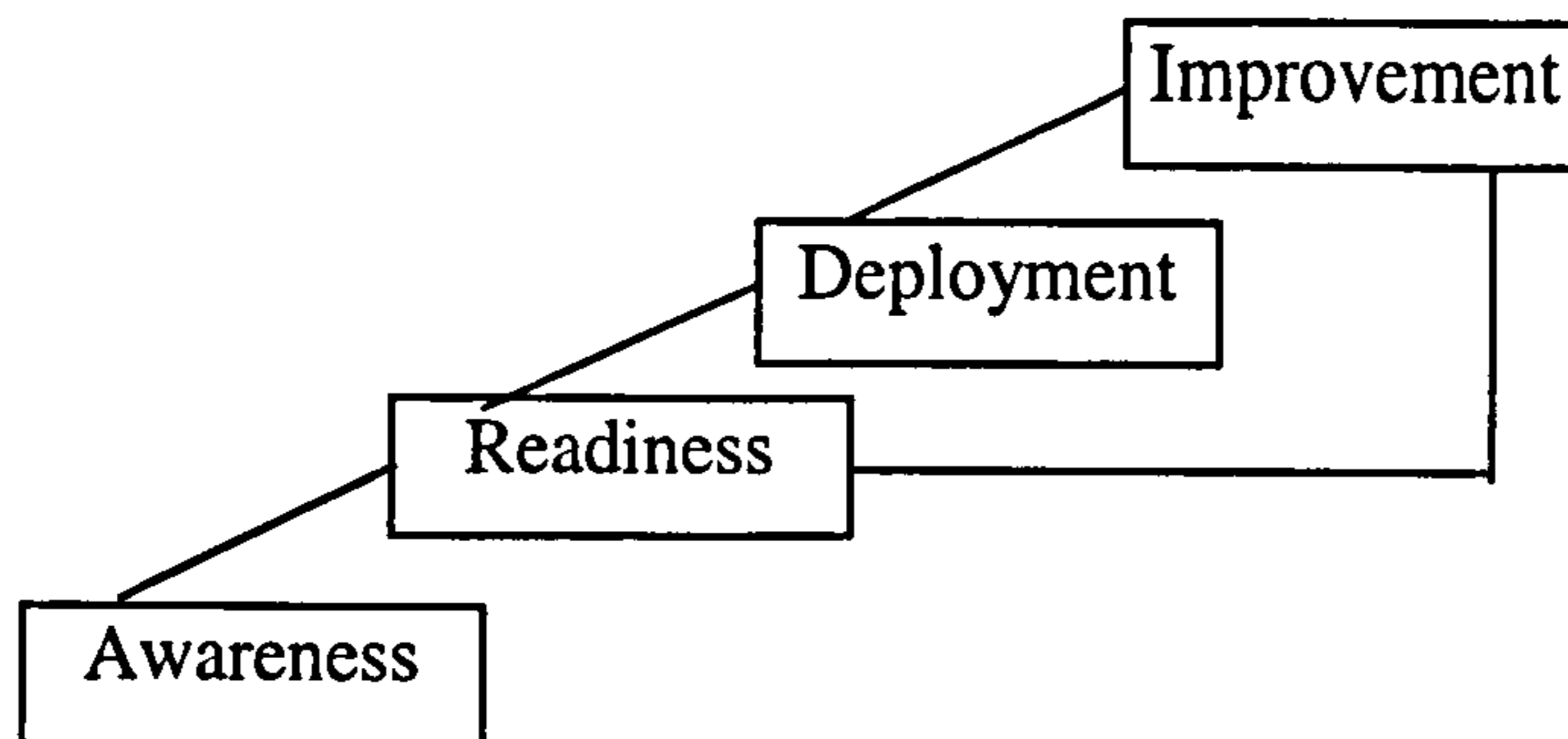


Figure 3.2: The improvement cycle (de Graaf et al., 1996)

Chen (1996) has described two basic issues, which are very important for the success of implementation of CE: organisational management and human issues. Organisational management and human issues can be further sub-divided into other issues at three levels: individual level, team level, and organisation level (see Figure 3.3). A brief description on each of these levels is presented below (Brooks and Foster, 1997; Chen, 1996; de Graaf et al., 1996; Deasley and Lettice, 1997; Johansson et al., 1999; Thamhain, 1994; Tucker and Leonard, 1994; Tummala et al., 1996):

### *Individual Level Issues*

The individual level issues emphasise on areas related to an individual working in an organisation as a part of a team. Some of the issues covered under this area are communication and interaction among individuals; different cultural background and value system; and knowledge and experiences of an individual. These issues are outlined below:

- Different members emphasising their speciality, and different vocabulary for expressing the same thing within a multi-disciplinary team may cause obstacles of communication and mutual understanding;
- Conflicts among members when members give priority to their departments' benefits;
- Members at different research level may have different way of doing research in the team;
- Work habits influence the progress of project, for example designers do not want to share design details until it reaches to a mature level etc.;
- The gap of educational degree is harmful to CE;
- Value held by team members may be different to new product development, and they may be different degree of attentions to different aspects of development process, this may cause conflicts among team members;
- Different attitude of risk-taking may also cause conflicts among team members;
- Different moral character (which could be divided into two aspects, one individualism/collectivism and other is responsibility) may cause conflict among team members and influence communication among them; and
- Suitable interaction skills must be adopted in order to care about the social faces of other members.

### ***Team Level Issues***

Team level issues cover the areas, which are critical for a team within an organisation. These issues include development of a team, communication among team members, decision-making procedure within a team, reward system, team leadership, size of a team, etc.

Following are some of the above mentioned issues presented in detail:

- Establishment of the co-operate goal system among cross-functional, multi-disciplinary team (and could be virtual team) members;

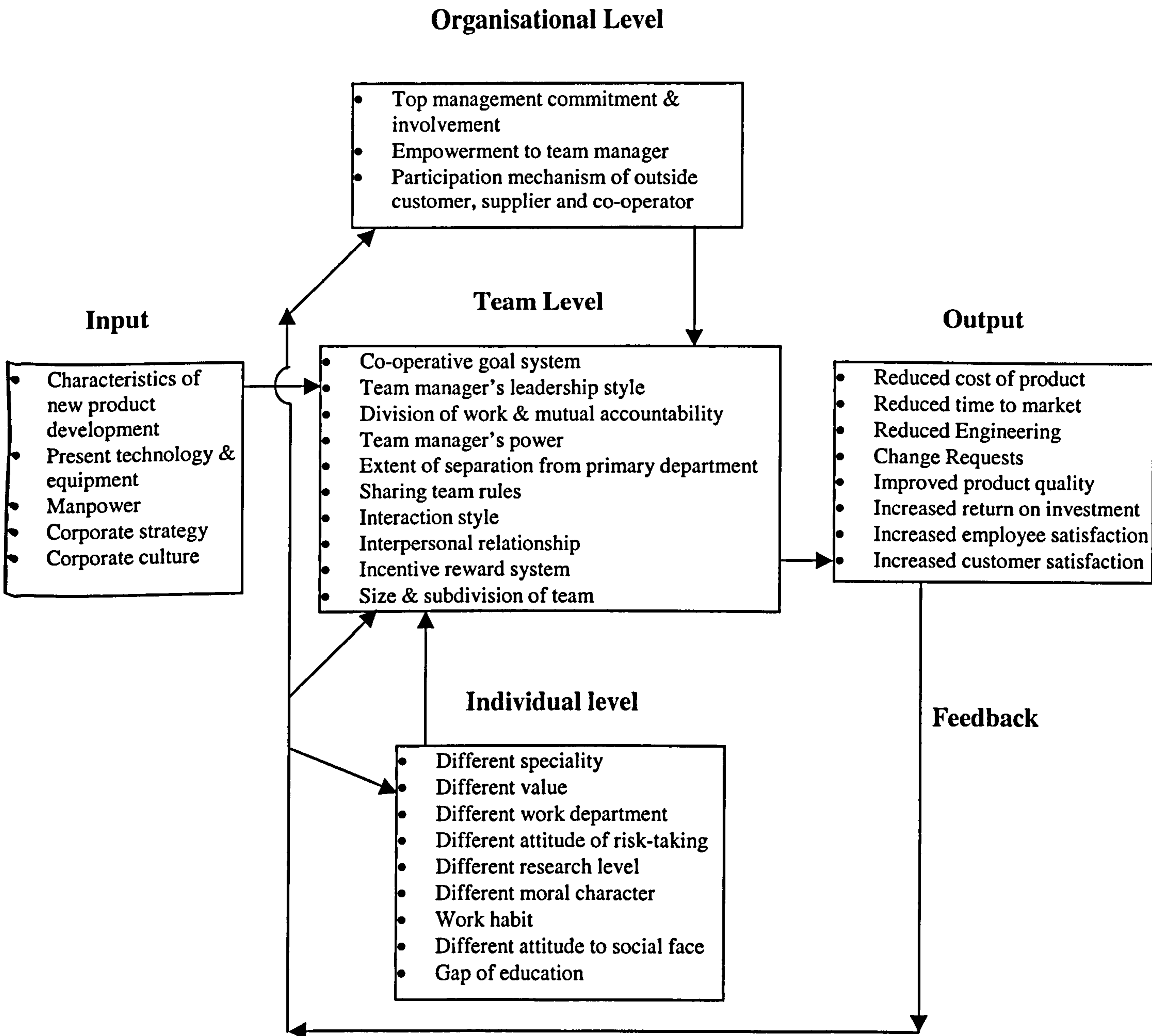


Figure 3.3: A comprehensive framework of organisational management and human factors for implementation of Concurrent Engineering (Chen, 1996)



- Division of whole work into parts at every development stage and assignment to every team members, and establishment of mutual accountability among team members;
- Establishment of common rule for effective communication, work procedure, problem solving and decision-making and this must be established on the agreement among every member;
- Interaction skill or style (very important at the times when one agrees or disagrees with other people's opinion);
- Incentive reward system should be established in order to motivate team members, and should be based on both personal performance and total team efforts;
- Team managers' leadership style is crucial to the performance of the team members;
- Team managers' power and influence in terms of getting work done and task achievement by sub-ordinates, awarding reward and promotions, and future career development;
- Extent of separation of a team member from his/her primary department (it may influence the management performance of the team);
- Inter-personal relationship among team members is essential for their co-operation; and
- Team size should be suitable for effective communication, co-operation, problem solving, and decision making (if there is a big team then it should be sub-divided into suitable size to achieve above-mentioned operations).

### ***Organisational Level Issues***

Organisational level issues discusses issues related to the top management within an organisation, authority given to a team leader, and involvement of supply chain throughout the project life cycle. This suggests:

- Top management commitment and involvement is crucial for the success of any project development process;
- Team leader/manager should be given power for utilising the available resources within the organisation; and
- Customers, suppliers and other co-operators must be involved throughout the project development process.

### **3.3 Critical Success Factors for CE Implementation in Other Industries**

#### **3.3.1 Introduction**

Based on an extensive literature review, it has been established that there are 10 leading critical success factors (CSFs) that contribute to a successful implementation of CE (Chen, 1996; Deasley & Lettice, 1997; Holmes, 1994; Tummala et al., 1996). These factors have also been included in a conceptual representation of the CE implementation process (see Figure 3.4). Figure 3.4 also shows four dynamic phases of this implementation process, which are described in the following section.

#### **3.3.2 Dynamic Phases of CE Implementation Process**

The first phase (see Figure 3.4) is a foundation phase, which permits an organisation to understand and become familiar with the changes demanded by CE. This is often an important commitment building phase and is likely to influence the success of the future phases (Deasley & Lettice, 1997). The first phase is then followed by a phase of higher

activity in which the formation of an integrated product development environment begins to take place, which is based on multi-disciplinary teamwork or sometimes called the CE team. The use of a CE team is most important during the early phases of a project when the benefits of working in parallel are greatest (Johansson et al., 1999). The next phase seeks to manage the boundary between the multi-disciplinary team environment and the rest of the organisation. The fourth and the last phase is about developing internal processes to capture the experiences and lessons from the early phases and apply them to later product development projects. This will help to institutionalise some of the new working practices with the aim of sustaining CE in the organisation.

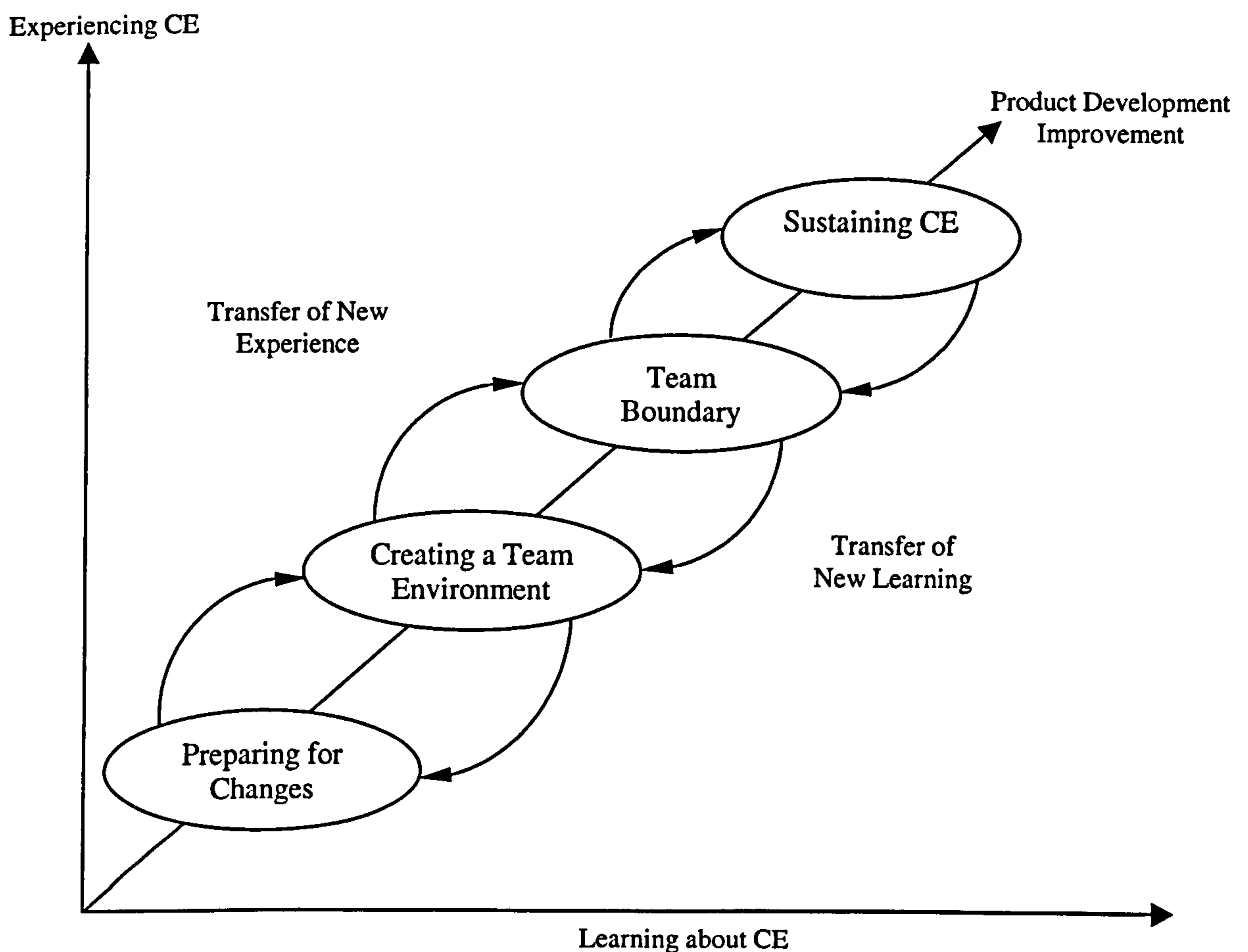


Figure 3.4: Four Dynamic Phases of CE Implementation Process (Deasley & Lettice, 1997)

### **3.3.3 Critical Success Factors for CE Implementation**

The 10 CSFs for CE implementation are described below using the 4 phases described in Figure 3.4:

#### **Phase 1: Preparing for Change**

##### **CSF 1) Development and Dissemination of Management Intention**

Senior Management must build a clear understanding of what implementing CE involves.

##### **CSF 2) Change Agents**

Change agents should be appointed by senior management to assist them in driving and monitoring the changes brought on by CE. These agents are often internal to the organisation in the form of a CE Champion and a CE Steering Committee. The CE Champion is a member of the management team and plays a key role. They must (Brooks & Foster, 1997):

- Be a senior person committed to and responsible for achieving the change outcome and gaining the targeted benefits
- Support the team's desire to work in a new way
- Ensure that the team receives support, training, and on-going facilitation
- Be prepared to defend or protect the team and their 'radical approach' in the face of pressures from the rest of the conventional organisation
- Communicate and promote the new way of working

On the other hand, the CE Steering Committee should set a clear performance target for the team, which is aggressive yet achievable. This indicates to the team WHAT they must achieve. The team must then decide HOW it is to be achieved through the development of a detailed project plan (Evans et al., 1994).

### CSF 3) Pilot Project(s)

CE must be implemented in a progressive manner. The initiation of one or two CE pilot projects, to show product development success, prior to expanding it to the whole organisation, is extremely common for CE implementation within any organisation.

### Phase 2: Creating an Integrated Product Development Environment (creating a team environment)

#### CSF 4) Integrated Product Development Teams

It is important that all the functional disciplines should be involved during the early design stage. The use of integrated product development teams (CE teams) should be extensive during a product development process. The selection of team members is generally done through considering the technical ability and availability of the members. An internal training and assessment centres could be set up, which can help identify good team players and harmonise their skills to project tasks.

#### CSF 5) Collocation

Sharing partial information incrementally during the stages of product design, when task mutual-dependency and ambiguity are high is vital to development speed.

#### CSF 6) Team Confidence

Senior management must ensure that the CE team is clear and confident about its role and responsibilities. If the CE team feels that their superiors support them then they will feel greater possession for their project tasks. This is especially important during the early creative stages of product development when the product specification is being defined and project plans are being produced.

#### Phase 3: Team Boundary Management

#### CSF 7) Develop Team Environment Interfaces

Senior management must understand, develop, and clarify the interfaces between the CE team and the rest of the organisation and communicate these to all employees.

#### Phase 4: Sustaining CE

#### CSF 8) Team Based Reward Systems

Reward systems need to be modified with the introduction of multi-disciplinary teamworking practices. As the division of labour becomes narrower, new performance metrics and career development plans need to be made.

### **CSF 9) Managing Integrated Product Development Projects**

Importance should be given to the way in which integrated product development activities are managed after the initial pilot CE project(s). It is important that the organisational structure and the business processes, which run through it, go together with CE working practices.

### **CSF 10) Developing Internal Learning Processes**

The changes made during the CE implementation process are very important experience. By using internal formal and informal learning processes such as project reviews, seminars, workshop etc., this new experience can be transferred to other workforce.

### ***3.3.4 Implementation of CSFs in the Construction Industry***

Deasley and Lettice (1997) have suggested the application of the CSFs to the Construction Industry as follows:

#### **i) Preparation for a Different Way of Working:**

The application of CSFs 1, 2 and 3 is key to the establishment of a suitable platform for CE implementation within the construction industry. Awareness training to strengthen the aims of the initiative, to build an environment of trust and to set the terms of reference of the CE team must be introduced from the beginning and continue throughout the project. The choice of team leader or “champion” also needs careful consideration, because he/she is the one who naturally interfaces with all parties. Deasley and Lettice (1997) suggest that in the construction industry, the structural engineer/designer could be the most suitable person. Similarly, the choice of pilot projects is vital because early success is needed to support the

long-term success of the whole project. Apart from human factor issues, a powerful integrating influence on team performance is the use of appropriate information technology. This is particularly important in construction, as team members are likely to be distributed over different geographical locations.

ii) Creating an Integrated Development Environment:

Much of the detailed activities discussed under CSFs 4 and 5 are applicable, in modified form, to construction. The integrated development offers the greatest potential for cost and lead-time reduction. Collocation issue can readily be realised in a “virtual construction team” environment. As discussed in CSF 6, team confidence is vital and can be ensured by good communications and continual training.

iii) Team Boundary Management:

The issues raised in CSFs 7, 8, 9 and 10 are possibly the most difficult to relate to the construction industry as experience in construction industry is limited in comparison with manufacturing. However, the CSFs do give a sign of important issues for the future when the sector has more experience. A vital issue will be that of team-based appreciation and reward, and the development of meaningful performance metrics on which to base them. It is also important to set up internal learning processes as a basis for continuous improvement.



### *3.3.5 Best Practice CE Environment*

Some of the key features of a best practice CE environment involve the contributions made by people, processes, and systems, which involve customer driven activities, lean processes, motivated teams with organisations, and effective and accessible information flow (Brooks & Foster, 1997). Each of them is further defined below in this section.

#### *Customer Driven Activities*

Customer driven activities include involvement of customers in the product development process, clear definition of customers' requirements, and good understanding of the market.

#### *Lean Processes*

Lean processes comprise of integrated strategies and plans for the product development that focus on integrating activities, information 'pull' from downstream rather than 'push' from upstream, and controlled and measured parallel working towards product development.

#### *Motivated Teams*

The characteristics of motivated teams within the organisation are that they are multi-disciplinary teams, co-located, focused roles of each team member, single point responsibilities of each team member, authority and empowerment of team leader/management, excellent skill based, and recognition and rewards to the team members for their efforts.

### *Effective Information Flow*

Timely and accessible information means use of best practice tools e.g. CAD & EDM, visibility of information and documentation, visible progress status of the product, selective access to product data, reuse of existing product data, single master source of product data, and configuration management & change control within the organisation during the product development process.

The above mentioned key features of CE environment can be adopted in the construction industry to implement CE effectively within the industry, and in fact some of these are already being practised within the industry. For example clients are involved during the project development process and client's requirements are clearly defined and known by each member of project development team. Similarly, the industry has already moved towards the lean construction concept, which includes controlled and measured parallel working during the project development, development of plans and strategies that focus on integrating activities, etc. As far as teams within a construction organisation is concerned, they are multi-disciplinary, co-located, each team member has particular role and is responsible for his/her task, and team management has authority to take decisions for particular issues. The issue of effective information flow and accessibility of this information is now gaining more importance within the industry. Best practice tools such as CAD and EDM are being used with the industry, existing project data is reused, and integrated databases are being developed for particular projects to store project data that is accessible to the project development team (Khalfan, 2000).

### *3.3.6 Benchmarking CE Best Practice*

Benchmarking and its process is defined here, which must be understood to identify industry best practices. Benchmarking first gained popularity with a publication by Camp (1989) describing a methodology for improving business performance initiated by the Xerox Corporation in 1976. He defines benchmarking as the search for best practice that will lead to better performance of an organisation. The approach is described as a positive, practical process to change operations in a structured manner by comparing and learning from the performance of operations either within the same organisation, with direct product competitors, or alternatively with world class businesses (Dann et al., 1996). The emphasis of this business improvement method is not simply on the comparison of the organisation products and services, but also on the execution of the observed best practices within the organisation. Furthermore, supporters of the benchmarking philosophy recommend that it should be an ongoing process within any organisation (Camp, 1989; Watson, 1993). Camp offers a practical eleven-step model of the benchmarking process, which is shown in the Figure 3.5.

Benchmarking methodology begs the following question: “How do companies know whether their formal processes represent best practice for beating the competitions?” In response to this question, Dann et al. (1996) has proposed that a benchmarking classification or taxonomy should also be developed, which will allow companies to compare themselves with similar development projects and providing a model for implementation based on Camp’s model. Also by conducting such an exercise would help to ensure that CE implementation is effective within an organisation where formal process is responsible for prescribing a product

development process, and acting as a map for planning and guiding CE activities (Ainscough & Yazdani, 1999). Therefore, companies, wishing to stay in front of the competition, are more likely to succeed by adopting “best practice” outside their market sector and ‘to steal shamelessly’ from the practices left untouched by their competitors. This may be carried out in a process called ‘generic’ benchmarking (Dann et al., 1996). However, whilst benchmarking exercises have proved to be successful, and applications for the method are rapidly growing, the technique can be resource intensive, and time consuming. Also finding a suitable partner who is a “world leader” is not always an easy task. Thus, benchmarking can be impractical, particularly to the smaller businesses.

**Planning**

- 1) Identify what is to be benchmarked
- 2) Identify comparative companies
- 3) Determine data collection

**Analysis**

- 4) Determine current performance gap
- 5) Project future performance levels

**Integration**

- 6) Communicate benchmarking findings and gain acceptance
- 7) Establish functional goals

**Develop Action Plans**

- 8) Implement specific actions and monitor progress
- 9) Recalibrate benchmark

**Maturity**

- 10) Leadership position attained
- 11) Practices fully integrated into process

Figure 3.5: Camp’s Model of Benchmarking (Camp, 1989)

### *3.3.7 Benefits and Improvements*

In this sub-section, benefits and advantages of CE implementation, and improvements within an organisation due to the implementation is outlined. CE has potential to improve a company's performance in the global marketplace. For this to happen the time-to-market must be reduced, as must the costs of developing new product, and the quality and product variety must be increased (Melling, 1996). It has also been observed that through establishing concurrent working practices, a company or an organisation can gain the full advantage of increased flexibility and a more strong process, while a team focus reduces development risks and provides an overall higher design and production quality (Holmes, 1994).

It is possible to shorten product development lead times by up to 50% by integrating suppliers in the development process (Johansson et al., 1999). And in order to shorten the time-to-market of any product, it should be designed right first time in order to reduce redesign of the product and this can be achieved by introducing CE practices within the organisation. Other benefits of CE introduction and implementation include improvement in communication, quality and production costs, and a reduction in design change and design repetition (Melling, 1996). Thamhain (1994) has described benefits and advantages of using CE in Table 3.1.

Implementation of CE can bring a number of improvements within an organisation. These improvements could be seen in the form of design, procurement, production, and support productivity. Improvements within design productivity include reuse of standard part data, less rework in design, etc. Procurement productivity can be seen in terms of reduced

inventory through better planning, less material scrap due to late design change, etc. Improvements in production productivity can be seen in form of reduction in rework and scrap, right information at the right time, material definition linked to work packages, cost of change identified and managed, improved and integrated planning, improved build strategy, etc. And support productivity can be realised in form of single product data model, logistic support analysis record, data availability etc (Brooks & Foster, 1997).

Table 3.1: Potential Advantages of Using Concurrent Engineering (Thamhain, 1994)

- |   |
|---|
| <ul style="list-style-type: none"><li>• <b>Speed</b> – More rapid project execution, shorter development or implementation time</li><li>• <b>Cost</b> – Lower project cost</li><li>• <b>Market Response</b> – Faster reaction time and responsiveness to changing markets and customer requirements</li><li>• <b>Predictability</b> – Higher accuracy of projects plans, their schedules and budgets</li><li>• <b>Quality</b> – Higher overall quality of end product through effective technology transfer</li><li>• <b>Risk</b> – Lower implementation risks</li><li>• <b>Complexity</b> – Ability to execute higher levels of system/project complexity</li><li>• <b>Innovation</b> – Higher level of product and process innovation</li><li>• <b>Customer Satisfaction</b> – Can be increased for user-focused developments</li></ul> |
|---|

### 3.3.8 Bottlenecks in CE implementation

The following are some of the bottlenecks, which cause obstruction during CE implementation within any organisation (Componation & Byrd, 1996; Constable, 1994; de Graaf & Sol, 1994; Hills, 1992; Sharon, 1992):

- Unclear and indistinct Project Development Process (PDP);
- Unreliable and segregated planning;

- Unclear strategy for CE implementation;
- Insufficient communication of corporate strategy and its translation into achievable goals;
- Lack of inter-disciplinary communication throughout PDP (within both technical and non-technical departments);
- Cultural barriers to change within the organisation;
- Lack of integration in the teams;
- Unclear product/project architecture;
- Too strict customers/client requirements;
- Insufficient technical skills of the team members;
- Lack of complete product requirement (caused by insufficient understanding of customer requirements for product performance, lack of understanding of interaction between the product and other product or system, or a lack of understanding of internal skill level for the design and manufacture of the product);
- Lack of clear understanding of risks (includes risks associated with the skill level of the design team, competition for limited organisational resources, funding limitation, economic conditions, and supplier difficulties resulting in extended lead times);
- Lack of systems to support early decision making by the product development team, and feedback to the team;
- Lack of quality design staff who have both high levels of technical skill and an understanding of the entire product and product development process;
- Dominant team leader (who simply imposes his/her opinions on team members); and
- Competition among teams (e.g. each team does its best to secure the facilities and resources that are needed and this may mark the beginning of conflict between teams);

For the construction industry, most of the bottlenecks are the same as those outlined above. For instance; unclear strategy for CE implementation; insufficient inter-disciplinary communication; cultural barriers to change; lack of integration in the teams; too strict client's requirements; lack of clear understanding of risks; and dominant team leader. After the identification of these bottlenecks, which affect CE implementation within any organisation, the next step in CE implementation is to formulate the strategies and plans to overcome these bottlenecks and problems within the industry.

### *3.3.9 Summary & Conclusion*

This section has discussed the application of CE within the construction industry. It has outlined the critical success factors for implementing CE in other industry sectors in detail and their applicability to the construction industry. The key features of a best practices CE environment, based on CE implementation in the other industries such as manufacturing and software engineering, have also been outlined. It has also discussed the bottlenecks and problems during CE implementation in other industries. The following conclusions can be drawn:

- It is important to address the identified CSFs and adopt the features of the best practice CE environment from the other industries to ensure effective CE implementation within the construction industry;



- It is important to keep in mind and share the lessons learnt from CE implementation in the other industries and try to overcome identified problems and bottlenecks during CE implementation; and
- CE implementation in the construction industry needs to be planned and tailored to suit the particular needs of the industry.

### **3.4 Concurrent Engineering in Construction**

In the context of the construction industry, Evbuomwan and Anumba (1998) defined Concurrent Engineering as an “...attempt to optimise the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximising concurrency and collaboration in working practices.” This is in sharp contrast with the traditional approach to construction project delivery.

#### ***3.4.1 The Traditional Approach***

In the construction industry, based on the client brief, the architect produces an architectural design, which is given to the structural engineer, who on completing the structural design passes the project to the quantity surveyor to produce the costing and bill of quantities. This goes on until the project is then passed on to the contractor who takes responsibility for the construction of the facility. This scenario, which is similar to the ‘over the wall’ approach (Evbuomwan and Anumba, 1998; Prasad, 1997) is shown in Figure 3.6.

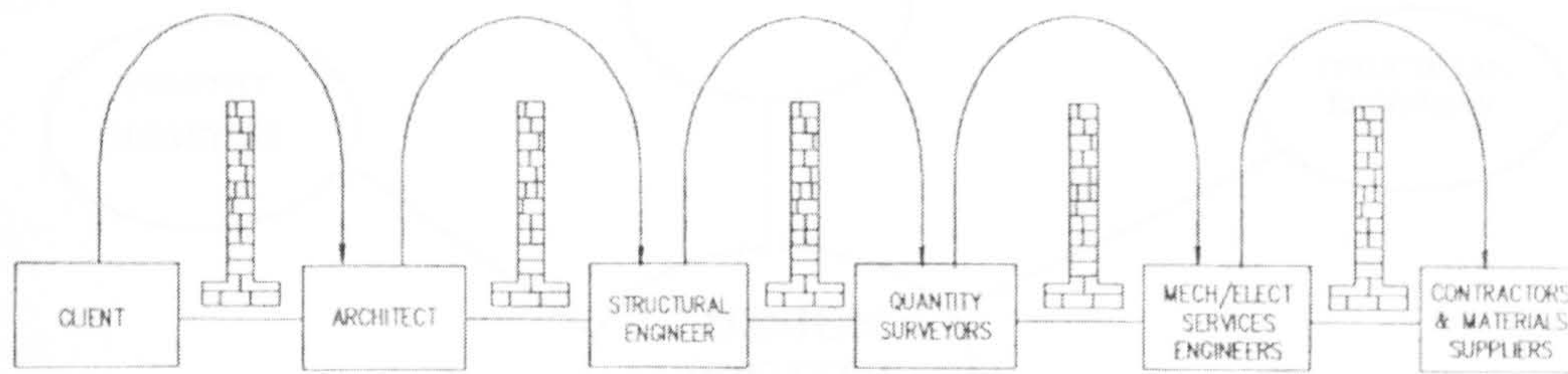


Figure 3.6: The over the wall approach (Evbuomwan and Anumba, 1998)

The key disadvantages prevalent with this approach include:

- The fragmentation of the different participants in the construction project, leading to misperceptions and misunderstandings;
- The fragmentation of design and construction data, leading to design clashes, omissions and errors;
- The occurrence of costly design changes and unnecessary liability claims, occurring as a result of the above;
- The lack of true life-cycle analysis of the project, leading to an inability to maintain a competitive edge in a changing marketplace; and
- Lack of communication of design rationale and intent, leading to design confusion and wasted effort.

To address these issues, there is an urgent need for a shift in paradigm within the construction industry. This should involve the adoption of new business strategies, with the aim of integrating the functional disciplines (see Figure 3.7) at the early stages of the construction project (Evbuomwan and Anumba, 1998).

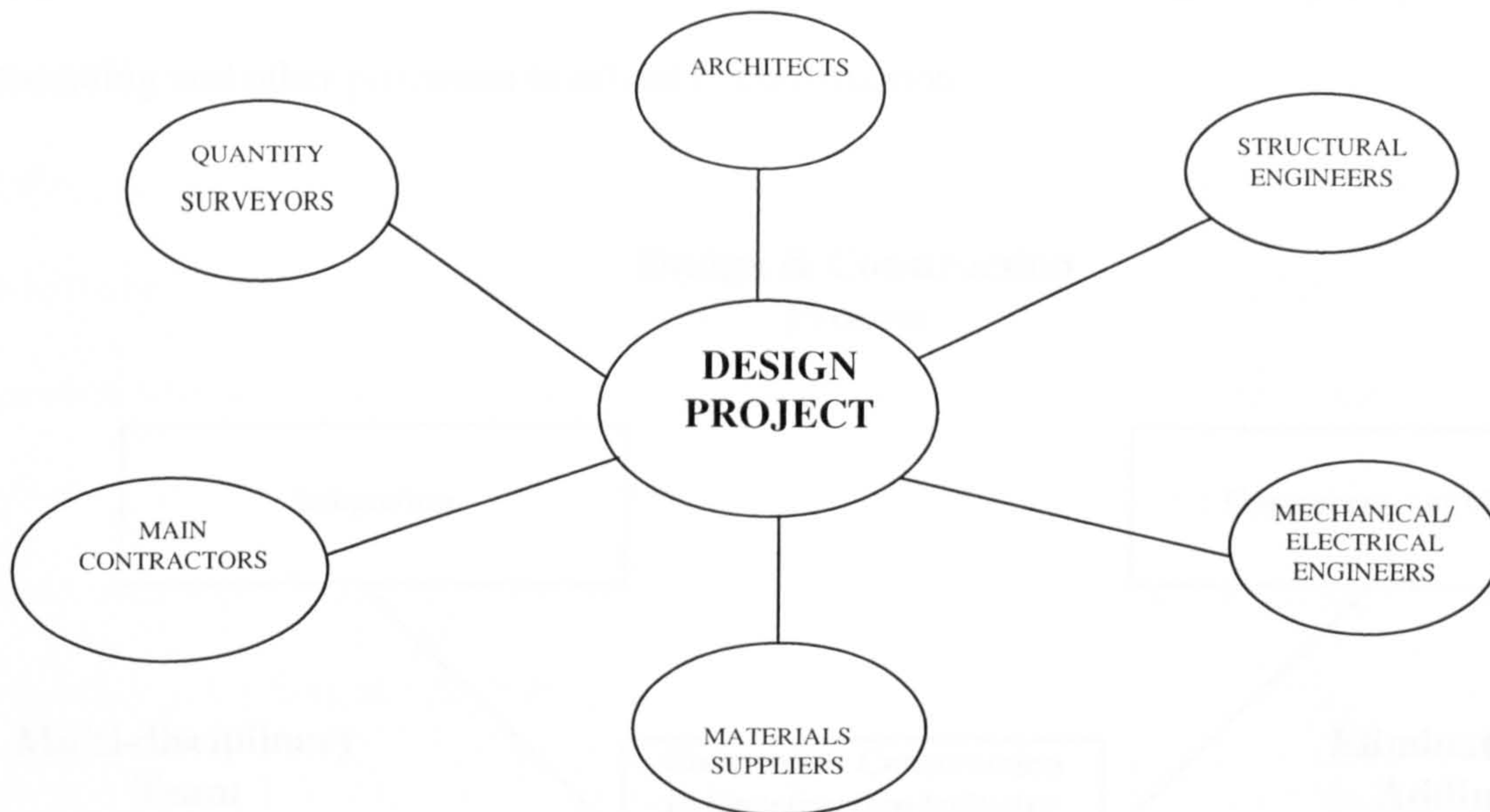


Figure 3.7: An integrated project team (Evbuomwan and Anumba, 1998)

### 3.4.2 The Application of CE to Construction

There is an urgent need to improve the performance of the construction supply chain participants. This can be achieved during the design process by considering all aspects of the project's downstream phases concurrently. Incorporating requirements from the construction, operation and maintenance phases at an early stage of a project would undoubtedly lead to an overall improvement in project performance. The essential constituents of 'Concurrent Construction' are as follows (Love and Gunasekaran, 1997):

- The identification of associated downstream aspects of design and construction processes;
- The reduction or elimination of non-value-adding activities; and
- The development and empowerment of multi-disciplinary teams.

A conceptual model explaining the application of CE in construction industry is presented in Figure 3.8. In order to develop a cost effective construction system, there is a need to

integrate various activities in construction industry including design, procurement, accounting and other processes involved in construction.

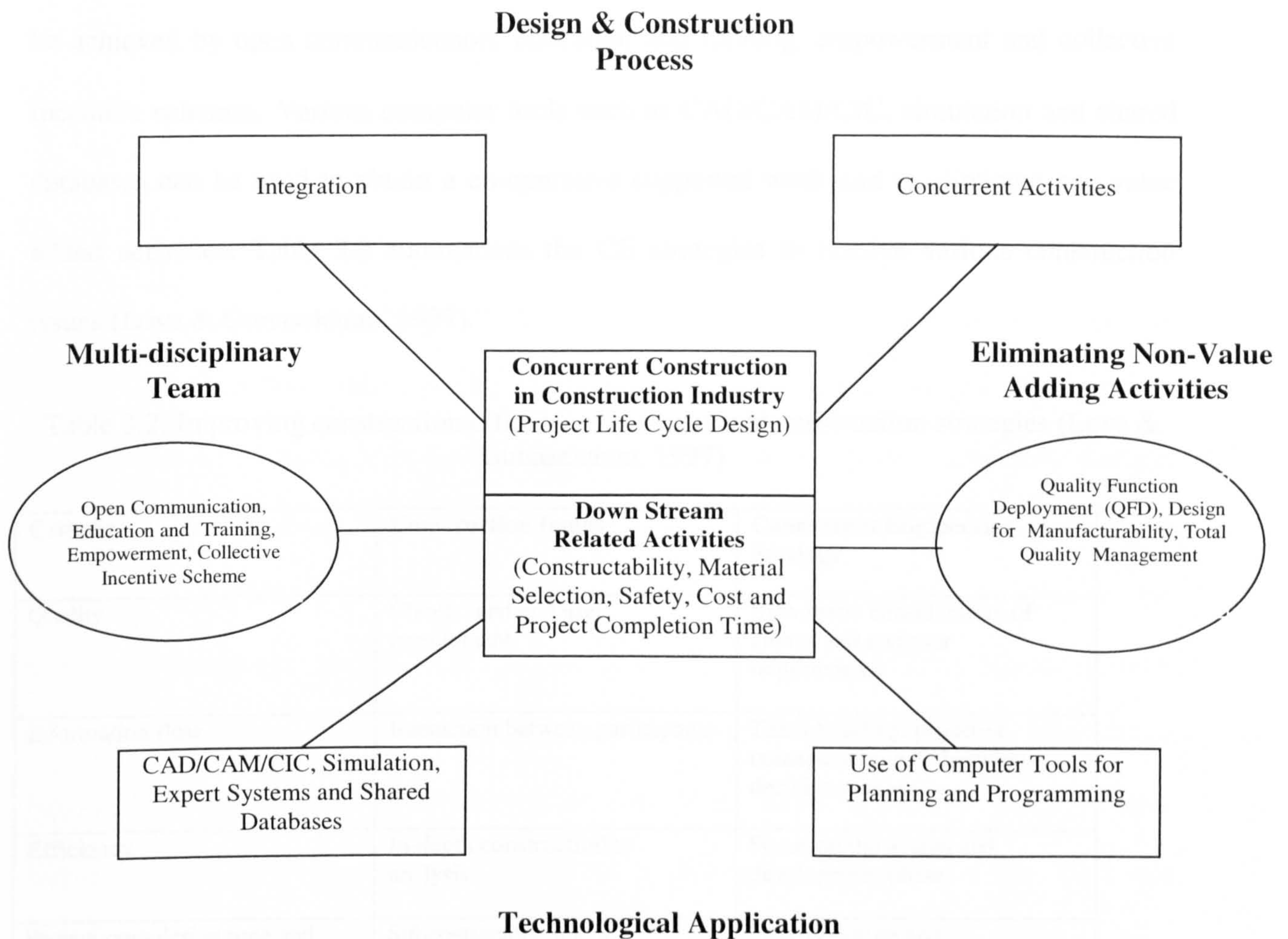


Figure 3.8: The application of CE in Construction industry (Love & Gunasekaran, 1997)

The simultaneous consideration of these activities at the design stage will improve the performance of construction industry by eliminating non-value-added activities at the downstream-related activities with help of a multi-disciplinary team. The downstream-related aspects should include constructability, material selection, project completion time and cost

reduction, skills available and safety. Technologies and concepts such as QFD, Design for Manufacturability, and TQM can be used for eliminating non-value added activities such as rework, scrap, unscheduled maintenance and inventory. The multi-disciplinary teamwork can be achieved by open communication, education and training, empowerment and collective incentive schemes. Various computer tools such as CAD/CAM/CIC, simulation and shared databases can be used to obtain a co-operative supported work and to eliminate non-value added activities. Table 3.2 summarises the CE strategies to resolve various construction issues (Love & Gunasekaran, 1997).

Table 3.2: Improving construction efficiency by concurrent construction strategies (Love & Gunasekaran, 1997)

Criteria	Construction Issues	Concurrent Engineering Strategy
Quality	Clients' and end user requirement	Systematic consideration of clients and end user requirements
Information flow	Interaction between participants	Team-building, proactive management, collaboration decision making
Efficiency	In-depth constructibility analysis	Focus on the design and development phase
Project completion time and cost	Subcontractors, major subcontractors, rework and errors, inflexible procurement systems	Quality design and documentation, involvement of subcontractors and major contractors during the early stage of the design phase, CIM, robots
Major cultural, behavioural, organisational issues	Client and end user participants for co-operative supported work	Leadership, motivation, incentives, training, multimedia
Design optimisation	Non-value adding activities, delay in the project completion	Design for constructibility, design for quality
Elimination of non-value adding activities	Physical movement of resources, information exchange, and hand-over between subcontractors	JIT, life cycle design, design for construction, activity based analysis

In order to introduce aspects of CE in the construction project delivery process, various research efforts have been undertaken. These include *ToCEE*, which focused on developing information exchange systems that support a CE environment over the building lifecycle (ToCEE, 1997); *CICC*, which was concerned with enabling communication across the whole of construction project and at all stages of the lifecycle (Duke & Anumba, 1997); *CONCUR*, which focuses on electronic information exchange from the inception to tendering and construction planning stage (CONCUR, 1999); *COMMIT*, which addresses the issues of integration and collaboration by efficient information management (Rezgui et al., 1997); *DESCRIBE*, which focuses on the development of software to facilitate concurrent storage, access, and modification of design information, irrespective of the location of the designer (Carnduff et al., 1997); and *IDS*, which deals with the integration of various tools for the concurrent design and fabrication of steel structures (Wailes et al., 1997). A detailed account of all these above-mentioned efforts is compiled and presented by Kamara et al. (2000). They have concluded that much more needs to be done if the reported benefits of CE in other industries such as manufacturing can be realised in construction industry. It is also concluded that an important aspect of CE implementation in the construction industry, which is often overlooked, is the need to carry out a readiness assessment of the construction supply-chain for CE implementation. This is expected to establish the level of CE maturity of different sectors of the supply-chain with a view to informing implementation efforts. Therefore, in order to establish the level of maturity and improve planning for CE implementation, the construction industry needs a specific readiness assessment model (Khalfan and Anumba, 2000a).

## 3.5 CE Readiness Assessment

### 3.5.1 Introduction

As discussed earlier, one approach which has been successfully used to improve CE implementation planning is to conduct a readiness assessment of an organisation prior to the introduction of CE as shown in Figure 3.9. This helps to investigate the extent to which the organisation is ready to adopt Concurrent Engineering (Componation & Byrd, 1996), and to identify the critical risks involved in its implementation within the company and its supply chain. CE Readiness Assessment has been successfully used for the planning of CE implementation in several industry sectors, notably manufacturing and software engineering.

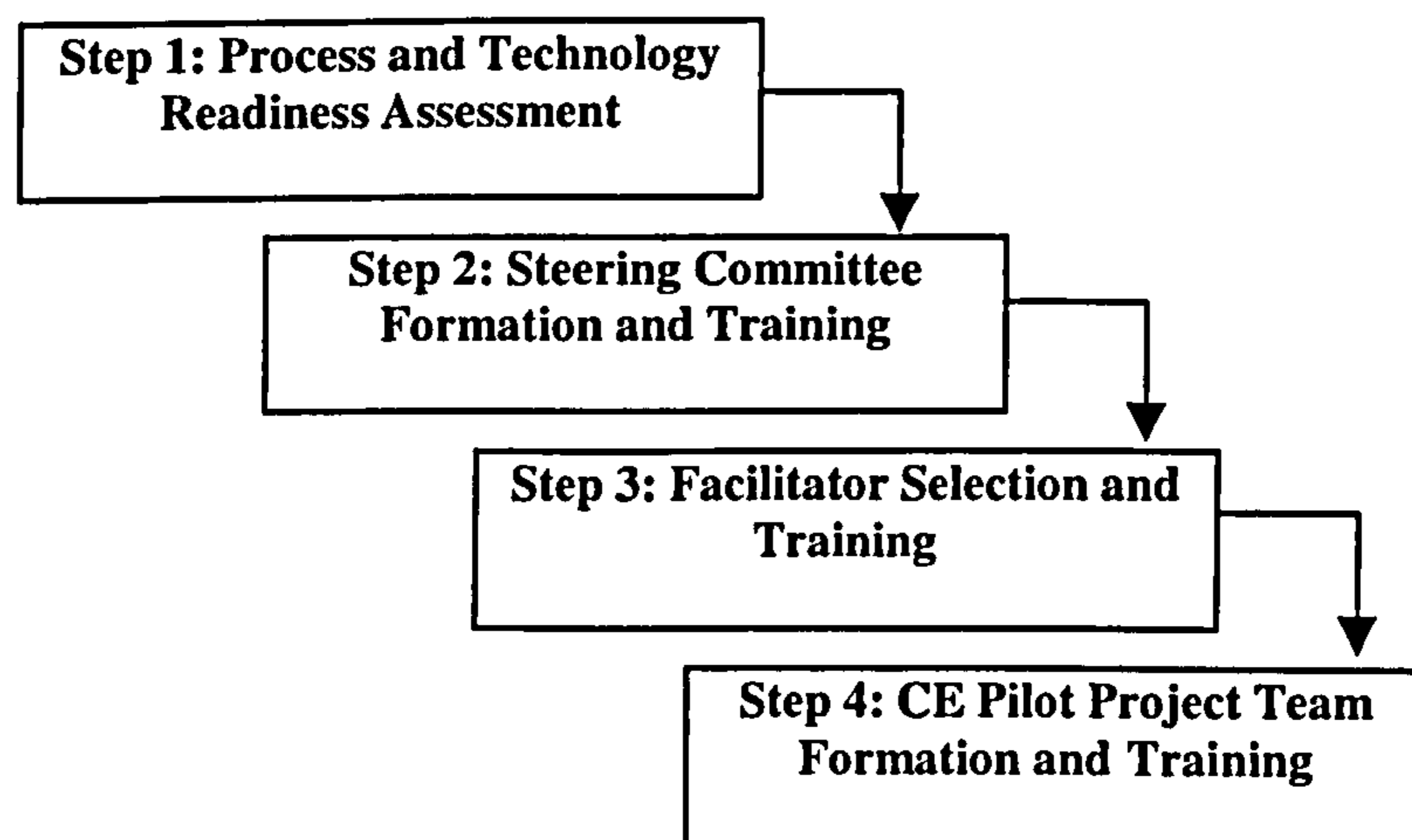


Figure 3.9: Implementation Methodology for Concurrent Engineering (Componation & Byrd, 1996)

The four steps include the process and technology readiness assessment, steering committee formation and training, facilitator selection and training, and CE pilot project team formation

and training. The primary building block of the implementation strategy is the process and technology readiness assessment. This step is used to gather information in order to customise the implementation plan to meet the individual organisation's needs (Compton & Byrd, 1996).

### *3.5.2 The Need for CE Readiness Assessment*

While Concurrent Engineering (CE) is gaining acceptance, some implementation efforts have not realised their full potential for reducing costs, reducing time, and increasing efficiency, effectiveness and performance for product development efforts. This is due in part to insufficient planning to support the implementation (Compton & Byrd, 1996). One approach that has been successfully used to improve CE implementation planning is to conduct a readiness assessment of an organisation prior to the introduction of CE. The assessment supports to investigate the readiness of the organisation for Concurrent Engineering adoption, and to outline the risks involved in its implementation. CE Readiness Assessment has been successfully applied for the planning of CE implementation in several industry sectors, and it is described below in the next section.

### *3.5.3 Readiness Assessment Criteria*

The movement toward a CE environment involves a major paradigm shift. This requires a major reengineering of the organisation's design process. The readiness assessment should



evaluate the organisation's understanding that product development is a process rather than a set of independent functions. With this in mind, a set of 10 criteria was developed (see Table 3.3) to use as a base for conducting a readiness assessment (Componation & Byrd, 1996).

Table 3.3: Readiness Assessment Criteria (Componation & Byrd, 1996)

CRITERIA	DESCRIPTORS
Customer Focus	<ul style="list-style-type: none"> <li>• Understanding of the customer requirements &amp; expectation</li> <li>• Constant attention to customer satisfaction</li> <li>• Rapid assessment &amp; accommodation of new priorities</li> </ul>
Process Focus	<ul style="list-style-type: none"> <li>• Documentation of process capabilities &amp; metrics</li> <li>• Understanding of the value chain &amp; linkages with the customer &amp; suppliers</li> <li>• Modelling of process workflow</li> <li>• Identification &amp; control of critical process parameters</li> <li>• Relentless pursuit of improvement</li> </ul>
Team Member Selection	<ul style="list-style-type: none"> <li>• Level of efforts and skill determination</li> <li>• Customer &amp; marketing team members</li> <li>• Research &amp; development team members</li> <li>• Design &amp; engineering team members</li> <li>• Manufacturing &amp; field support team members</li> </ul>
Team Development	<ul style="list-style-type: none"> <li>• Team performance measures</li> <li>• Team technical training</li> <li>• Team training in team operations &amp; social tools</li> <li>• Facilitator training</li> <li>• Steering committee training</li> <li>• Removal of organisational barriers to effective teaming</li> </ul>

CRITERIA	DESCRIPTORS
Accommodation of teams within the Organisation	<ul style="list-style-type: none"> <li>• Physical or virtual co-location</li> <li>• Career paths for members of cross-functional teams</li> <li>• Team recognition &amp; incentives</li> <li>• Management directive for team responsibilities authority &amp; accountability</li> </ul>
Management System	<ul style="list-style-type: none"> <li>• Risk reduction planning</li> <li>• Integrated master planning &amp; scheduling</li> <li>• Value-based resource allocation</li> <li>• Cost/schedule control system;</li> <li>• Technical performance monitoring</li> </ul>
Mechanism for Rapid Product Assurance	<ul style="list-style-type: none"> <li>• Adoption of standards &amp; robust design principles</li> <li>• Application of computer-aided design &amp; simulation tools</li> <li>• Uses of rapid prototyping tools</li> </ul>
Technology System & Product CE	<ul style="list-style-type: none"> <li>• Communication planning</li> <li>• Co-ordination of support services</li> <li>• Corporate memory</li> <li>• Integrated tools &amp; databases</li> </ul>
Senior Management	<ul style="list-style-type: none"> <li>• Steering committee for CE issues</li> <li>• Commitment to the resolution of issue at the lowest possible level</li> <li>• Commitment to support CE through the transition cycle</li> <li>• Relentless pursuit of improvement</li> </ul>
Discipline	<ul style="list-style-type: none"> <li>• Doing what it takes to get the job done-with integrity</li> <li>• Consistency – common methodologies &amp; measurements</li> <li>• Minimising changes late in the development cycle</li> </ul>

## **3.6 Readiness Assessment Tools and Models**

### *3.6.1 An overview*

There are several tools and models, which are being used for readiness assessment of organisations for concurrent engineering. This section compares these models and tools on the following basis:

- The aim of the tool;
- Who has developed this tool;
- What does it cover;
- Its application industry and sectors;
- The status of the tool;
- Usage of the tool either as a CE readiness assessment or CE implementation tool; and
- Its appropriateness for the construction industry.

A brief description and comparison of the models and tools (see Table 3.4) are presented below:

#### *a) RACE (Readiness Assessment for Concurrent Engineering)*

This tool was developed at West Virginia University (United States) in the early 90's and is widely used in the software engineering, automotive and electronic industries. It could be modified for use in the construction and other industries. The RACE-model is conceptualised in terms of two major components: the organisational processes for product development, and the information technology to support the product development process (Wognum et al.,

1996; CERC Report, 1993). The Process component is subdivided into ten elements and Technology into six as mentioned in Table 3.5.

*b) PMO (The Process Model of Organisation)*

This model was developed to assess and analyse the processes and technology of an organisation. The process model of organisation (PMO) is a model, which can basically be used for analysing and designing an organisation, its processes and technology in the context of the market in which that organisation operates. The model is used to detect bottlenecks that prevent the organisation to achieve its objectives. Hence, the model is useful in the awareness and readiness stages of the improvement cycle of the product development process (Wognum et al., 1996).

*c) PMO-RACE (A Combination of PMO & RACE)*

PMO-RACE is the combination of two models (PMO and RACE) which was developed by the researchers at University of Twente and Eindhoven University of Technology (Netherlands) in the mid 90's. Since the Process Model of Organisations (PMO) can support the identification of key problem areas and the definition of business drivers while the RACE-method is good at determining the performance level of the product development process and supporting the definition of improvement plans once the business drivers have been set, it was suggested that both methods could be combined to support improvement cycles. The combination would deliver 'the best of both worlds' (de Graaf and Sol, 1994).

*d) PRODEVO (A Swedish Model Based on RACE)*

PRODEVO was developed at SISD (Swedish Institute for Systems Development) and this development was parallel to the development of PMO-RACE tool. Some of the dimensions and also a couple of the questions are assimilated in the presented tool from RACE model, and to indicate a relation the working name, “Extended RACE”, was adopted earlier (Bergman and Ohlund, 1995).

*e) CMM (Capability Maturity Model)*

CMM was developed for software development and evaluation by the Software Engineering Institute at Carnegie Mellon University in order to manage the development of software for the US government, particularly that which was to be used by the Department of Defence in late 80's (Aouad et al., 1998). This model can be used as readiness assessment model and, in fact, the RACE model was developed based on ideas from CMM. The CMM model is also currently being used at the University of Sussex in developing benchmarks for process positions across various industries, including the construction industry.

*f) SPICE (Standardised Process Improvement for Construction Enterprises)*

This tool was developed at the University of Salford, United Kingdom, and is in the form of a questionnaire, which is designed to evaluate the key construction processes within a construction organisation (SPICE Questionnaire, 1998). SPICE is basically intended for evaluating the maturity of the processes of construction organisations and not for CE

readiness assessment. It is based on CMM and is presently a research prototype. However, it could be used to assess the process-related aspects of CE implementation.

*g) Project Management Process Maturity (PM)<sup>2</sup> Model*

This 5-Level (PM)<sup>2</sup> Model was developed at University of California, Berkeley in late 90s. The primary purpose of the (PM)<sup>2</sup> Model as a reference point or a yardstick for an organisation applying PM practices and processes. The Model further suggests an organisation's application expertise and the organisation's use of technology, and produces recommendations on how to hire, motivate, and retain competent people. It can also provide and guide necessary processes and requirements for what is needed to achieve a higher PM Maturity level (Kwak and Ibbs, 1997).

*h) SIMPLOFI Positioning Tool*

The tool was designed and developed by the Department of Manufacturing Engineering at Loughborough University. It formed part of the output of the SIMPLOFI (*Simultaneous Engineering through People, Organisation and Functional Integration*) project in the mid 90s. The tool focuses on the introduction of one specific product in an organisation. This tool assists those people who are responsible for product introduction within an organisation in answering the question: "I know what product I want to introduce – How do I organise the introduction of this product to achieve this most effectively?" (Brookes et al., 2000).

### **3.6.2 Framework for Comparison**

A framework is developed for comparing all the above mentioned tools and models and discusses the characteristics of them under a number of generic criteria, which include:

- Aspects covered – discusses the main issues addressed in each tool;
- The status of the tool – shows the current standing of the model/tool in terms of whether it is a research prototype, commercial tool or currently under development etc.
- Survey method – identifies how the data collection is carried out – that is either by questionnaires, interviews or both;
- Software availability – identifies those tools and models which are accompanied by a software that can be used during the readiness assessment;
- Ease of use – indicates the user-friendliness of the tools/models;
- The Usage of Tools for Readiness Assessment for CE – identifies the tools and models which can be used for CE readiness assessment; and
- Applicability to the construction industry – the basic purpose of this comparison is to identify the most suitable tool/model for the construction industry, this criterion assesses the potential use of the models and tools in the construction industry.

### **3.6.3 Findings**

From the comparative analysis shown in Table 3.4, it could be concluded that most of the tools and models address improvements in the product development process, and the use of technology to facilitate the development process. Some of the tools and models also cover the

Table 3.4: Comparison of CE Readiness Assessment & Related Models (Khalfan & Anumba, 2000c)

<b>Tools/Models → Criteria ↓</b>	<b>RACE</b>	<b>PMO</b>	<b>PMO-RACE</b>	<b>PRODEVO</b>	<b>CMM</b>	<b>SPICE</b>	<b>(PM)<sup>2</sup></b>	<b>SIMPLOFI</b>
<b>Aspects Covered</b> <ul style="list-style-type: none"> <li>• Customer focus</li> <li>• Product Assurance</li> <li>• Leadership</li> <li>• Team formation</li> <li>• Strategy deployment</li> <li>• Agility</li> <li>• Teams within the Organisation</li> <li>• Process focus</li> <li>• Management system</li> <li>• Discipline</li> </ul> <b>Technology</b> <ul style="list-style-type: none"> <li>• Project Architecture</li> <li>• Application tools</li> <li>• Communication</li> <li>• Co-ordination</li> <li>• Information sharing</li> <li>• Integration</li> </ul>	<b>Organisational Environment</b> <ul style="list-style-type: none"> <li>• Task environment</li> <li>• General environment</li> </ul> <b>Processes</b> <ul style="list-style-type: none"> <li>• Primary processes</li> <li>• Control processes:</li> <li>• <i>Strategic level,</i></li> <li>• <i>Adaptive level, &amp;</i></li> <li>• <i>Operational level</i></li> <li>• Support processes</li> </ul>	Aspects covered are the same as PMO & RACE because this is the combination of both of these tools	<ul style="list-style-type: none"> <li>• Customer user focus</li> <li>• Process focus</li> <li>• Team &amp; project focus</li> <li>• Life-cycle perspective</li> <li>• Communication</li> </ul>	<ul style="list-style-type: none"> <li>• Pre-project Phase</li> <li>• Pre-construction Phase</li> <li>• Construction Phase</li> <li>• Post-construction Phase</li> <li>• Information Technology</li> <li>• Simulation</li> <li>• Integration</li> <li>• Intelligence</li> <li>• Communications</li> <li>• Visualisation</li> <li>• IT support</li> </ul>	<ul style="list-style-type: none"> <li>• Brief Management</li> <li>• Project Planning</li> <li>• Project Tracking &amp; Monitoring</li> <li>• Contract Management</li> <li>• Quality Assurance</li> <li>• Project Change Management</li> <li>• Risk Management</li> <li>• Organisation</li> <li>• Process Focus</li> <li>• Organisation</li> <li>• Process Definition</li> <li>• Training Programme</li> <li>• Inter-disciplinary Co-ordination</li> <li>• Peer Review</li> <li>• Technology Management</li> </ul>	<ul style="list-style-type: none"> <li>• Planning to execute a project</li> <li>• Definition of project activities</li> <li>• Cost estimates for the project</li> <li>• Project Management (PM) process</li> <li>• PM-related data collection and analysis</li> <li>• Utilisation of PM tools and techniques</li> <li>• Working as a team</li> <li>• Senior management support</li> </ul>	<ul style="list-style-type: none"> <li>• The structure of teams</li> <li>• Control mechanisms (whether control mechanisms should reside with functions or projects)</li> <li>• The degree to which the process should be parallelised</li> <li>• How specialised people operating the process should be</li> <li>• The degree of automation in the tools used</li> </ul>	
<b>Status of Tool/Method</b>	Commercial	Development Ongoing	Development Ongoing	Development Ongoing	Commercial	Research Prototype	Development Ongoing	Commercial



Survey Method	Questionnaire & Interview	Interviews, Description of past and current projects, formal procedures and quality hand book	Questionnaire & Interview	Questionnaire & Interview	Questionnaire & Interview	Questionnaire & Semi-structured Interview	Questionnaire	Questionnaire
Software Availability	Yes, also uses other software (e.g. SPSS)	Can use any modelling software	Yes	None	Yes, but also use other software e.g. SPSS	None.	None	Yes
Ease of Use	Yes, but technological aspect is complicated to answer and is only for specialists.	Yes, but seemed to be incomplete, that's why merged with RACE later on	Yes	Yes	Yes	Yes, MCQs are developed with additional space for comments	Yes.	Yes, user-friendly software
Can be used for Concurrent Engineering Readiness Assessment?	Yes, basically made for this purpose	Basically used for analysing & designing organisations	Yes, mainly for readiness assessment but also used for CE implementation process	Basically developed for assessing concurrent engineering (CE) process	Yes, but basically used for CE Implementation process	Basically used for Process Improvement	Basically used as a yardstick for an organisation applying PM practices and processes	Basically used to assist those, who are responsible for product introduction within an organisation
Appropriateness for use in Construction	Yes, but requires some modifications	Yes, but basically used for analysing and designing an organisation, its process and technology	Yes, but RACE model requires modification before applying to construction	Yes, but it requires changes to address construction specifically	Yes, but basically developed for software industry, therefore it requires changes before applying to construction	Yes, but this tool is basically made for process improvement within construction projects	Yes, but this tool is basically developed to determine and to position an organization's relative PM level with other organisations	Yes, but this tool focuses on the introduction of one specific product in an organisation. Therefore, in any construction organisation, it can be used for a specific project and it would give the position of the project and not the position of the organisation

organisational environment to support the development process. The status of the tools and models shows that most of them are under development with only very few being used on a commercial basis. With regard to software availability, there are only a few tools and models which are accompanied by their own software. Although many of the tools and models are easy to use. Most of the tools and models reviewed can also be used as a CE readiness assessment tool after appropriate modification. However, some of the tools and models were basically designed for CE readiness assessment. An assessment of the use of these tools and models within the construction industry shows that none of the tools and models is ideally suited for use in construction (Khalfan & Anumba, 2000a).

### **3.7 CE Readiness Assessment of the Construction Industry**

#### **3.7.1 The Need**

As discussed in previous sections, CE Readiness Assessment is used to improve CE implementation. It is conducted before the introduction of CE within an organisation, and investigates the extent to which the organisation is ready to adopt CE. Whilst this has been carried out in other industry sectors, it is unusual for such assessments to be undertaken in construction supply chains. Furthermore, Muya et al. (1999) showed that current industry practices do not support integration of the whole supply chain during the construction process. It is therefore imperative that, for CE implementation in the construction industry to deliver the expected benefits, a readiness assessment of the construction industry should be undertaken. This will ensure that all sectors of the

industry have reached an acceptable level of maturity with respect to the critical success factors for CE implementation, and will indicate the likelihood of the following benefits:

- Better and more effective CE implementation within the construction industry;
- Enabling the industry to evaluate and benchmark its project delivery processes;
- Development of more appropriate tools for CE implementation within the industry;
- Enabling the industry to identify areas which require improvements or changes; and
- Enabling the industry to realise the need for CE implementation in order to bring about improvements in the whole project delivery process.

### *3.7.2 Choice of an Assessment Model for Construction*

After analysing the comparison matrix (see Table 3.4), the RACE would be the most appropriate for use as the Readiness Assessment Tool for Concurrent Engineering in the construction industry because of the following reasons:

- Aspects covered in RACE model such as customer focus, team formation, management systems, communication and integration systems, etc., can be used readily for CE readiness assessment in the construction industry, after some modification, due to the similar structure and requirements of the construction industry;
- Commercial usage of the RACE model makes it more reliable;
- The RACE model questionnaire addresses and assesses the critical business drivers in the construction industry; and

- Since RACE is basically a CE readiness assessment model, it is more appropriate than other tools and models, which were developed to assess the project/product development process within an organisation.

However, the RACE model requires adaptation and modification for this purpose. This is because RACE was developed for readiness assessment for concurrent engineering in other industries such as manufacturing and software engineering industry. Thus, it needs to be tailored to the requirements of the construction industry and the people working within the industry. The following are some of the reasons which indicate that RACE in its current form is not suitable for the construction domain and requires modification for use in assessing the construction industry:

- RACE is designed for assessing the readiness of other industries such as software, automotive, manufacturing, and electronic industries, all of which have different characteristics to construction;
- Aspects covered focus on the processes in the above mentioned industries and require changes to assess the construction process;
- The structure of teams within the above mentioned industries are different from typical construction project teams;
- The level of technology usage in the afore-mentioned industries is different from that in the construction industry;
- The products of the other industry sectors satisfy a large number of customers whereas a construction project is one-off in nature, typically fulfilling the needs of a particular client or organisation;

- The level of integration, communication, co-ordination, and information sharing are different between construction and the above-mentioned industries; and
- Managing a manufacturing product and a construction project require different levels of management skills.

Therefore, there is a need to develop a model, which covers critical issues related to the construction; focuses on the team structure and team performance within an organisation and on a construction project; specifically concentrates on the level of technology usage within the construction supply chain; addresses client's satisfaction and requirements; evaluates level of communication, integration, co-ordination, and information sharing; and examines the overall project management tools, techniques, and skills of the construction organisations.

### **3.8 Summary**

The discussion covered in the chapter is based on a literature review on the CE readiness assessment, its application to other industries, and current tools used to carry out the readiness assessment. The chapter has discussed the definition of CE, CE implementation, CE readiness assessment, the assessment criteria, introduced available tools and models briefly, which are being used to carry out a readiness assessment, their appropriateness to be used as readiness assessment tool for the construction industry, and the comparison of available tools and models, and its criteria.

The comparison shows that all the available tools are developed to assess the CE implementation process and the readiness to adopt CE for either the manufacturing industry or software industry, and there is a need of a tool which checks the readiness of construction organisation.

Therefore, the discussion and comparison, done in this chapter, will help in developing the readiness assessment model for the construction industry with the help of modification of existing tools, which could be used to check the readiness of a construction organisation for the adoption of concurrent engineering concept.

## **Chapter 4: Development of a CE Readiness Assessment Model for Construction**

This chapter explains the development of a new CE readiness assessment model – the BEACON model - for the construction industry and presents some of its major features along with benefits of using the model and its associated questionnaire.

### **4.1 Background**

A CE readiness assessment model has been developed for assessing the construction industry. The proposed prototype model named ‘Concurrent Engineering Readiness Assessment Model for Construction’ (CERAMConstruct Model), is shown in Figure 4.1, which was later on developed into the BEACON Model. A questionnaire was also developed for the CERAMConstruct Model, which covers all the elements shown in the model. The proposed model had similarities with the RACE model in terms of the key assessment elements (i.e. most of them cover the same issues), questionnaire criteria, and diagrammatic representation (spider or radar diagram). However, it differs from the RACE model in that it focuses specifically on construction processes. The model is divided into two sections or aspects (as shown in Figure 4.1). The upper half presents eight process-related elements and the lower half contains four technology-related issues. The process aspect includes the client focus regarding the project, improvement in the construction process itself, formation and development of teams for carrying out project tasks, improving the management systems of the organisation, maintaining the project and process standards, bringing agility into the construction process, and

employing and exploiting project strategy. The Technology aspect includes the services related to communication, co-ordination, information sharing and integration (Khalfan & Anumba, 2000b).

The development of the model was carried out in several steps. A literature review of CE in other industries was carried out to identify the critical success factors and pit-falls during CE implementation. The next step was the review of CE readiness assessment models used in other industries; this included a comparative study, which is summarised in Table 3.5 in the previous chapter. These steps then led to the development of the CERAMConstruct model and its associated questionnaire. Before using the model for the assessment within the construction industry, a pilot study was carried out for both the model and its associated questionnaire (Khalfan et al., 2001). The purpose of the pilot study was to validate the model and its associated questionnaire, and obtain feedback for further refinement of the model and its associated questionnaire. The pilot study was carried out with three construction organisations, whose senior management staff filled in the assessment questionnaire. The questionnaire was also given to the academic staff including two lecturers and two research associates to fill in and comment on it. The feedback and comments obtained from the pilot study suggested areas for improvement within the questionnaire and the model itself. The pilot study also revealed the following limitations of the model:

- Inadequate focus on people and product issues in the model;
- The four-level assessment scale of the model meant that there was no neutral or middle level;
- Too much reliance on the RACE Model;



- The model was considered to be a coarse-grained model in terms of number of elements assessed; and
- Inadequate construction context in some of the critical issues.

Therefore, in order to incorporate the feedback from the pilot study and overcome the limitations, the model was refined and modified, resulting in a new model, the BEACON model. This refined model is presented in Figure 4.2.

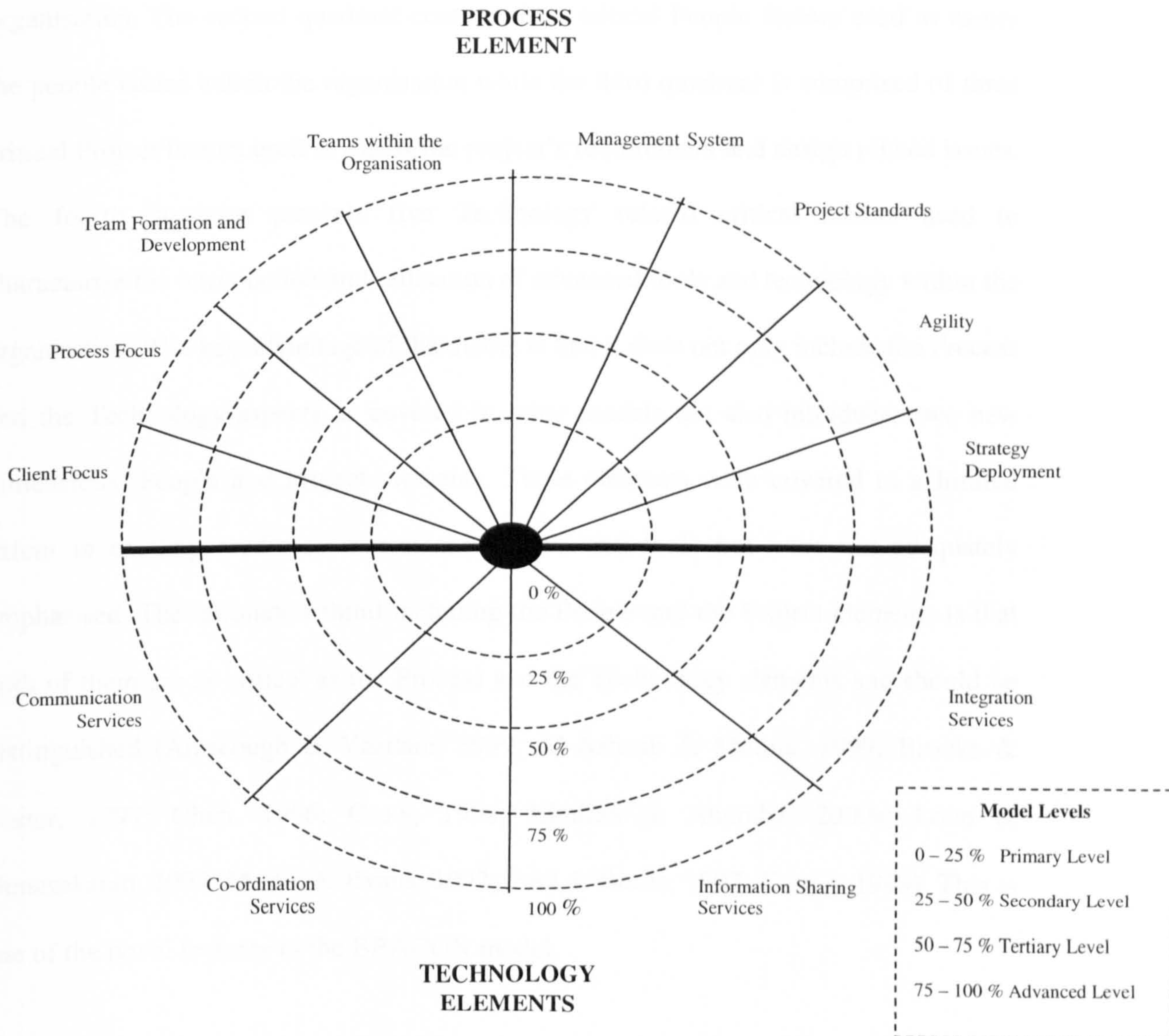


Figure 4.1: CERAMConstruct Model (Khalfan & Anumba, 2000b)

## **4.2 The BEACON Model**

The BEACON Model (see Figure 4.2) and its associated questionnaire (see Appendix 1) are divided into four quadrants or sections to represent four elements or aspects of the model, which are Process, People, Project, and Technology. The first quadrant contains five critical process factors used to assess the Process maturity level of a construction organisation. The second quadrant contains four critical People factors used to assess the people issues within the organisation while the third quadrant is comprised of three critical Project factors used to assess the project's requirement and design related issues. The fourth quadrant presents five Technology related critical factors used to characterise the introduction and utilisation of advanced tools and technology within the organisation. The key advantage of the model is that it does not only include the Process and the Technology aspects as covered in other models but also introduces two new dimensions, People and Project elements. These elements were covered to a limited extent in existing readiness assessment models and tools but were not adequately emphasised. The rationale behind including the People and the Project elements is that both of them are as critical as the Process and the Technology elements and should be distinguished (Ainscough & Yazdani, 1999; Al-Ashaab & Molina, 1999; Brooks & Foster, 1997; Chen, 1996; Crow, 1994; Khalfan & Anumba, 2000a; Love & Gunasekaran, 1997; Martin & Evans, 1992; Paul & Burns, 1997; Young, 1999). This is one of the novel features in the BEACON model.

Although the BEACON Model is an evolution of the RACE Model but it is different from the RACE Model in many ways:

- The main difference is the introduction of the People and Project Elements (which are unique features of the BEACON Model) in addition to the basic Process and Technology Elements in the RACE Model;
- Another key difference is in the assessment questionnaire, which is completely different both in terms of content and context. As highlighted in section 4.5, the questions in the BEACON Model Questionnaire are drawn from a variety of sources and are construction-specific;
- The critical issues and aspects covered under each element of the BEACON model are more construction-focused than the RACE Model; and

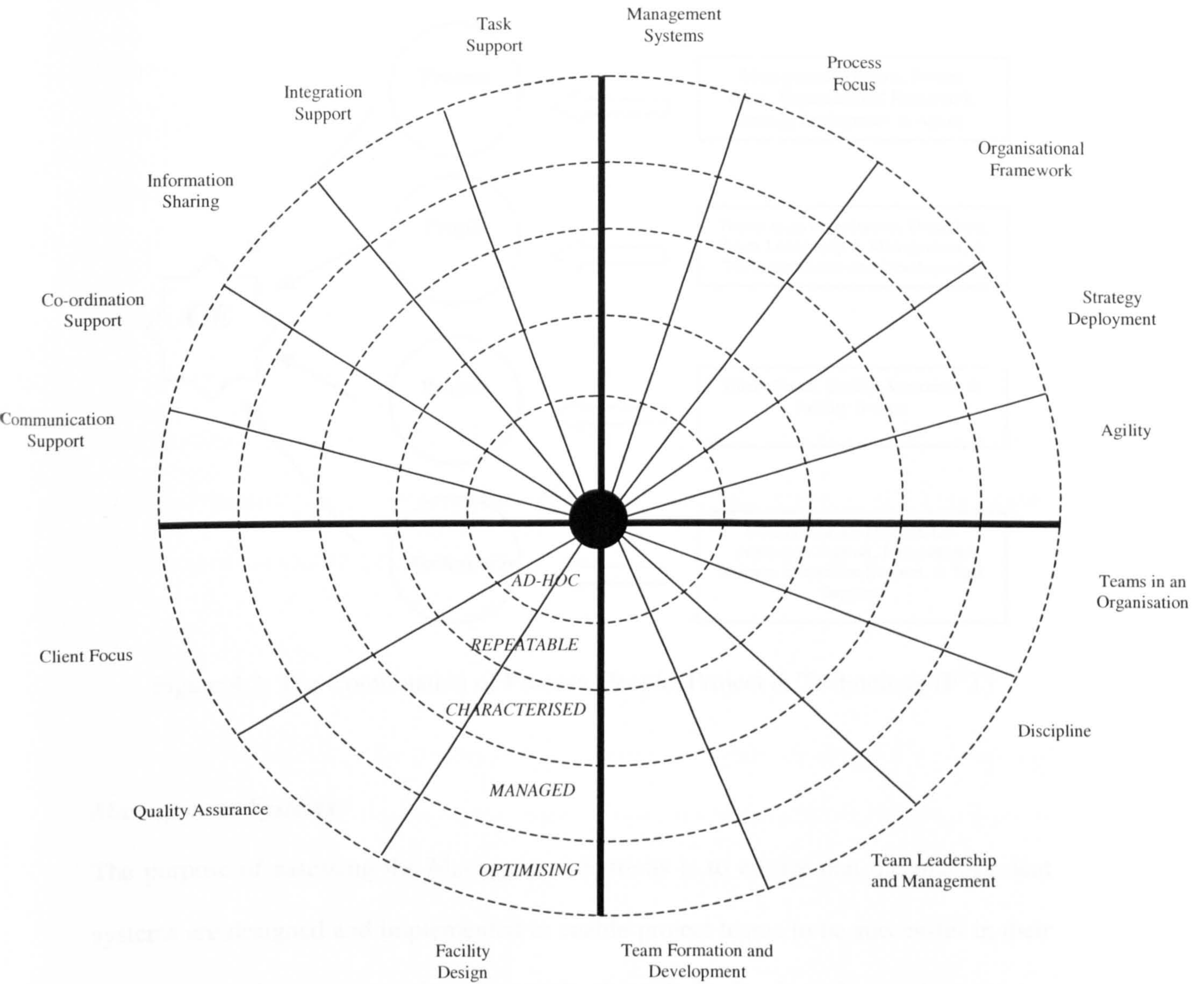
The BEACON maturity levels are adopted from Process maturity level within the RACE Model, but then these levels were translated into a construction context for the BEACON Model and applied to all four elements – People, Project, Process, and Technology.

### **4.3 BEACON Model's Elements and Critical Factors**

The BEACON Model consists of four elements, which are Process, People, Project, and Technology. In this section, the critical factors under each elements are described briefly. The model can also be presented as P<sup>3</sup>T Model, as shown in figure 4.3.

**TECHNOLOGY ELEMENT**

**PROCESS ELEMENT**



**PROJECT ELEMENT**

**PEOPLE ELEMENT**

Figure 4.2: BEACON Model

**4.3.1 Process Element**

The Process element is consist of five critical factors, which are Management Systems, Process Focus, Organisational Arrangements, Strategy Deployment, and Agility.

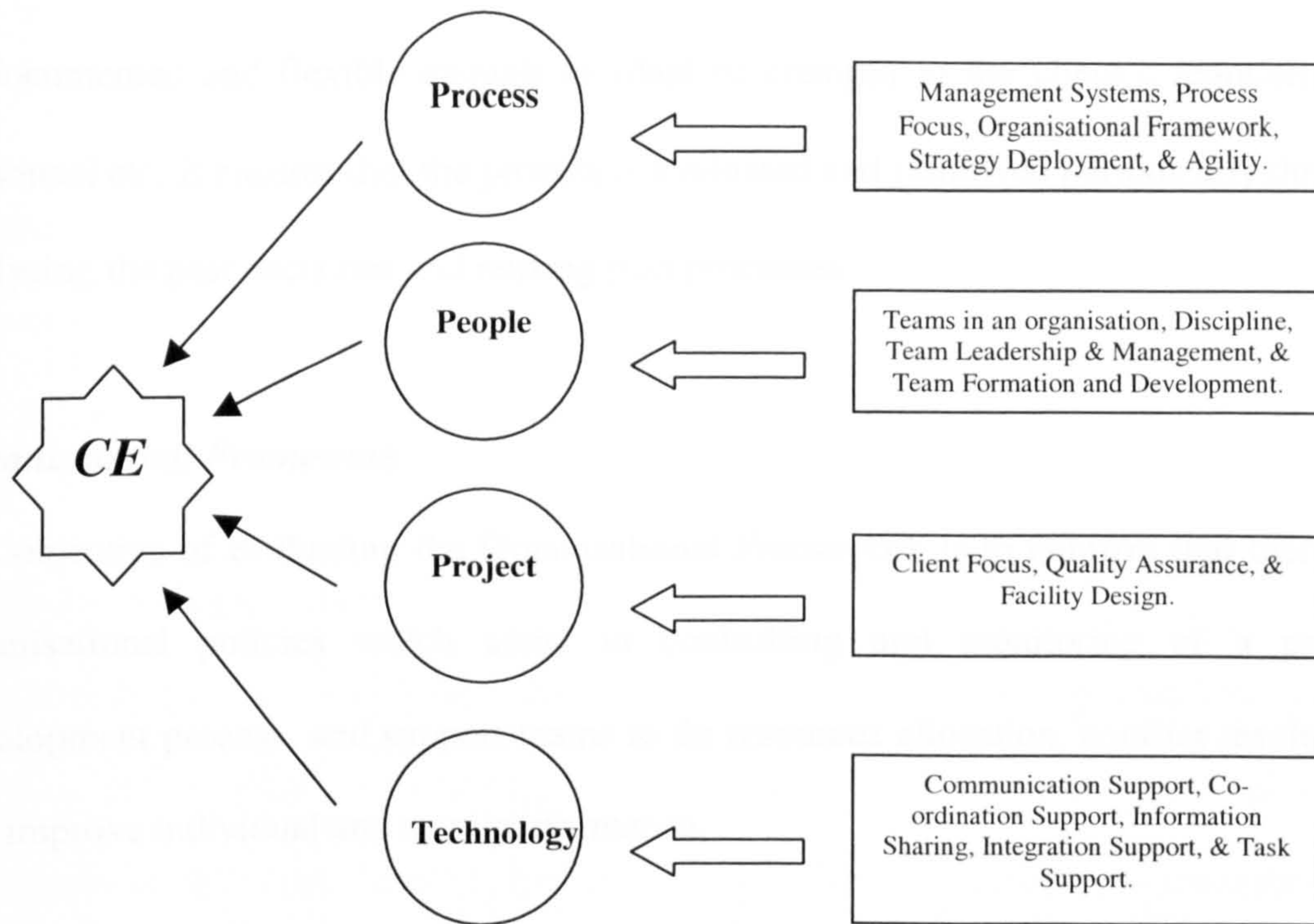


Figure 4.3: The Combination of Process, People, Project & Technology (P<sup>3</sup>T)

### **Management Systems**

The purpose of assessing the Management Systems is to ensure that the management systems are designed and implemented to enable project teams to be successful in their objectives, and are improved continuously through feedback and periodic reviews. Management systems include planning, scheduling, controlling and tracking of a project development process, resource planning, contract management, performance measurement, financial accounting system, risk management, contingencies plans etc.

### ***Process Focus***

The aim of checking the Process Focus is to verify that the project development process is documented and flexible enough to adapt to changes in the client's requirements, personnel etc. It ensures that the process is evaluated and improved periodically through analysing the past decisions and reusing past processes.

### ***Organisational Framework***

The objective of evaluating the Organisational Framework is to confirm that there are organisational policies which assist in controlling and monitoring of a project development process, and support teams to do resources allocation, conflict resolution, and improve individual and team performance.

### ***Strategy Deployment***

The purpose of assessing the Strategy Deployment is to ensure that the business strategy is clear, consistent, and focuses on the improvement of a project development process. It also ensures that teams are set up to address client's requests, and to identify & prevent future problems.

### ***Agility***

The aim of evaluating the Agility is to confirm the ability of an organisation to respond efficiently and effectively to changes in a project development process, and making sure that the assets are reused. It also evaluates whether the corporate memory of the organisation is maintained and made available to all members of the project development team and sub-teams.

### **4.3.2 People Element**

People element comprises of four critical factors, which include Teams in an Organisation, Discipline, Team Leadership and Management, and Team Formation and Development. These elements are briefly described below.

#### ***Teams in an Organisation***

This checks the extent to which there are diverse disciplines and specialist groups working as sub-teams. It ensures that the teams have authority and can easily communicate with each other. It also ensures that there are policies to measure team performance and to plan and conduct peer-reviews within the teams.

#### ***Discipline***

This is intended to verify that all members of a team abide by the disciplinary rules and regulations, and are committed to and share team rules. It ensures that team members submerge their individual agendas and stick together when difficult issues arise.

#### ***Team Leadership and Management***

The objective of evaluating the Team Leadership and Management is to ensure that selection of team leaders is on the basis of their technical and managerial skills. It also ensures that the team leaders are responsible for the completion of a project and have authority to enlist new members and take team related decisions.

### ***Team Formation and Development***

The basic purpose of assessing the Team Formation and Development is to confirm whether the organisation has strategies for team formation and development, and is arranging training sessions for team members to upgrade their technical skills. It also assesses whether each member of the project development team and sub-teams understands his/her responsibilities, has common purpose, and interacts with others on continuous basis.

#### ***4.3.3 Project Element***

There are three critical project factors under this element, which are Client Focus, Quality Assurance, and Facility Design.

##### ***Client Focus***

The Client Focus factor ensures that the client is a part of the project development team throughout the design and construction phases of the facility. It also ensures that all project decisions are prioritised based on client's needs, and all members of the teams understand the client's requirements and respond appropriately to changes in client's requirements.

##### ***Quality Assurance***

The objective of checking the Quality Assurance is to confirm that project standards and quality assurance activities are adopted and maintained. It also confirms that there are



policies to ensure required project quality and analyse feedback from the construction site.

### ***Facility Design***

The aim of the Facility Design factor is to verify that preliminary designs of the facility are prepared and discussed before entering into the final design and construction phases and relevant past designs are also consulted and used to design the current facility. It also ensures that the design of the facility is flexible enough to address any changes, and encourages repetitive and standard construction procedures.

#### ***4.3.4 Technology Element***

This includes five critical factors that are Communication Support, Co-ordination Support, Information Sharing, Integration Support, and Task Support, and these all are described below briefly.

##### ***Communication Support***

Communication Support is concerned with ensuring that the interaction between team members by electronic means and that all team members are connected to each other in a network. It also explores the extent to which team members use e-mail facilities, exchange project data over a network, and use computers for virtual meetings and interaction.

### ***Co-ordination Support***

The aim of evaluating the Co-ordination Support is to confirm that the project data is available electronically in the form of central project model, which facilitates co-ordination of all members of teams. It ensures the availability of systems that are used to support project monitoring, conflict recognition, resolution, negotiation, and trade-offs among the teams.

### ***Information Sharing***

This seeks to verify that the information required for the project development process is accessible in electronic form and is managed by an appropriate data base management system. It ensures that the advantage of multimedia technology is taken, a master model of resource information is also used, and the full corporate memory of relevant project information and decisions is maintained.

### ***Integration Support***

The aim of evaluating the Integration Support is to confirm that all members of teams are integrated through a shared integrated information model and all members of the teams use a common operating system. It also confirms that data translation techniques are used, and data exchange standards are supported.

### ***Task Support***

The purpose of assessing the Task Support is to ensure that CAD, simulation tools, and past design information are effectively used for facility design. It also ensures that

available technology is improved and task support tools are evaluated to determine their effect on a project.

#### **4.4 Maturity Levels**

For each of the elements, five levels have been adopted from the RACE model (CERC Technical Report, 1992), which indicate the level of maturity of an organisation with respect to the quality of project development process, team-working, completed project itself, and technology employed within the organisation.

The BEACON Model's maturity levels are based on an adaptation of the levels associated with the Process Element of the RACE Model and applying them to all the Elements of the BEACON Model. The maturity levels were defined in the manufacturing and software engineering context within the RACE Model and only focused on the level of maturity of an organisation with respect to the Process Element. But their translation to the construction industry has been done in such a way that now they are applicable to all the Elements of the BEACON Model and are cast in a construction context.

These five levels are Ad-hoc, Repeatable, Characterised, Managed, and Optimising and are described in Table 4.1. The Ad-hoc Level indicates that an organisation does not have any idea about CE practices or is not ready to adopt CE whereas Optimising Level shows that the organisation is ready to adopt CE or is already practising CE within its project delivery process.

Table 4.1: BEACON Model Maturity Levels (adopted from RACE model)

Maturity Level	Description
<i>Ad-hoc</i>	This level is characterised by ill-defined procedures and controls, and by confused and disordered teams that do not understand their assignment nor how to operate effectively. Informal interaction with the client is observed, management of the project development process is not applied consistently in projects, and modern tools & technology are not used consistently.
<i>Repeatable</i>	Standard methods and practices are used for monitoring the project development process, requirements changes, cost estimation etc. The process is repeatable. There are barriers to communicate within the project development team. Interaction with the client is structured but it is only at the inception of the project. Minimal use of computer and computer-based tools.
<i>Characterised</i>	The project development process is well characterised and reasonably well understood. A series of organisational and the process improvements have been implemented. Teams may struggle and fall apart as conflicts are addressed but a team begins to respect individual differences. Most individuals are well aware of client's requirements but client is not involved in the process. Moderate use of proven technology for increasing group effectiveness.
<i>Managed</i>	The project development process is not only characterised and understood but is also quantified, measured, and reasonably well controlled. Tools are used to control and manage the process. The uncertainty concerning the process outcome is reduced. Work is accomplished by the project development team and conflicts are addressed. Client is involved throughout the process. Appropriate utilisation of available technology and computer-based tools.
<i>Optimising</i>	A high degree of control is used over the project development process and there is a major focus on significantly and continually improving development operations. Team performance is regularly measured, and performance measures are continuously validated. Client is a part of project development team from inception and all project decisions are prioritised based on client's needs. Optimal utilisation of appropriate plant and technology & technology-mediated group work is observed.

## 4.5 The BEACON Questionnaire

A model-based questionnaire (called the BEACON Questionnaire) has been developed for use in assessing construction organisations such that the elements covered in this model would be assessed using this questionnaire.

The design and development of a set of questions under each critical factor for each element is based on ensuring coverage of key CE principles and issues. The issues addressed were derived from the literature review on CE implementation efforts in other industries resulting in critical success factors and lessons learnt, issues covered in the RACE model which could be relevant to the construction industry, and aspects of the construction industry itself which have influence on CE implementation.

The assessment scale of the questionnaire has five possible options: “Always”, “Most of the Time”, “Sometimes”, “Rarely”, and “Never”. The BEACON questionnaire can be used for assessing CE readiness of:

- a) A static construction organisation, for example an architectural or construction organisation etc., having their own organisational structure and having different teams for different on-going projects; and
- b) A virtual construction organisation, which consists of various members from different construction organisations, forming a Project Development Team (PDT) and working on a single project (Khalfan et al., 2000). Figure 4.4 illustrates the PDT and its sub-teams, which may be responsible for supervising the whole project development process from inception until hand-over.

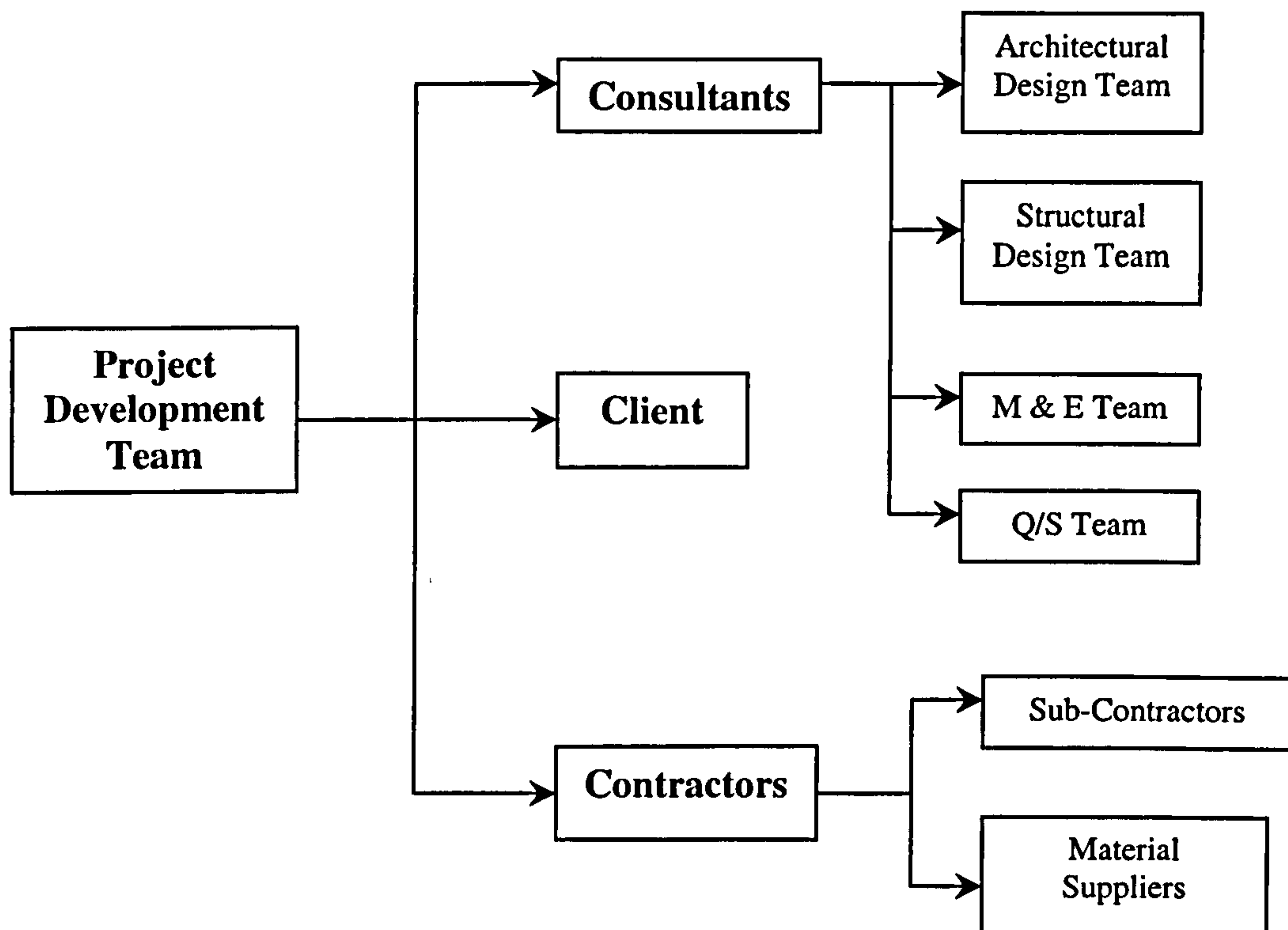


Figure 4.4: Typical Team Structure within a Virtual Construction Organisation (Khalfan & Anumba, 2000b)

#### 4.6 Discussion

The development of the BEACON model is important for the implementation of CE within the construction industry. The benefits of the model are outlined below:

- The BEACON model and its associated questionnaire are specifically tailored to meet the needs of the construction supply chain;
- It addresses four key elements or aspects of CE implementation which are only partly addressed by other models;
- The model will enable the development of guidelines for the effective and more appropriate implementation of CE in construction;

- The model will enable the construction industry to identify aspects of its project delivery process that require improvements to facilitate CE implementation;
- The survey and assessment could be carried out either in the form of structured interviews, or alternatively, an electronic version of the questionnaire could be developed and completed by remote respondents; and
- Even for organisations not considering the implementation of CE, the model can act as a useful tool for self-assessment on the four key elements: Process, People, Project, and Technology.

#### **4.7 Summary & Conclusions**

This chapter has presented a new CE readiness assessment model – the BEACON model - for the construction industry and presented some of its major features. The benefits of the model and its associated questionnaire were also discussed. The following conclusions can be drawn:

- Implementation of CE within the construction industry has the potential to contribute towards client satisfaction by improving quality, adding greater value, reducing cost, and reducing construction schedules;
- It is also necessary to carry out CE readiness assessment of the industry before CE implementation so as to ensure that maximum benefit is achieved;
- In order to assess the industry, a specific CE readiness assessment model is required because existing models are not appropriate in their present form; and

- The BEACON model has been developed specifically for CE readiness assessment of the construction supply chain, and will facilitate the formulation of strategies for effective CE implementation in the construction industry.



## **Chapter 5: Development of the BEACON Software**

This chapter describes the development of a software programme for the BEACON Model. This includes the objectives of the software, its system architecture, its implementation environment, and its actual development. The chapter also explains how to use the software, and the benefits of its use. The software is developed as a Microsoft Access application, and designed to facilitate responsiveness and quick processing.

### **5.1 Introduction**

The software implementation of the BEACON Model involved a number of activities, which included: the establishment of the purpose, scope and desired features of the software, the selection of an implementation environment, and the actual development (or programming) of the system. Following these, the model was validated through use in the assessment of several construction organisations. In the subsequent sections, development of the software is presented in detail.

### **5.2 Objectives of the BEACON Software**

The primary objective of the BEACON software was to automate the CE readiness assessment of the construction industry using the BEACON model questionnaire. It was also intended to improve the efficiency of the assessment process by automatically generating the BEACON model diagram, which graphically illustrates the assessment results, and also be able to compare results. The

intention, ultimately, is to make the system web-based so that organisations can readily access the model and use it as a tool for self-assessment.

### **5.3 System Architecture**

To ensure that the desired objectives of the BEACON software were satisfied, an architecture for the software, illustrated in Figure 5.1, was developed. It consists of three main modules. These modules provide:

- The means for defining current status by data collection;
- Questionnaire response analysis; and
- Result generation and presentation.

The first module takes input of data from users or a company regarding the current practices within that company in a form of a series of questions on specific topics. The second module then assigns the relevant score to the responses of the questionnaire and transfers data for result generation. The third module generates the results in form of BEACON model diagram and presents it to the user or to the company. A report generation module could be included in the higher version, which would not only come up with diagrammatic representation of the results but also indicate areas required immediate consideration for improvements and solutions for any lacking.

The three modules facilitate the storage and retrieval of information from the data storage facility. The user-interface interacts with all three modules, which are interconnected. The arrows linking the modules indicate that input, storage, viewing and editing of responses can be done at any stage in the process.

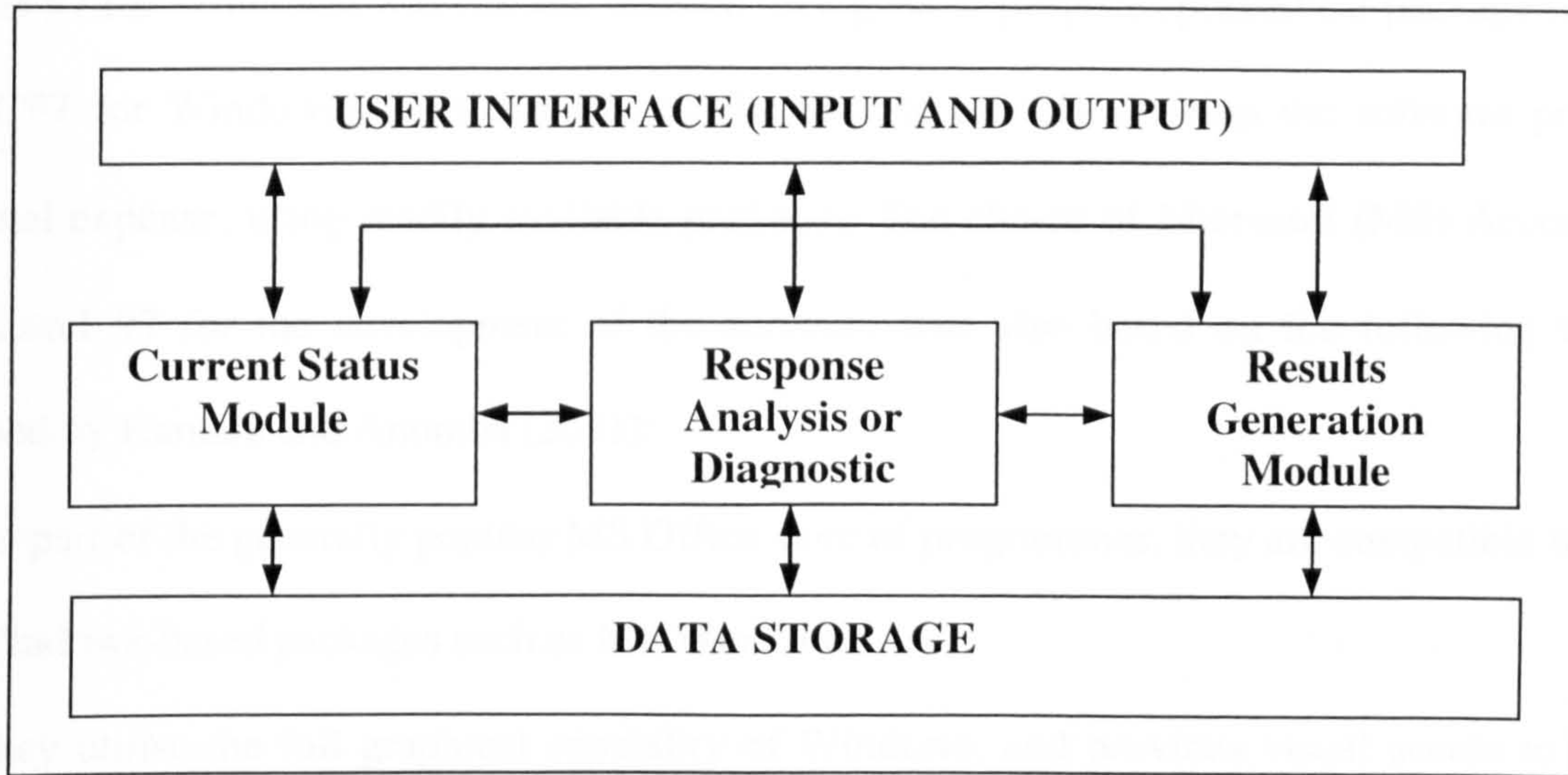


Figure 5.1: System architecture of the BEACON Model

#### 5.4 Implementation Environment

The implementation environment for a software and general system development is usually based on a number of options that, according to Britton and Doake (1996), include:

- Programming in a procedural, third-generation language (3GL) (e.g. FORTRAN) where the programmer has to describe in detail how every task is to be carried out;
- Programming in a problem-oriented fourth-generation language (4GL) (e.g. C and C++) where the programmer merely has to define what must be done;
- Using a general-purpose integrated package which incorporates facilities such as word processing, spreadsheets, database and report generators; and
- Use and customisation of specific application (commercial) packages.

In the development of the BEACON software, a general-purpose database package (Microsoft Access 97 for Windows) was chosen, assisted by a general-purpose spreadsheet package (Microsoft Excel 97 for Windows). This was due to the need to quickly develop the software program at minimal expense, using readily available packages. The choice of Microsoft (MS) Access 97 and MS Excel 97 for the development of the software was also based on the following rationales outlined by Kamara and Anumba (2001):

- As part of the generally popular MS Office suite of programmes, they are compatible with other Windows-based packages such as MS Word, etc;
- They utilise the full graphical capability of Windows, and provides visual access to data and simple, direct ways to view and work with information;
- MS Office packages are readily available and are quite cost effective;
- MS Access facilitates, through the use of macros, the automation of many tasks without the need for programming; and
- In-built design tools in MS Access assist in the development of forms and the generation of results by exporting data to MS Excel for generating diagrams and importing these back for presentation.

## **5.5 Development of the BEACON Software within MS Access**

The BEACON software allows users not only to fill in the assessment questionnaire on their own, but also to view the results in the form of a radial diagram, similar to the BEACON Model diagram. The development of the software followed the general procedure for developing MS Access database applications. The development of tables, queries, forms, reports, and macros for the

software was carried out using the facilities provided within Access, and linked with Microsoft Excel for calculating and plotting the results of the Readiness Assessment.

Forms, in MS Access could be used either to create a data entry form or as a switchboard form to open other forms or, it is sometimes used to create a custom dialogue box to accept users' input. In the BEACON software, forms are used as switchboard forms and to create data entry forms. The data entry forms are then linked to tables, which are used to store the responses on each critical factor under the four elements of the BEACON Model in a structured manner. In order to facilitate the automation, macros are used. A macro is a set of one or more commands that perform a particular action, for example, opening or closing a form. A command button is created and linked to a macro and then used to run that macro, for example, a command button 'Save' would run a macro, which saves the database file in Access. The following section describes the use of forms, tables, and macros within the BEACON Model software.

The questionnaire is implemented through a series of forms in MS Access. Each check box on the forms is given a specific score or value, as shown in Table 5.1. All the comments and scores are automatically recorded in 'Tables' linked to the Forms. Macros are used (while developing the Forms) for different functions such as saving the responses, exporting data to a spreadsheet, and switching from one form to another. A built-in macro is used for exporting data to MS Excel. For this purpose, a 'Save' button is provided on the main menu form of the questionnaire. This is linked to the macro using OLE (Object Linking and Embedding), and when the button is clicked, it opens a new spreadsheet (spreadsheet 1) with the same name and exports all the data to it automatically. It also updates the responses in the spreadsheet 1 when they are changed and saved again.

Table 5.1: Scores of the Responses

Responses ⇒	<i>Always</i>	<i>Most of the Time</i>	<i>Sometimes</i>	<i>Rarely</i>	<i>Never</i>
Score ⇒	4	3	2	1	0

The OLE (Object Linking and Embedding) function is used in the BEACON software to import and update the BEACON model diagram from the spreadsheet. The basic function of OLE is to embed a diagram, which is developed in any MS package as an object. It does not only embed the diagram but it also links it to its original source such that when the original source object is modified, the embedded object will be modified automatically.

A second Excel spreadsheet, which is linked to Spreadsheet 1, is also created. The link between these two spreadsheets is such that when there is a change in the data in the original spreadsheet (Spreadsheet 1), it is reflected in the second one. The second spreadsheet is used to plot a radial graph from the data. This radial graph, which has a similar data presentation format as the BEACON Model diagram, is then imported back to the MS Access file in a form format and can be viewed when the result button is clicked. A flow chart is presented in Figure 5.2, which provides a diagrammatic representation of the above process.

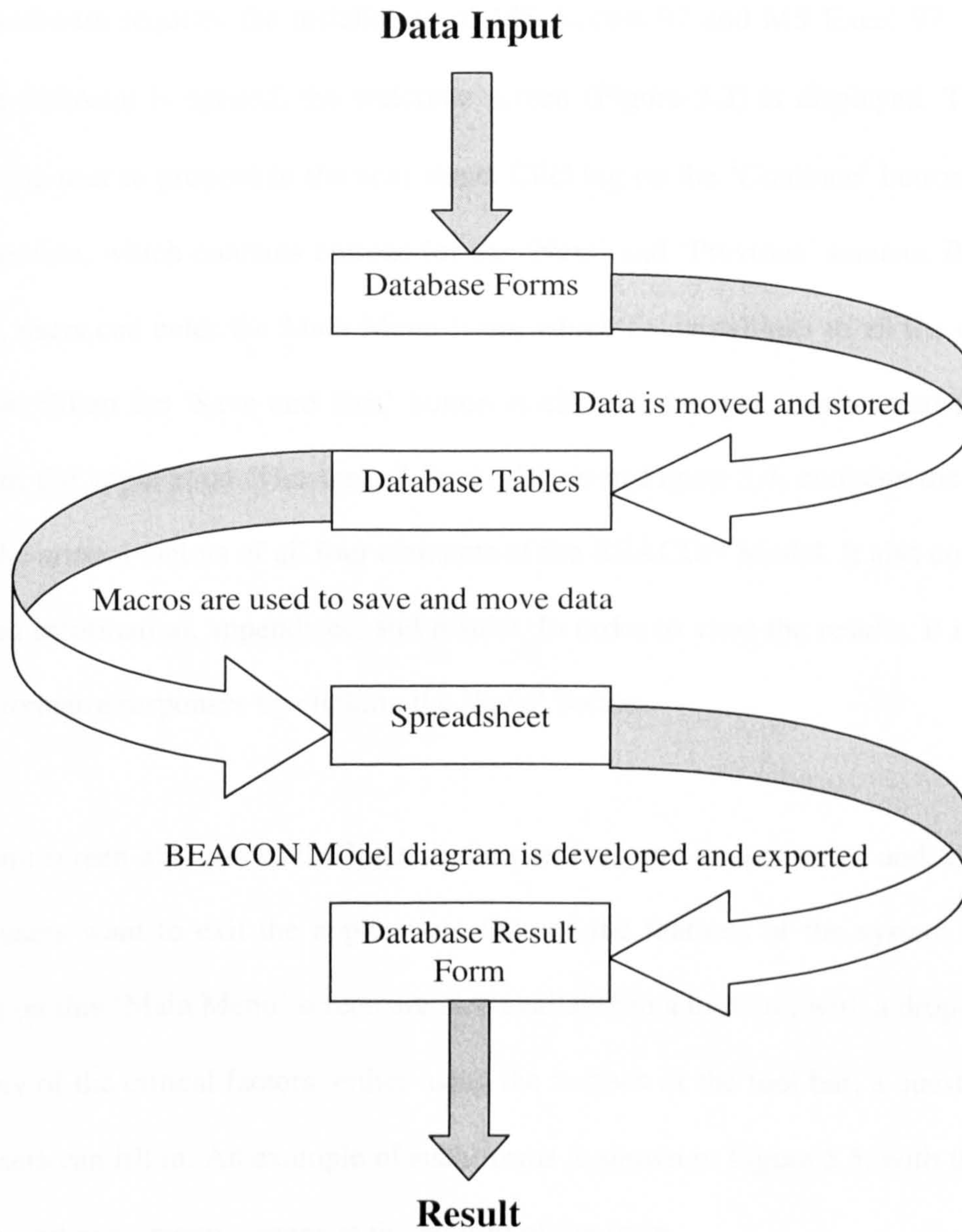


Figure 5.2: Integration of Database and Spreadsheet in BEACON Software

## 5.6 Using the BEACON Software

Running the software requires the installation of MS Access 97 and MS Excel 97. When the file containing the software is opened, the welcome screen (Figure 5.3) is displayed. The 'Continue' button allows the user to proceed to the next stage. Clicking on the 'Continue' button will open the introduction section, which contains buttons for the 'Next' and 'Previous' screens. By clicking the 'Next' button, users can enter the Main Menu form, which contains links to all the other forms in the application. When the 'Save and Exit' button is clicked, the user is prompted to confirm the decision to quit the application. The control form, shown in Figure 5.4, contains the questionnaire forms for all the critical factors of all four elements of the BEACON Model. It also contains links to the background information, appendices, and results. In order to view the results, it is necessary to save the questionnaire responses by clicking the 'Save' button.

The Main Menu screen also shows the links to the previous and next screens, and 'Save and Exit' button if the users want to exit the application. One of the features of the system is that all the button options on this 'Main Menu' screen are also available in a tool bar, with a drop-down format. By clicking any of the critical factors, either using the buttons or the tool bar, a questionnaire form appears that users can fill in. An example of such forms is shown in Figure 5.5, with the links to the previous, next, and main menu screens at the bottom of the form.

After completing the questionnaire, users can save their responses by using the 'Save' button. In order to view the results, the users can click on the 'View Result' button on the main menu or the result viewing facility from the tool bar by using 'Result' drop down menu. This takes the users to



the results form, as shown in Figure 5.6. Figure 5.7 summarises the stages of the application diagrammatically.

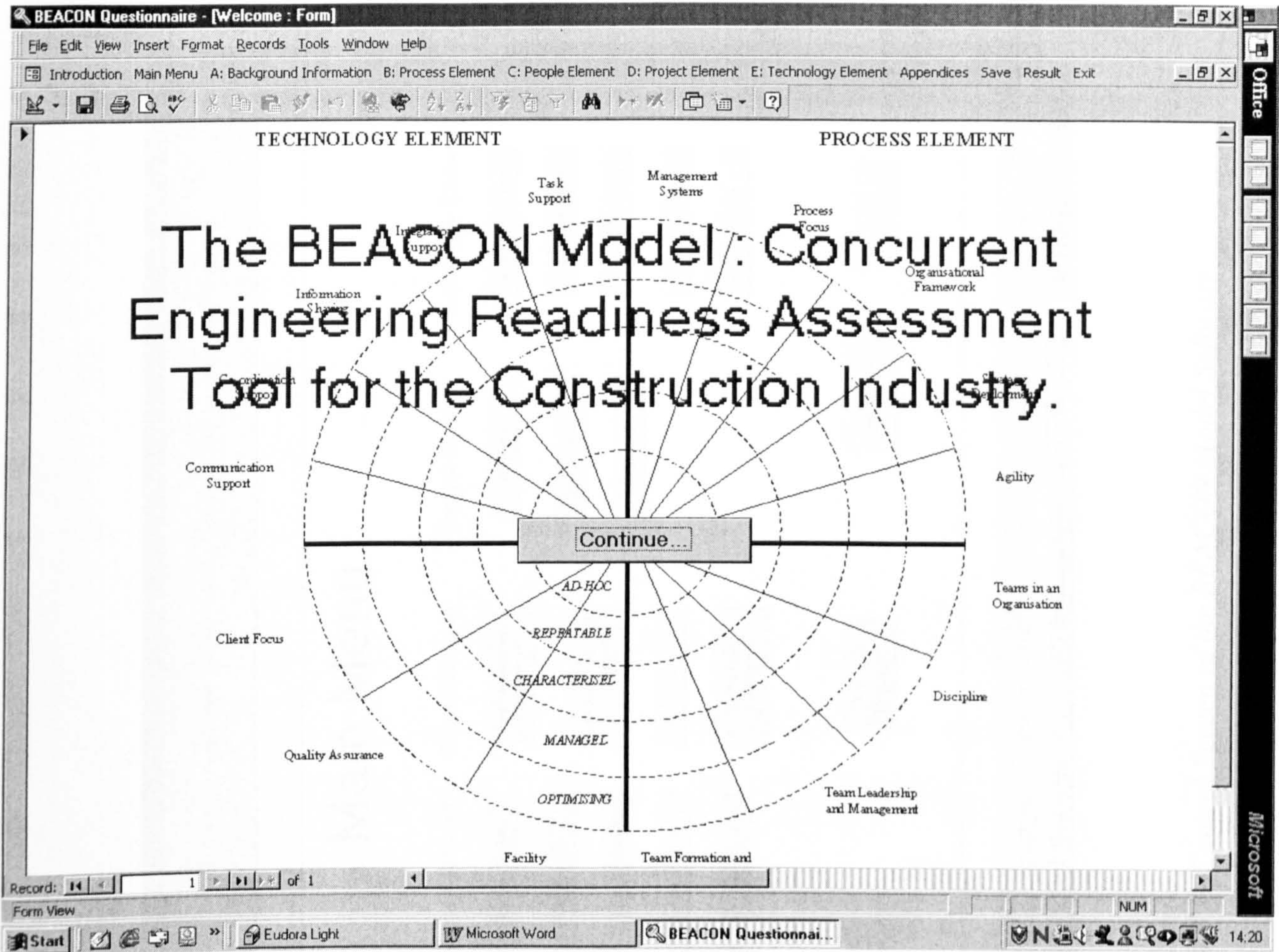


Figure 5.3: Welcome Screen of the BEACON Model Software

Each separate plot or series on the diagram could be used to compare the historical performance of a company. For example, if series 1 shows the maturity level of a company in January 2001, then series 2 could be used to plot the status in July 2001, and both of these series could be used to show the improvement in each critical factor for all the elements within the model within the given period.

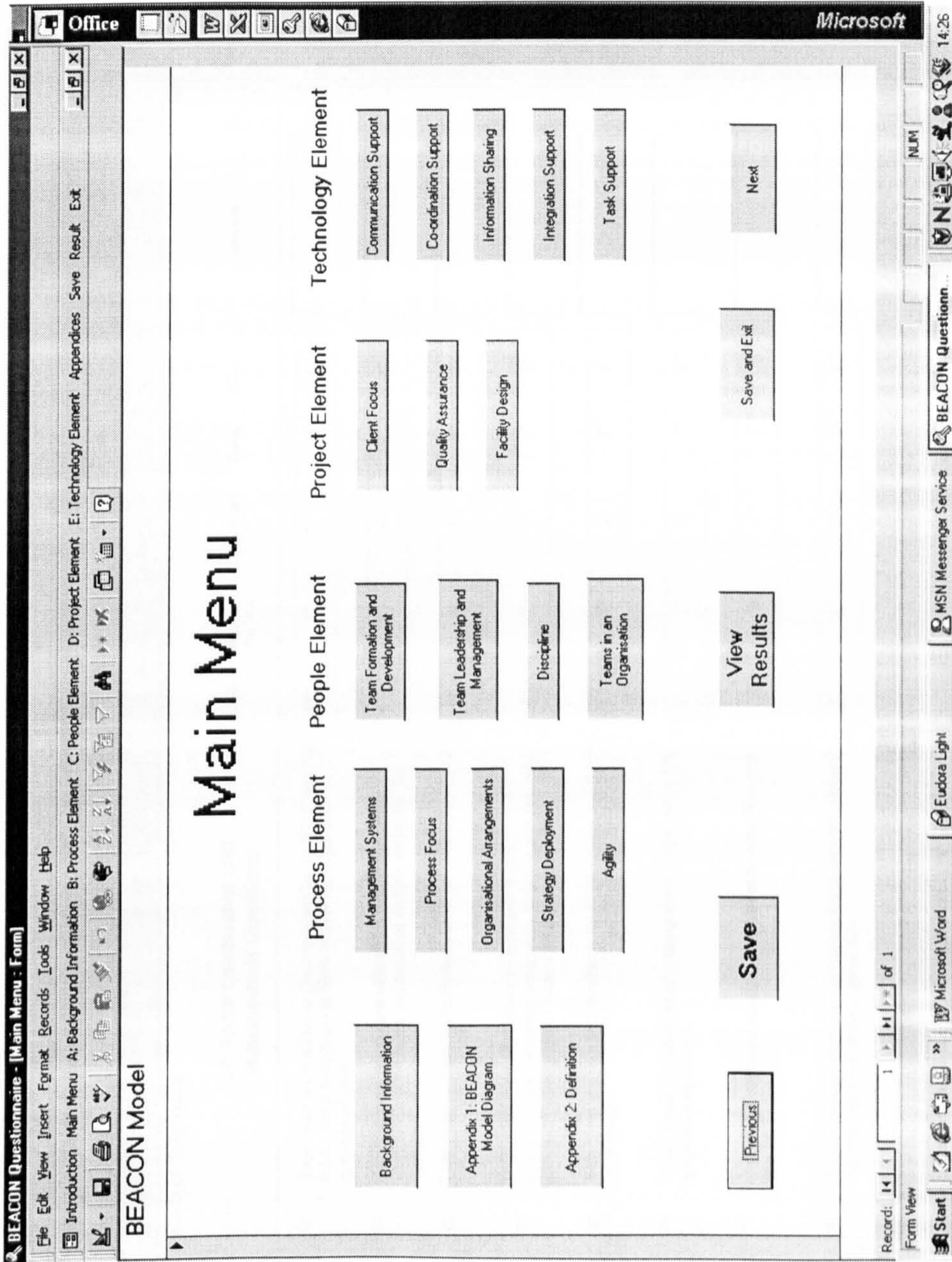


Figure 5.4: Control Screen of the BEACON Model Software

BEACON Questionnaire - [Section C: People Element]

File Edit View Insert Format Records Tools Window Help

Introduction Main Menu A: Background Information B: Process Element C: People Element D: Project Element E: Technology Element Appendices Save Result Exit

Office Microsoft

14:41

### People Element

#### C2: Team Leadership and Management Questions

S. No	Always	Most of the Time	Sometimes	Rarely	Never	Comments
01	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
02	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
03	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
04	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
05	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
06	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
07	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
08	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	

Record: 1 of 1

Form View

Start Microsoft Word MSN Messenger Service BEACON Questionnaire... Endure Light NLM

Figure 5.5: A Typical Questionnaire Form for Critical Factors

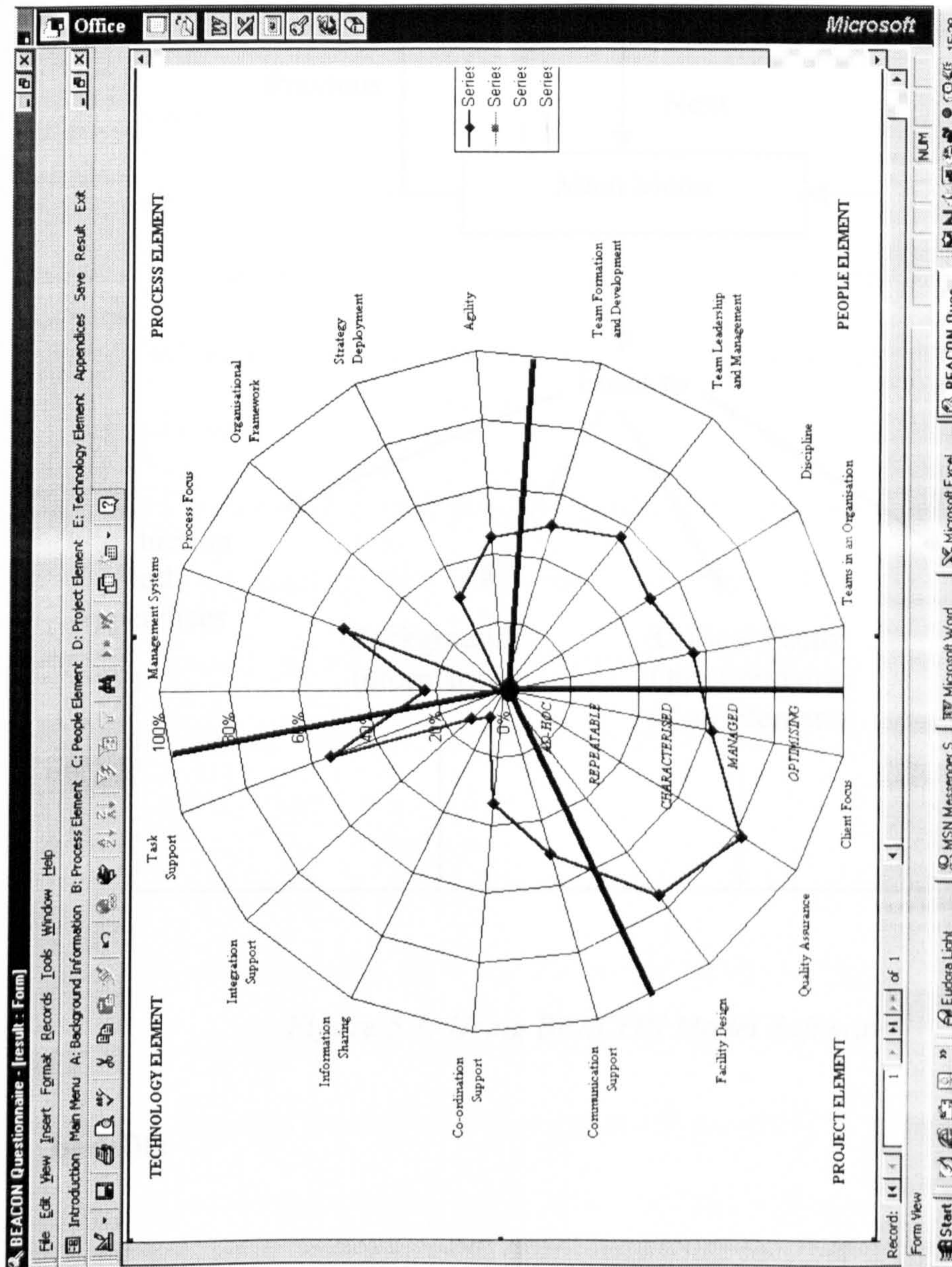


Figure 5.6: Result Form for Critical Factors

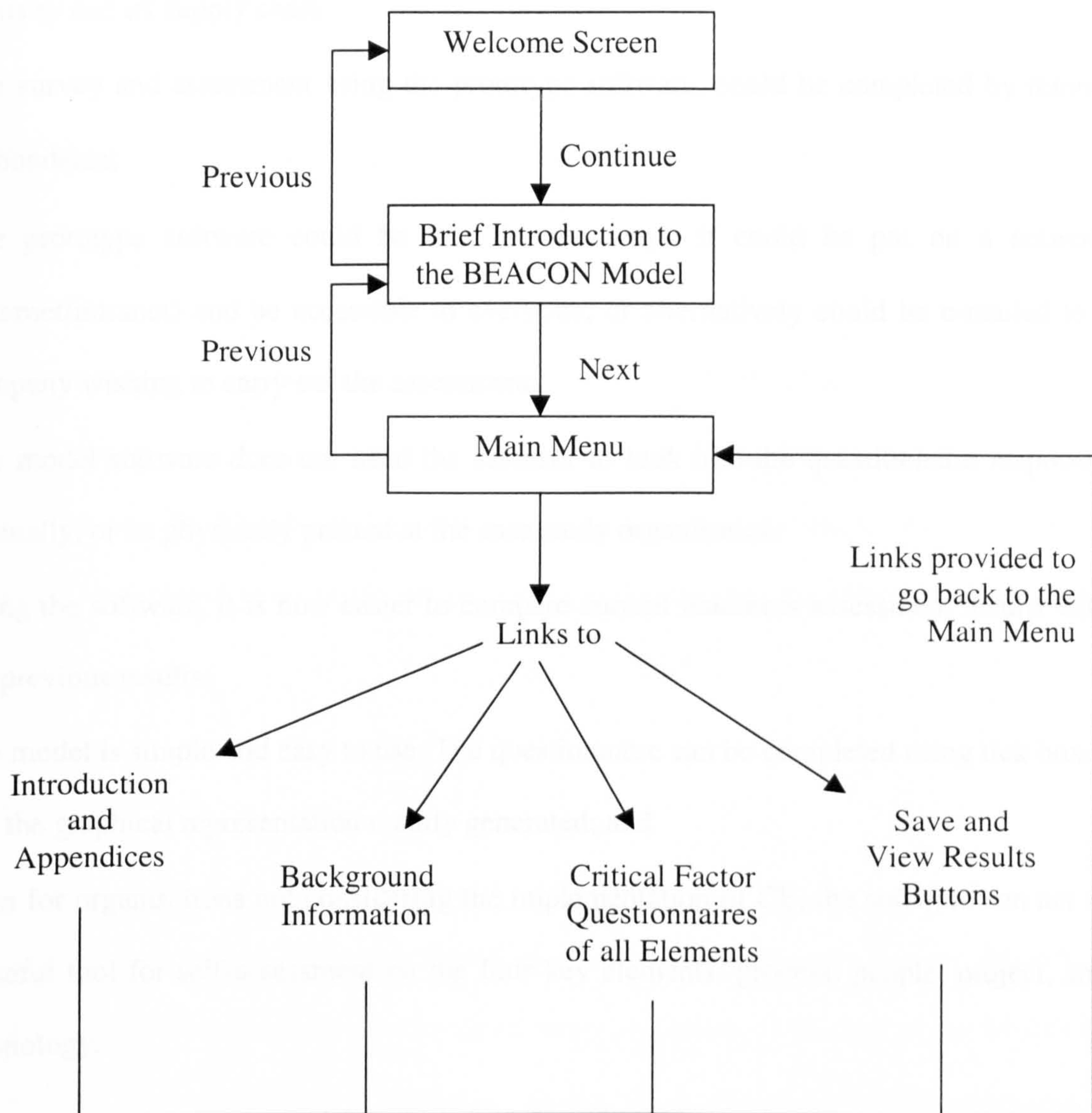


Figure 5.7: Using BEACON Model Software

## 5.7 Benefits

The development of the BEACON model software is important for the CE readiness assessment within the construction industry. The benefits of the electronic version of the model are:

- The BEACON software is specifically tailored to meet the needs of the construction industry and its supply chain;
- The survey and assessment using the prototype software, could be completed by remote respondents;
- The prototype software could be used in two ways: it could be put on a network (internet/intranet) and be accessible to everyone, or alternatively could be e-mailed to a company wishing to carry out the assessment;
- The model software does not need the assessor to look into the questionnaire responses manually, or be physically present at the case study organisation;
- Using the software, it is now easier to compare current readiness assessment results with the previous results;
- The model is simple and easy to use. The questionnaire can be completed using tick boxes and the graphical representation readily generated; and
- Even for organisations not considering the implementation of CE, the software can act as a useful tool for self-assessment on the four key elements: process, people, project, and technology.

Where there are many benefits, there are few shortcomings of the software. The software is only a prototype to demonstrate capability and maturity of an organisation for adoption of Concurrent Engineering. The software also needs enhancement in certain areas, for example improvement in screen appearance, introduction of help features, etc. A report generation module could also be introduced, which would not only come up with diagrammatic representation of the results but also indicate areas required immediate consideration for improvements and solutions for any lacking.

Since the development of the BEACON software was undertaken in parallel with the readiness assessment of the construction supply chain, the software was not actually used in the assessment itself. However, it was used to plot the readiness assessment results on the BEACON Model once the information on the manually completed questionnaire were input to the system.

The above mentioned use of the software enabled it to be validated and evaluated; this focused on the appropriateness and usability of the software, and also tested its result generation feature. Thus the BEACON software could be used by organisations to undertake CE readiness assessment or simply to measure their performance in the four critical areas on a periodic basis.

## **5.8 Summary**

This chapter has discussed the development of a software programme for the BEACON Model. It has presented the objectives for developing an electronic version of the BEACON Model, and its development. This includes the system architecture, the implementation environment, and its development using MS Access and MS Excel. The chapter also outlined how the software works and how it generates the results. At the end some of the key benefits of the software were also outlined and proposed possible improvements.

## **Chapter 6: CE Readiness Assessment of the Construction Supply Chain**

This chapter presents and discusses the results of the CE readiness assessment case studies, carried out within the UK construction industry using the BEACON Model. It discusses the objectives of the assessment and the methodology adopted for it, followed by the full description of the results of the assessment and comparison of different sectors of the construction supply chain including clients, consultants, contractors, sub-contractors, and material supplier and manufacturers.

### **6.1 Objectives of the Assessment**

In order to assess the CE readiness of the UK construction industry, case studies were carried out using the BEACON Model. One of the reasons for carrying out case studies is the fact that they help to solve current problems through an examination of what has happened in the past and what is happening now, and thus save a lot of time (Yin, 1989). The basic aim of the assessment is to collect results from sample studies in order to come up with the general strategies and considerations for CE implementation within the industry. Other objectives of the assessment were to:

- Assess the readiness of the construction supply chain for CE implementation;
- Identify the areas which need improvement in order to fully adopt CE in an organisation;
- Identify the relative strengths of each of the Elements and criteria that support CE;
- Compare one sector to another within the industry; and
- Explore the applicability of the BEACON Model for assessing the construction industry in other countries.

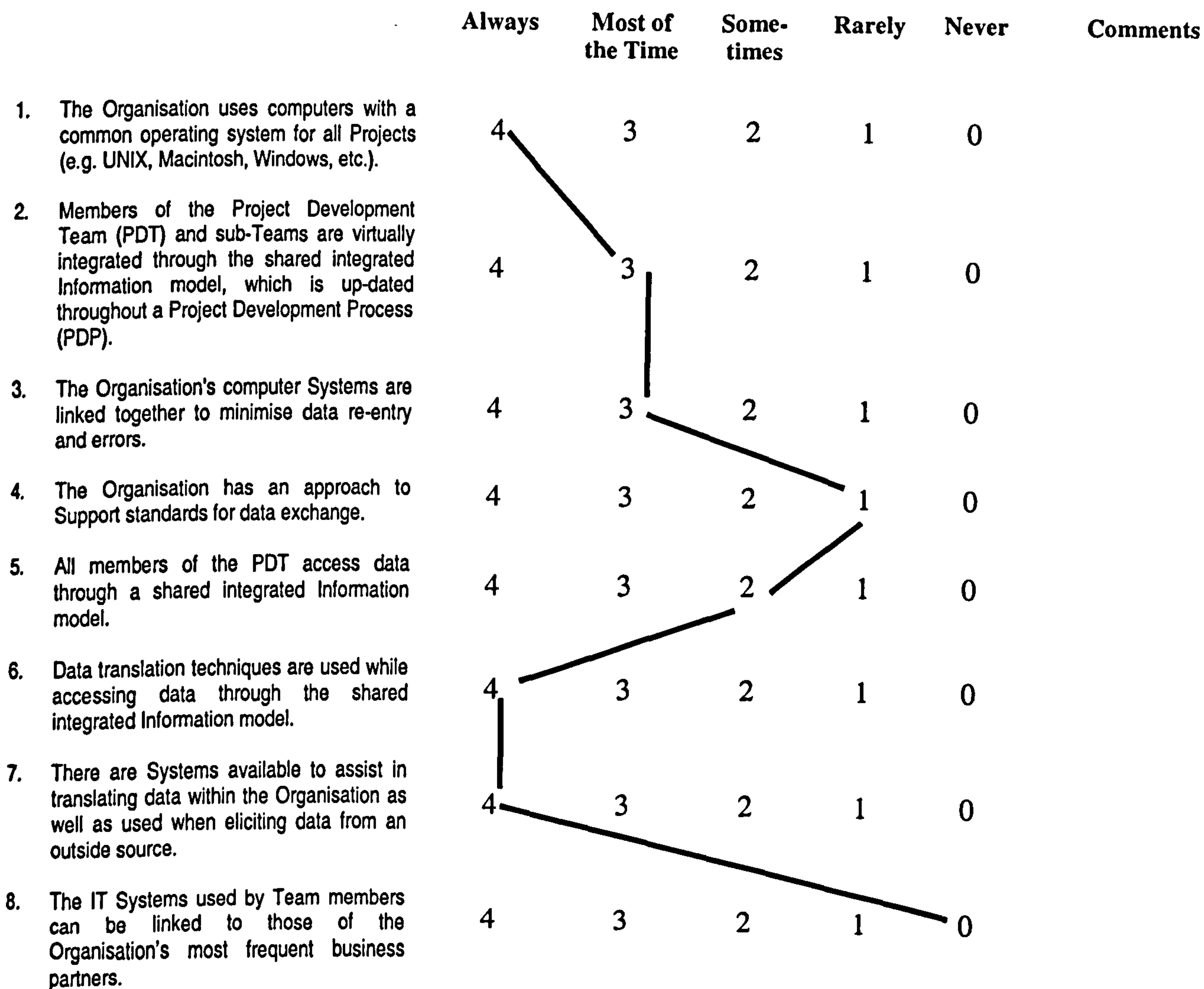


## **6.2 Methodology**

For the purpose of the case studies, the industry was divided into five categories: Clients, Consultants, Contractors, Sub-contractors, and Material Suppliers and Manufacturers. Ten companies within each category were selected randomly from the 'New Civil Engineer Plus' web site in order to get sample results. Each company was contacted and the most appropriate person was identified. This individual came from either senior or middle Management, who had knowledge about the company and could adequately complete the questionnaire. Questionnaires were then sent out along with a covering letter to the identified person in all the selected companies. The contact person was given enough time to fill in the questionnaire, so that he/she could consult with the other people within their organisations about the issues covered in the questionnaire.

In order to prepare the results in form of a BEACON Model diagram, responses of the questionnaire survey were used. The diagram could then give a summary of the readiness of an organisation for the adoption of Concurrent Engineering. It could also be used to identify the relative strengths of each of the Elements and the criteria that support Concurrent Engineering. The relative levels for each of the Elements were determined using the reported responses to each of the Element, covered in the questionnaire. The results of the survey were intended to help with the formulation of CE implementation strategies for the construction industry. Specific areas where functional barriers to CE implementation exist could also be identified so that action could be taken.

The readiness assessment questionnaire could also be used to develop a set of profiles for the organisation for each critical factor. For example, a profile could be developed for 'Integration Support' after joining the scores with straight lines (see Figure 6.1). The scores or the values corresponding to each response are shown in Table 5.1 in the previous chapter. There is also scope to summarise the comments received on each critical factor from a completed questionnaire for a particular company and use these when developing the CE implementation strategies for that company.



**Figure 6.1: Integration Support Profile**

Scoring in the profile is set in such a way that one can get the highest score of 4 for “Always” and 0 for “Never”. A score of 0 shows that in order to implement Concurrent Engineering, an organisation should think about these issues and areas which are never considered. A score of 4 shows that an Organisation is already practising some of CE aspects. For responses such as “Does Not Apply” or “Don’t Know”, respondents were asked to provide further details in the comment space provided with each question or in the comment space at the bottom of each critical factor.

All four elements and underlying critical factors have been given equal importance because they are all critical for the construction industry (see Section 4.2). Also, it would be unwise to introduce subjective weightings that may limit the appeal of the model. However, provision is made for respondents to rank the four elements of the model (most important and least important) from their organisational point of view. This could help to compare the results with the rankings to see whether an organisation is performing well in a specific area, which is most important for them. It could also be used to customise the results for a particular organisation by incorporating the ranking as a form of weighting.

It should be noted that the BEACON Model was developed in a generic form, but with sufficient flexibility to customise it according to the needs of any individual or project organisation. The generic unweighted model is considered adequate in its present form as it does not present absolute results – the results are useful for relative comparisons between:

- Critical factors;
- Key elements;
- Individual organisations;
- Project organisations;

- Different points in time;
- Different sectors of the construction supply chain; etc.

The flexibility of the model is such that weightings can be readily introduced at a variety of levels in accordance with the needs and priorities of an organisation, which could be different from other organisations. This would then enable organisations to assess their performance and readiness according to their available resources, priorities, and business needs.

As far as the summation of all the scores is concerned, in order to calculate the percentage for each critical factor and to plot them on the BEACON Model diagram, the actual score for each question of the critical factor was taken. For example, the Integration Support results are summed across 8 questions to receive a total score of 21 by using the score for each question. If all responses were 'Always' for each of the questions or statements, then the total score would be 32. Therefore, for Integration Support, it would result in an Element percentage of 65.625% ( $21/32 \times 100$ ) out of a possible 100%. This percentage would then be plotted on the model within the 'Managed Level'. Most of the results were developed manually but some of them were also generated using the BEACON Software when it was developed.

A summary of all critical factors' profiles could be shown in the BEACON Model diagram as a radial diagram after plotting the percentages for each factor (see Figure 6.2). This would show the organisation's relative strengths on each of the elements and the critical factors that support CE. It should be noted that the wider the diagram the more ready a construction organisation is to adopt CE. In order to plot the profiles of each factor in the model diagram, profiles' scores were converted into percentages according to the procedure mentioned earlier.

The percentages for all the factors were then plotted on the diagram and joined to get a spider or radar diagram as shown in Figure 6.2.

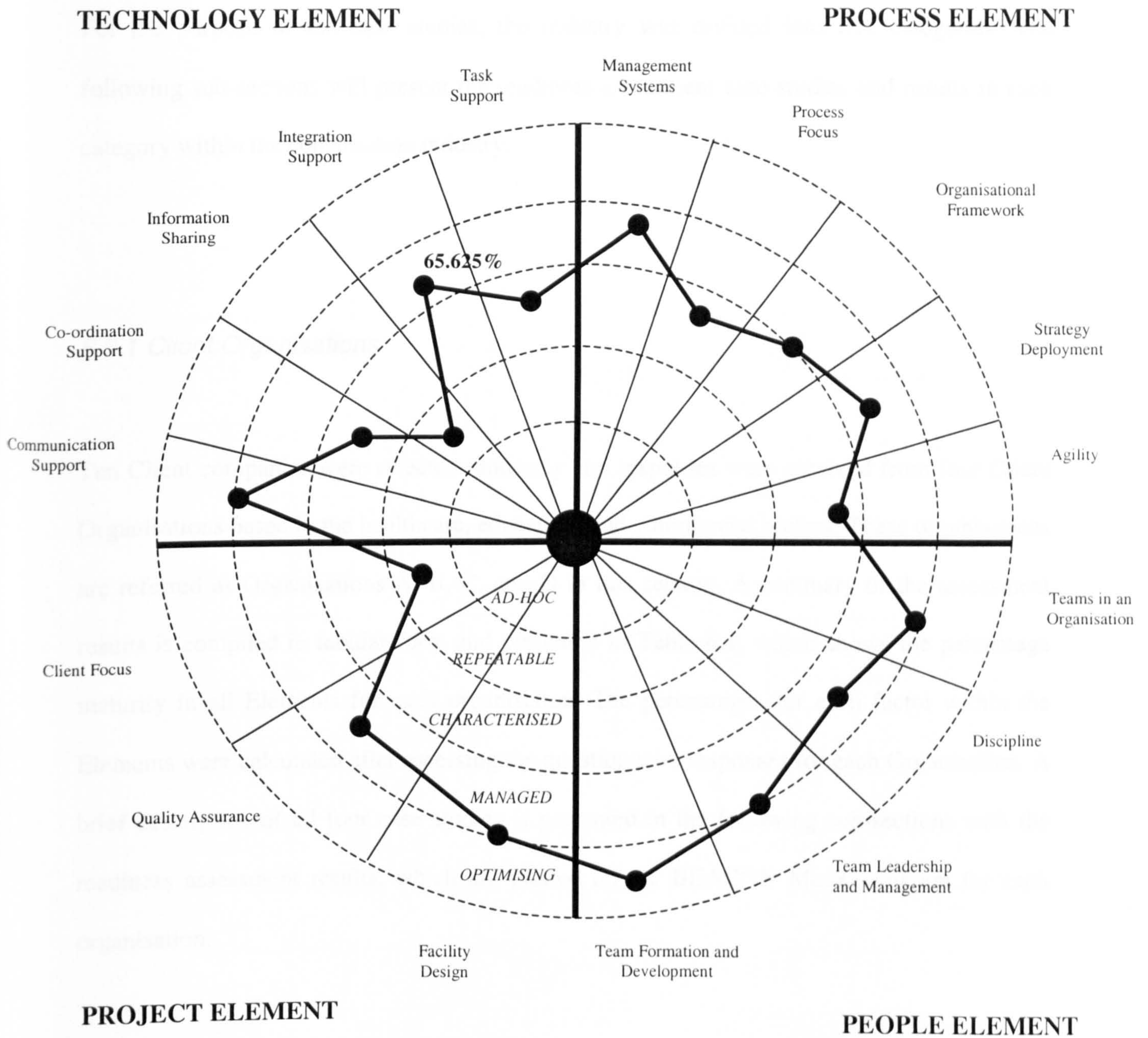


Figure 6.2: Presentation of assessment result on BEACON Model Diagram

### **6.3 Assessment of the Construction Supply Chain**

For the purpose of the case studies, the industry was divided into five categories. The following sub-sections will present the readiness assessment case studies and results in each category within the construction industry.

#### **6.3.1 Client Organisations**

Ten Client companies were selected randomly and responses were received from four Client Organisations based in the healthcare, education, and commercial sectors. These organisations are referred as Organisations A, B, C, and D in this section. A summary of the assessment results is compiled in tabular form and presented in Table 6.1, which shows the percentage maturity in all Elements for each organisation. The percentages for each factor within the Elements were calculated after assessing the questionnaire responses for each Organisation. A brief description of all four case studies is presented in the following sub-sections with the readiness assessment results, which are plotted on the BEACON Model diagram for each organisation.

Table 6.1: A Summary of Readiness Assessment Results for Client Organisations

Organisations→ Elements↓	Organisation A (%)	Organisation B (%)	Organisation C (%)	Organisation D (%)
<b>Process Element</b>	<i>Avg.: 53.1</i>	<i>Avg.: 79.77</i>	<i>Avg.: 80.26</i>	<i>Avg.: 59.4</i>
Management Systems	43 %	69.23 %	92.3 %	60 %
Process Focus	58.33 %	84.6 %	86.5 %	52 %
Organisational Framework	53.33 %	77.5 %	72.5 %	70 %
Strategy Deployment	57.5 %	100 %	80 %	57.5 %
Agility	53.33 %	67.5 %	70 %	57.5 %
<b>People Element</b>	<i>Avg.: 62.21</i>	<i>Avg.: 71.46</i>	<i>Avg.: 76.51</i>	<i>Avg.: 64.06</i>
Team Formation and Development	61.67 %	77.5 %	80 %	62.5 %
Team Leadership and Management	68.75 %	100 %	81.25 %	75 %
Discipline	63.54 %	50 %	78.13 %	75 %
Teams in an Organisation	54.87 %	58.33 %	66.67 %	43.75 %
<b>Project Element</b>	<i>Avg.: 55.19</i>	<i>Avg.: 88.66</i>	<i>Avg.: 87.51</i>	<i>Avg.: 76.33</i>
Client Focus	50.76 %	95.5 %	95.5 %	81.8 %
Quality Assurance	41.67 %	84.37 %	78.13 %	75 %
Facility Design	73.15 %	86.11 %	88.89 %	72.2 %
<b>Technology Element</b>	<i>Avg.: 40.74</i>	<i>Avg.: 36.49</i>	<i>Avg.: 68.33</i>	<i>Avg.: 70.52</i>
Communication Support	44.17 %	37.5 %	75 %	75 %
Co-ordination Support	25 %	27.78 %	69.4 %	75 %
Information Sharing	45.47 %	43.18 %	72.72 %	61.4 %
Integration Support	44.8 %	37.5 %	68.75 %	72 %
Task Support	44.25 %	N/A	55.76 %	69.2 %

**Case Study 1: Organisation A**

Organisation A is a large client organisation in the healthcare sector with 5,000 employees and over £200m annual turnover. The respondent commented in the questionnaire that the Process Element is the most important and the Technology Element is the least important Element from the Organisation’s point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.3. This shows that Organisation A is in the ‘Characterised level’ of CE readiness except for some of the critical factors, which indicates the ‘Managed level’ for the Organisation. This concludes that the Organisation A is not ready to adopt CE. The areas, which need attention, are all the critical factors within the Technology Element, and most of the critical factors within all the other Elements.

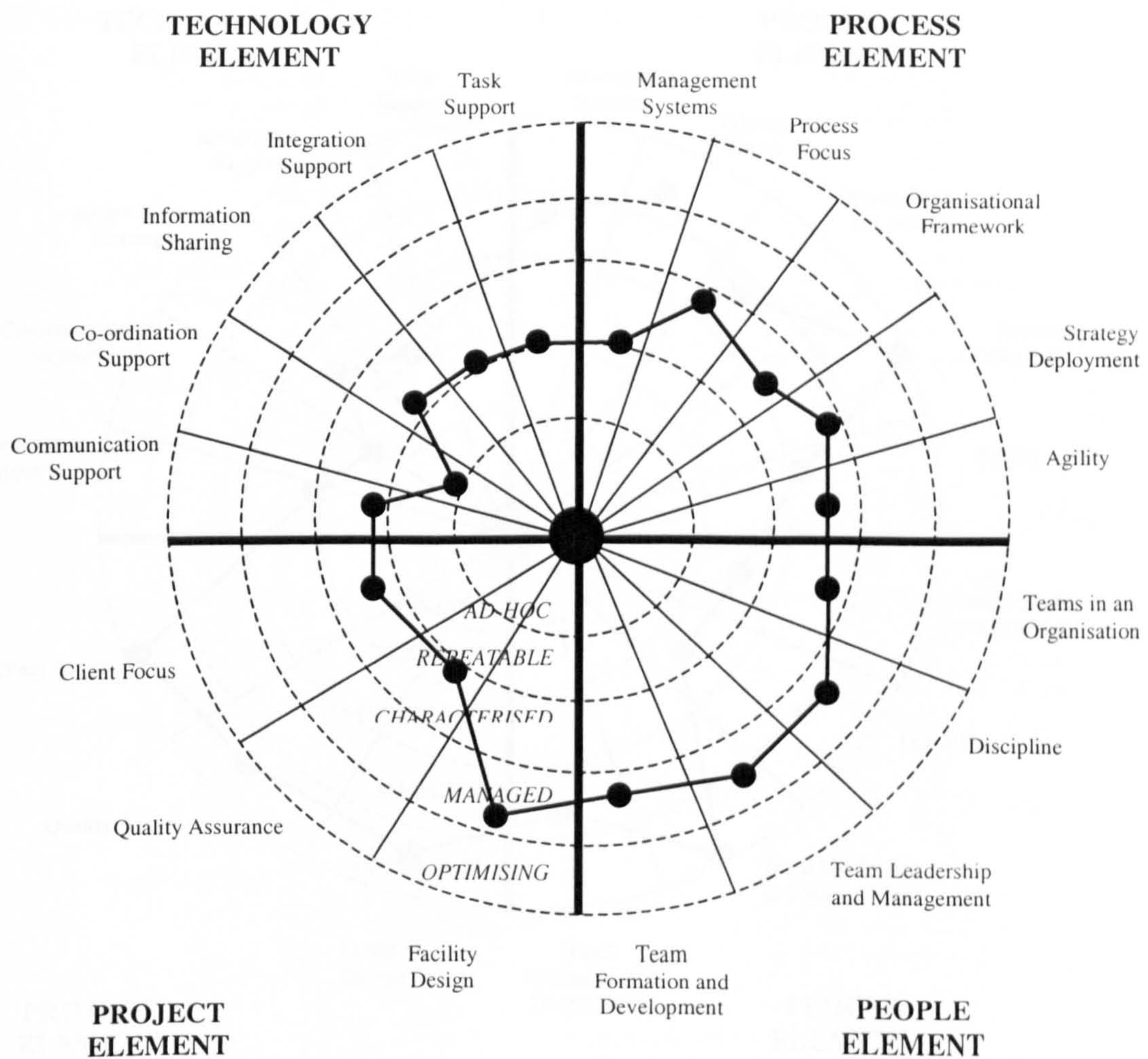


Figure 6.3: CE Readiness Assessment of Organisation A



**Case Study 2: Organisation B**

Organisation B is a small client company in commercial sector with over 25 employees. Responses to the questionnaire indicate that the People Element is the most important and the Technology Element the least important Element from the organisation’s point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.4. The results show that Organisation B is in the ‘Managed level’ except for some of the critical factors, which are either in the ‘Optimising level’ or ‘Repeatable level’. This concludes that Organisation B is not fully ready to adopt CE and requires improvements in all the critical factors within the Technology Element, and the Discipline and Teams in an Organisation factors within the People Element.

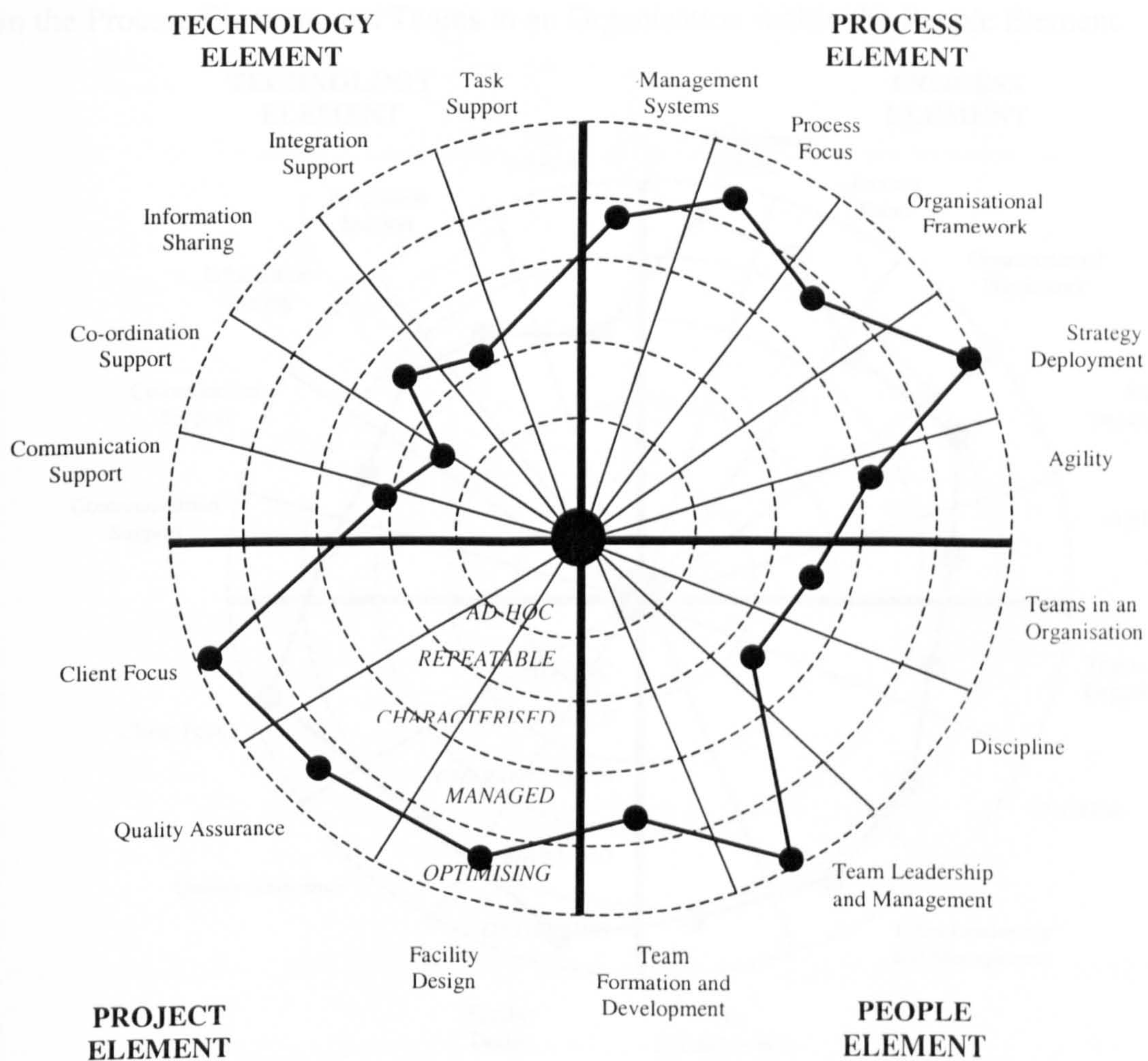


Figure 6.4: CE Readiness Assessment of Organisation B

**Case Study 3: Organisation C**

Organisation C is another large client organisation in the academic sector with over 3,000 employees and with over £100m annual turnover. According to the background Information in the questionnaire, the People Element is the most important and the Technology Element is the least important Element from the Organisation’s point of view. The readiness assessment result is plotted on the BEACON Model diagram shown in Figure 6.5. The assessment result shows that some critical factors are in the ‘Optimising level’ while the rest are in the ‘Managed level’. This concludes that the Organisation C is ready to adopt CE and may have already adopted CE in some of the critical factors within the Elements. The areas that needed improvements, are Task Support within the Technology Element, Organisational Framework within the Process Element, and Teams in an Organisation within the People Element.

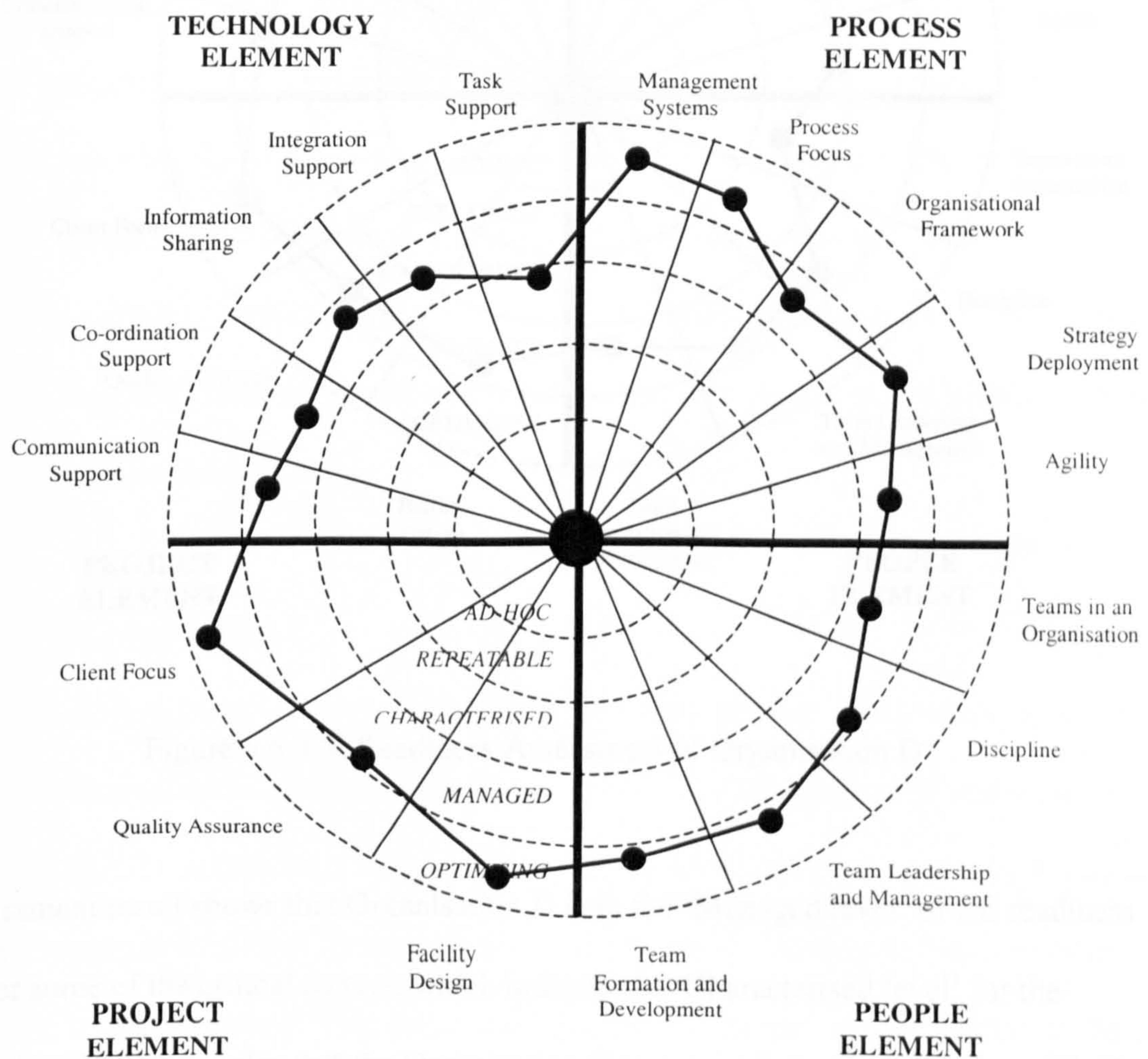


Figure 6.5: CE Readiness Assessment of Organisation C

**Case Study 4: Organisation D**

Organisation D is a medium-sized client organisation in the academic sector with around 500 employees. The organisation considers the People Element the most important and the Technology Element the least important. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.6.

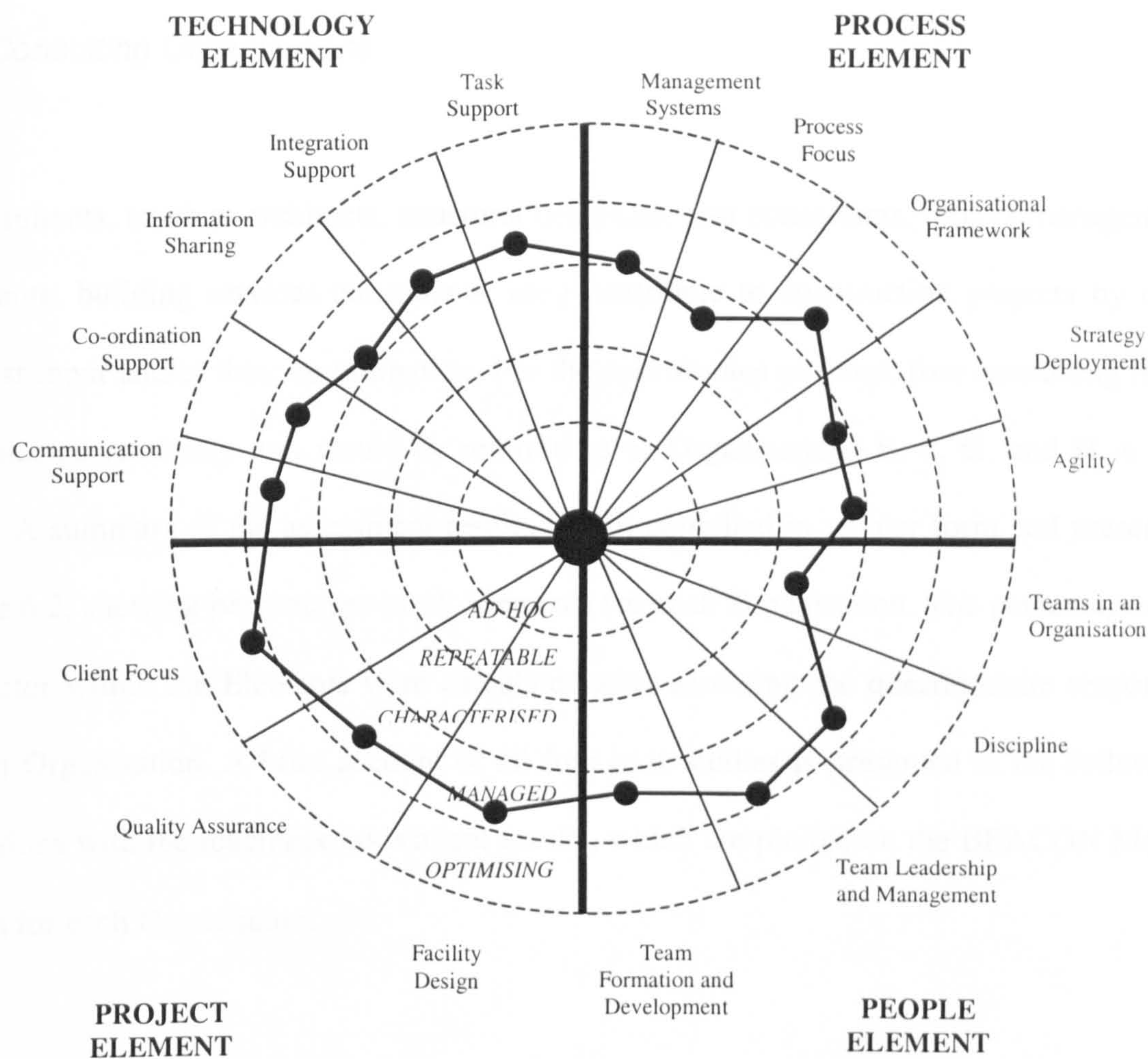


Figure 6.6: CE Readiness Assessment of Organisation D

The assessment result shows that Organisation D is in the 'Managed level' of CE readiness except for some of the critical factors, which indicate the 'Characterised level' for the Organisation. This concludes that the Organisation D is not yet fully ready to adopt CE. The

critical factors, which needed attention, are Information Sharing within the Technology Element, Teams in an Organisation & Team Formation and Development within the People Element, and all of the critical factors within the Process Element except Organisational Framework.

### ***6.3.2 Consulting Organisations***

All consultants, (such as architects, structural designers, cost consultants, project management consultants, building services consultants, etc.) contribute to construction projects by their specialist input and/or their co-ordination. For the case studies purpose, four consulting firms were selected randomly and would be referred to as Organisations E, F, G, and H in this section. A summary of the assessment results is also compiled in tabular form and presented in Table 6.2, showing percentages of all Elements for each Organisation. The percentages for each factor within the Elements were calculated after assessing the questionnaire responses for each Organisation. A brief account of all four case studies is presented in the following sub-sections with the readiness assessment results, which are plotted on the BEACON Model diagram for each Organisation.

#### ***Case Study 1: Organisation E***

Organisation E is a large building, engineering and management consultancy, involved in providing services across the whole industry, with over 10,000 employees and over £400m annual turnover. The respondents commented in the questionnaire that the People Element is the most important and the Project Element is the least important Element from the Organisation's point of view. The assessment results are plotted on the BEACON Model diagram shown in Figure 6.7. This shows that Organisation E is in the 'Optimising level'

except for some of the critical factors, which are either in the 'Managed' or 'Characterised levels'. This concludes that Organisation E is ready to adopt CE and may have already adopted a CE approach in some of the critical factors within the Elements. The areas that need the most attention are Co-ordination Support, Information Sharing and Integration Support within the Technology Element, Strategy Deployment and Agility within the Process Element, and Teams in an Organisation and Team Formation and Development within the People Element.

*Table 6.2: A Summary of Readiness Assessment Results for Consulting Firms*

Elements	Organisations			
	Organisation E (%)	Organisation F (%)	Organisation G (%)	Organisation H (%)
<b>Process Element</b>	<i>Avg.: 81.19</i>	<i>Avg.: 53.62</i>	<i>Avg.: 72.35</i>	<i>Avg.: 79.62</i>
Management Systems	82.69	59.62	76.92	67.31
Process Focus	80.77	38.46	67.31	80.77
Organisational Framework	90	37.5	60	87.5
Strategy Deployment	75	82.5	72.5	80
Agility	77.5	50	85	82.5
<b>People Element</b>	<i>Avg.: 79.01</i>	<i>Avg.: 77.08</i>	<i>Avg.: 68.5</i>	<i>Avg.: 76.98</i>
Team Formation and Development	65	75	75	72.5
Team Leadership and Management	81.25	81.25	71.88	68.75
Discipline	90.63	87.5	68.75	75
Teams in an Organisation	79.17	64.58	58.35	91.67
<b>Project Element</b>	<i>Avg.: 95.43</i>	<i>Avg.: 38.27</i>	<i>Avg.: 77.85</i>	<i>Avg.: 82.82</i>
Client Focus	97.73	31.82	56.82	77.27
Quality Assurance	96.88	46.88	90.63	90.63
Facility Design	91.67	36.11	86.11	80.56

<b>Technology Element</b>	Avg.: 67.38	Avg.: 27.61	Avg.: 80.1	Avg.: 36.15
Communication Support	100	27.5	82.5	32.5
Co-ordination Support	52.77	16.67	66.67	22.22
Information Sharing	54.55	22.73	81.82	40.91
Integration Support	46.88	25	90.63	31.25
Task Support	82.69	46.15	78.85	53.85

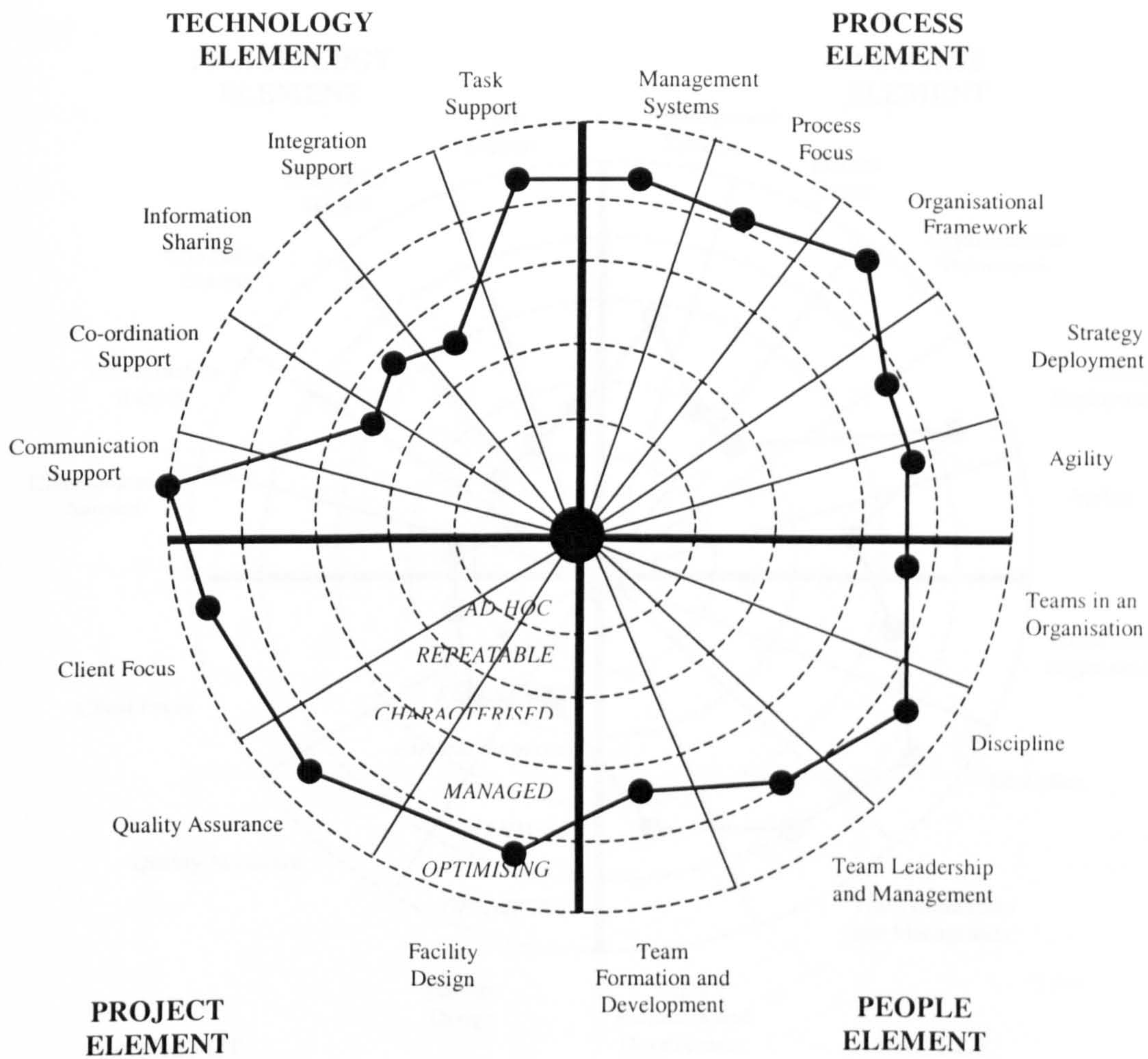


Figure 6.7: CE Readiness of Organisation E

**Case Study 2: Organisation F**

Organisation F is a small non-traditional housing and structural masonry consultant with around 180 employees and over £7.9m annual turnover. Responses to the questionnaire indicate that all the Elements of the BEACON Model are of equal importance to the

organisation. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.8. The results do not clearly define a single level for Organisation F because half of the critical factors are at the 'Repeatable level' while the rest are generally in higher levels, except Communication Support within the Technology Element which is at the 'Ad-hoc level'. This concludes that Organisation F is not ready to adopt CE and requires massive improvements in all critical factors, except the ones that are within the People Element.

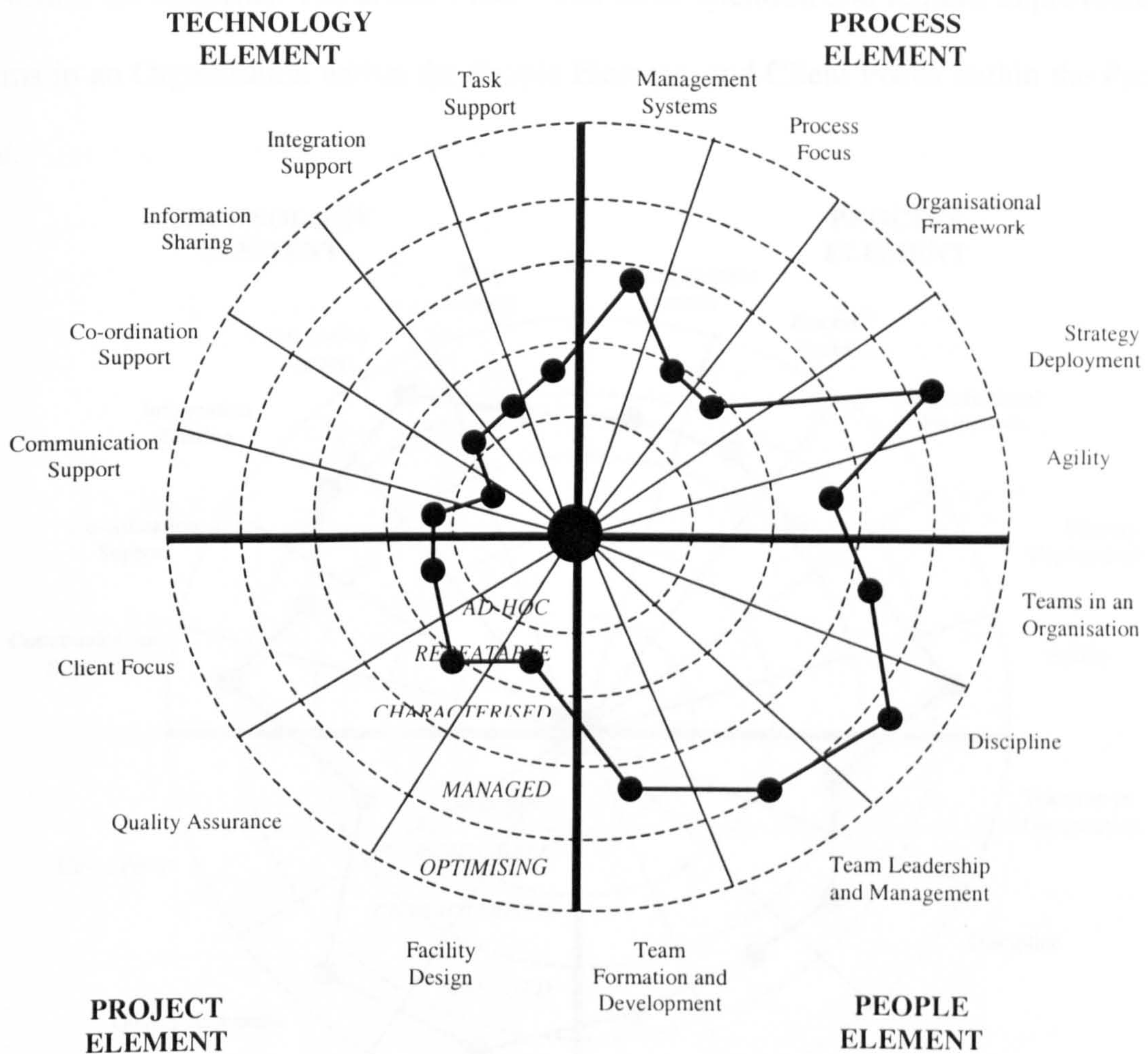


Figure 6.8: CE Readiness of Organisation F

### Case Study 3: Organisation G

Organisation G is a medium-sized engineering design consulting firm with over 560 employees and over £20m annual turnover. According to the background information in the

questionnaire, the People Element is the most important and the Technology Element the least important Element from the organisation's point of view. The readiness assessment result is plotted on the BEACON Model diagram shown in Figure 6.9. The assessment results show that some critical factors are at the 'Optimising level' while the rest are at the 'Managed level' except for a few of them which are in the Repeatable level. This concludes that Organisation G is ready to adopt CE and may have already adopted a CE approach in some of the critical factors within the elements. The areas, which need more attention and require improvements, are Teams in an Organisation within the People Element, and Client Focus within the Project Element.

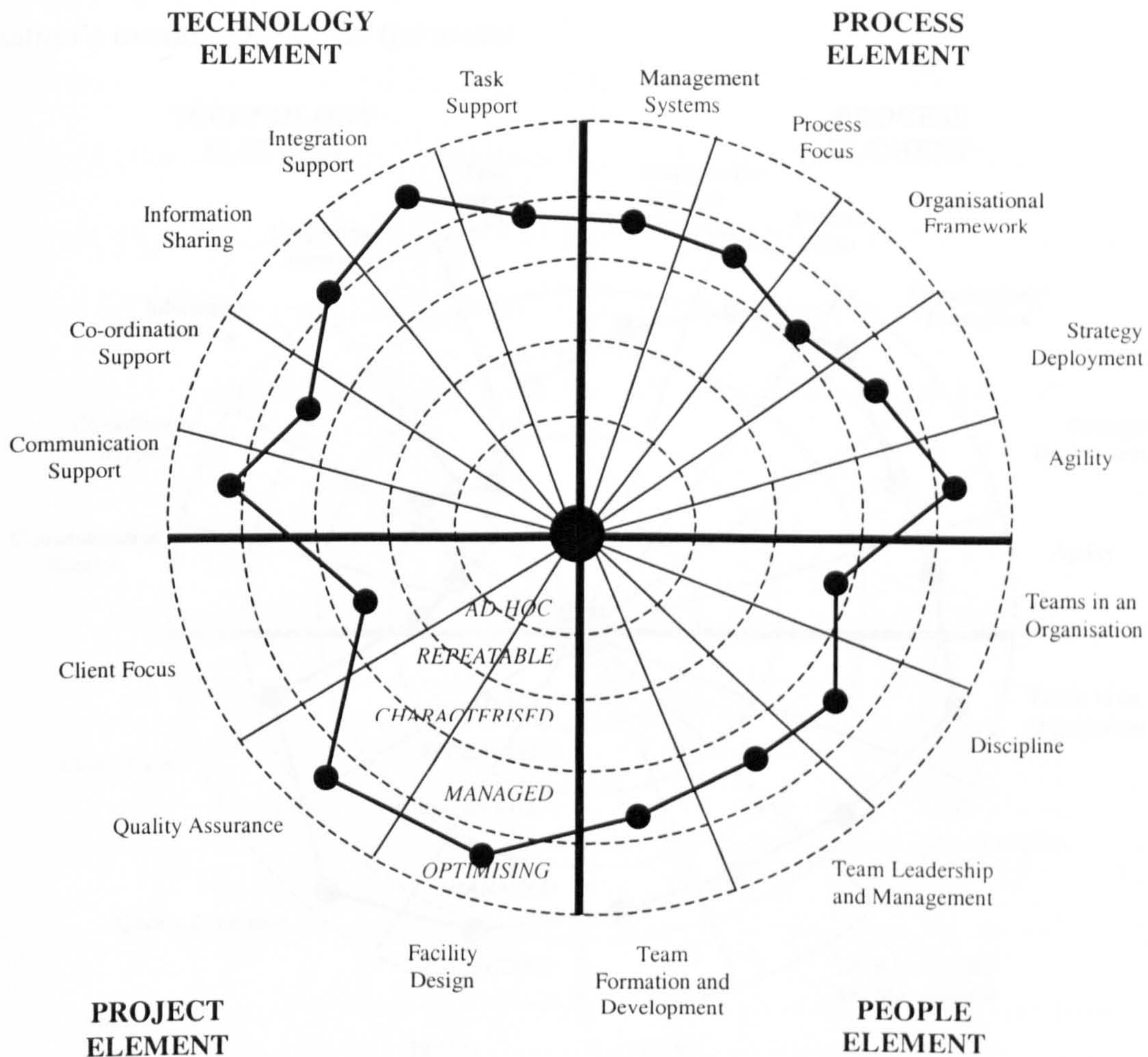


Figure 6.9: CE Readiness of Organisation G



**Case Study 4: Organisation H**

Organisation H is a medium-sized design consultancy firm, involved in building and design consultancy, with 800 employees and around £39m annual turnover. The organisation considers the People Element as the most important and the Technology Element the least important. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.10. The results do not clearly define a single level for Organisation H because critical factors within the Process, People and Project Elements are either at the ‘Managed level’ or ‘Optimising level’, but critical factors within the Technology Element are either at the ‘Characterised level’ or ‘Repeatable level’, which makes it quite difficult to comment on the Organisation’s overall position on the model.

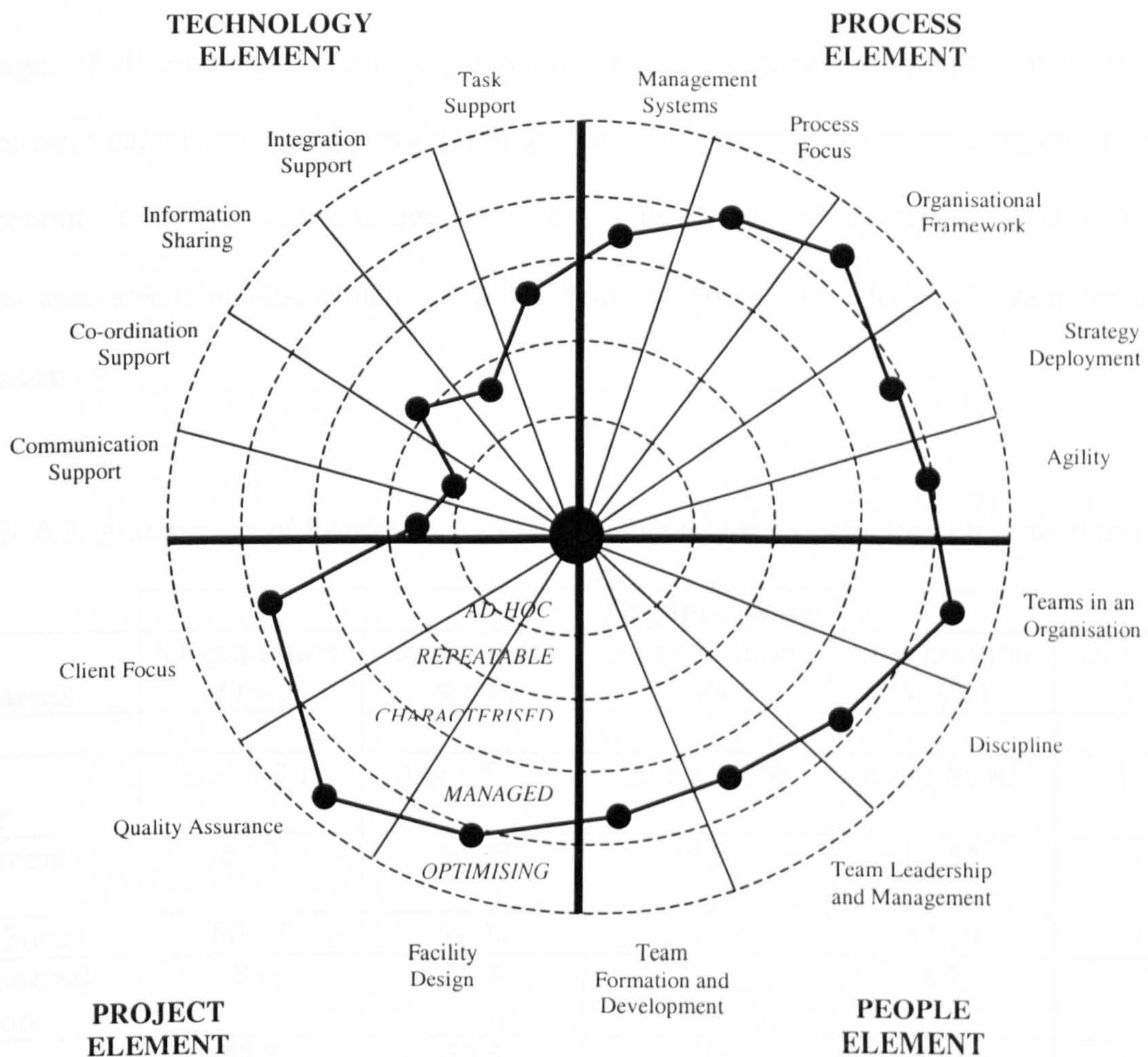


Figure 6.10: CE Readiness of Organisation H

However, it can be concluded that Organisation H is not ready to adopt CE and the Element that needs the most attention, is the Technology Element.

### *6.3.3 Contracting Organisations*

This section presents the results of the case studies, which were carried out within contracting organisations. Five contracting organisations were selected randomly for the case studies and would be referred to as Organisations J, K, L, M and N in this section. A summary of the assessment results is also compiled in tabular form and presented in Table 6.3, which shows percentages of all Elements for each organisation. The percentages for each factor within the elements were calculated after assessing the questionnaire responses for each organisation. A brief account of all five case studies is presented in the following sub-sections with the readiness assessment results, which are plotted on the BEACON Model diagram for each organisation.

*Table 6.3: A Summary of Readiness Assessment Results for Contracting Organisations*

<b>Elements</b>	<b>Organisations</b>				
	<b>Organisation J (%)</b>	<b>Organisation K (%)</b>	<b>Organisation L (%)</b>	<b>Organisation M (%)</b>	<b>Organisation N (%)</b>
<i>Process Element</i>	<i>Avg.: 82.19</i>	<i>Avg.: 58.23</i>	<i>Avg.: 72.46</i>	<i>Avg.: 86.85</i>	<i>Avg.: 70</i>
Management Systems	82.7	69.23	76.92	86.54	71.15
Process Focus	80.77	51.92	65.38	82.69	71.15
Organisational Framework	85	67.5	70	95	72.5
Strategy Deployment	82.5	57.5	80	87.5	65
Agility	80	45	70	82.5	70

<b>People Element</b>	<i>Avg.: 78.34</i>	<i>Avg.: 65.94</i>	<i>Avg.: 88.08</i>	<i>Avg.: 93.44</i>	<i>Avg.: 68.3</i>
Team Formation and Development	80	57.5	95	92.5	57.5
Team Leadership and Management	78.13	78.13	84.38	87.5	81.25
Discipline	84.38	71.88	93.75	100	78.13
Teams in an Organisation	70.83	56.25	79.17	93.75	56.25
<b>Project Element</b>	<i>Avg.: 76.57</i>	<i>Avg.: 54.14</i>	<i>Avg.: 86.11</i>	<i>Avg.: 95.19</i>	<i>Avg.: 71</i>
Client Focus	77.27	36.36	75	97.73	59.1
Quality Assurance	71.88	84.38	100	90.63	84.4
Facility Design	80.56	41.67	83.33	97.22	69.44
<b>Technology Element</b>	<i>Avg.: 74.11</i>	<i>Avg.: 54.06</i>	<i>Avg.: 79.67</i>	<i>Avg.: 71.29</i>	<i>Avg.: 58.67</i>
Communication Support	70	70	70	62.5	50
Co-ordination Support	69.44	41.67	72.22	63.89	66.67
Information Sharing	77.27	54.55	97.73	75	45.45
Integration Support	75	65.63	71.88	78.13	56.25
Task Support	78.85	38.46	86.54	76.92	75

### **Case Study 1: Organisation J**

Organisation J is a large contracting company with over 14,000 employees and over £1,800m annual turnover. The respondents commented in the questionnaire that the People Element is the most important and the Technology Element the least important element from the organisation's point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.11. This shows that Organisation J is at the 'Managed level' except for some of the critical factors, which indicates the 'Optimising level' for the organisation. This concludes that Organisation J is ready to adopt CE and may already have adopted a CE approach in some of the critical factors within the Elements. The areas which need attention are Communication Support, and Co-ordination Support within the Technology

Element, Quality Assurance within the Project Element, and Teams in an Organisation within the People Element.

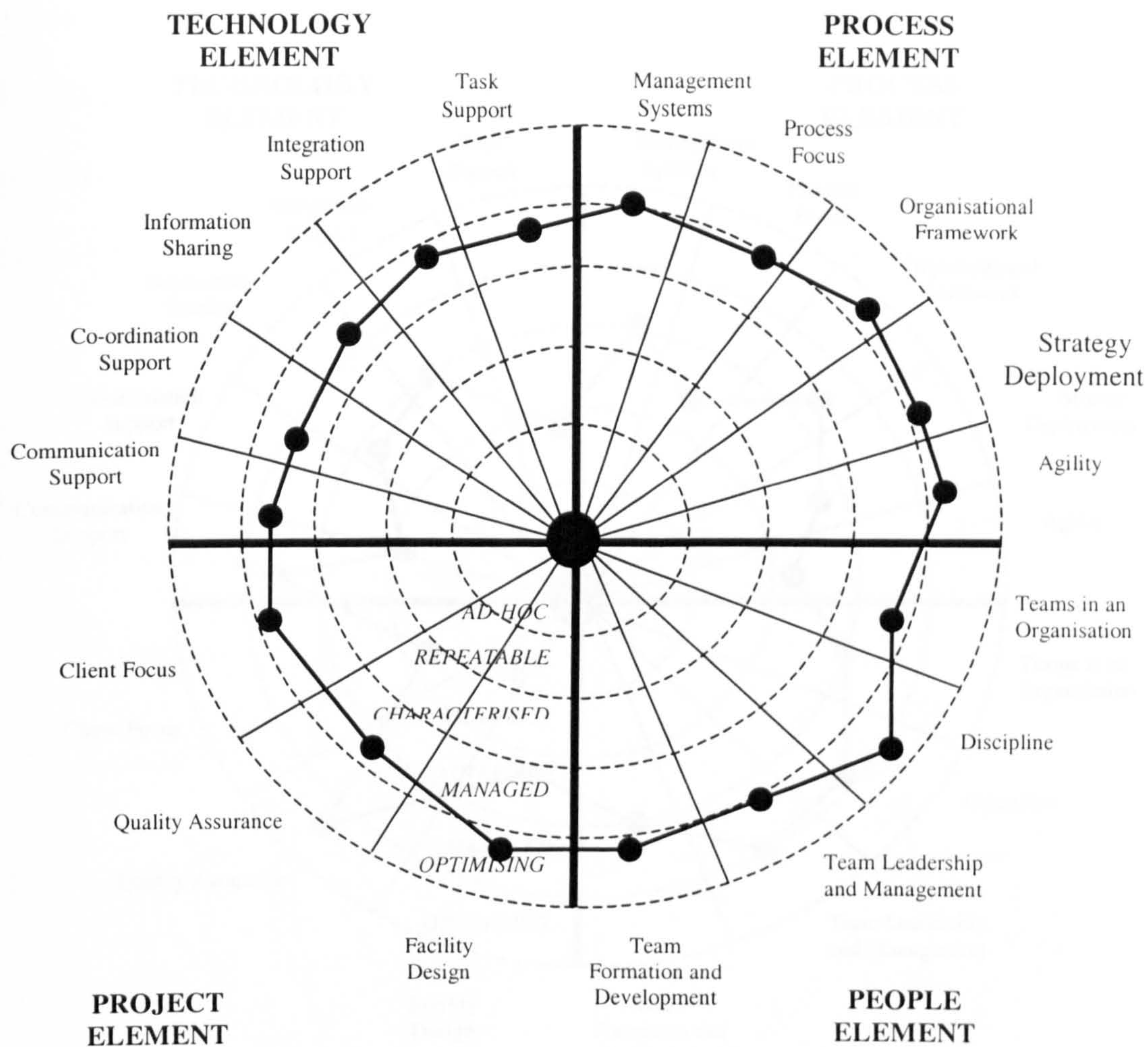


Figure 6.11: CE Readiness of Organisation J

### Case Study 2: Organisation K

Organisation K is a medium-sized contracting company with over 5,000 employees and over £450m annual turnover. Responses to the questionnaire indicate that the People Element is the most important and the Process Element the least important element from the organisation's point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.12. The results show that Organisation K is in the 'Characterised level' except for some of the critical factors, which are in the 'Managed level'. This shows that Organisation K

is not ready to adopt CE and requires improvements in almost all critical factors within the elements.

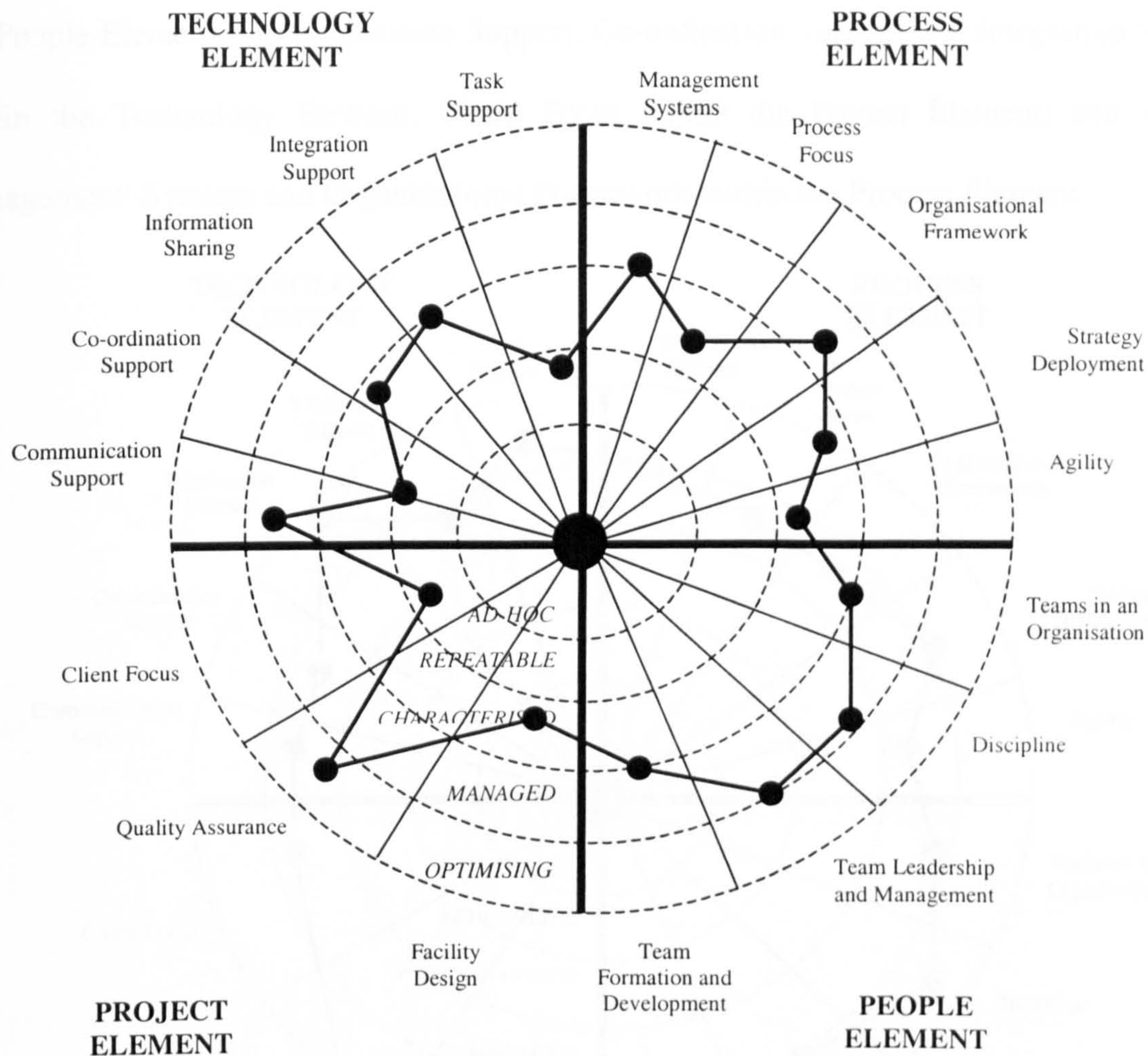


Figure 6.12: CE Readiness of Organisation K

### Case Study 3: Organisation L

Organisation L is a large design-and-build contracting organisation with over 20,000 employees and with over £5b annual group turnover. From the organisation's point of view, the People Element is the most important and the Technology Element the least important element. The readiness assessment results are plotted on the BEACON Model diagram shown in Figure 6.13. The assessment result shows that some critical factors are at the 'Optimising

level' while the rest are at the Managed level. This demonstrates that Organisation L is also ready to adopt CE and may have already adopted CE in some of the critical factors within the Elements. The areas which need minor improvements are Teams in an Organisation within the People Element; Communication Support, Co-ordination Support and Integration Support within the Technology Element; Client Focus within the Project Element; and Agility, Management Systems and Organisational Framework within the Process Element.

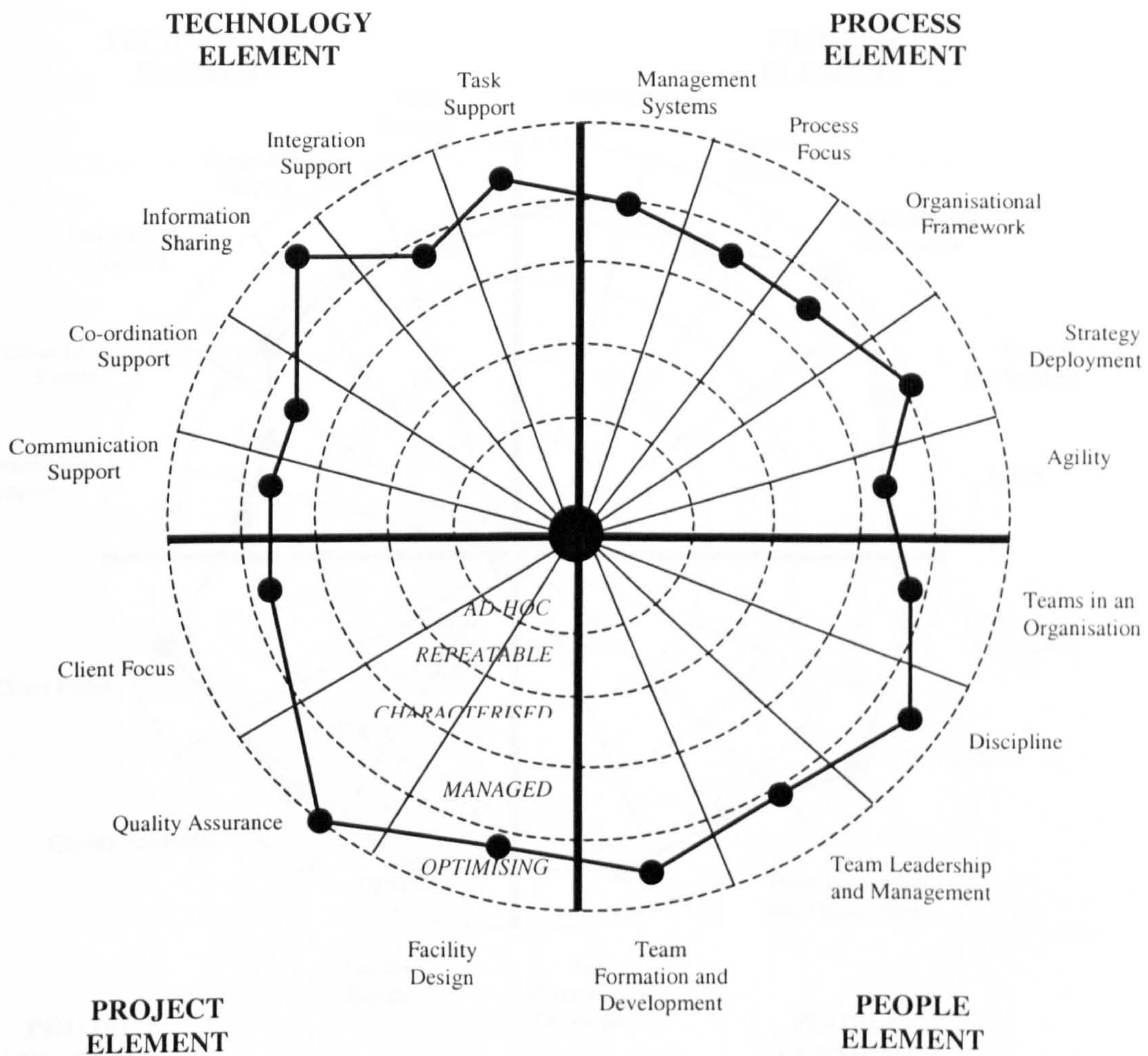


Figure 6.13: CE Readiness of Organisation L

**Case Study 4: Organisation M**

Organisation M is a medium-sized contracting company with 1,800 employees and with around £450m annual turnover. The organisation considers the Process Element of the

BEACON Model the most important and the Project Element the least important. Figure 6.14 shows the assessment result. It can be seen that Organisation M is generally at the 'Optimising level' except for the Technology Element, which indicates the 'Managed level' for the organisation. This concludes that Organisation M is ready to adopt CE and may have already adopted some aspects of CE in most of the critical factors within the elements. The Technology Element needs some minor attention.

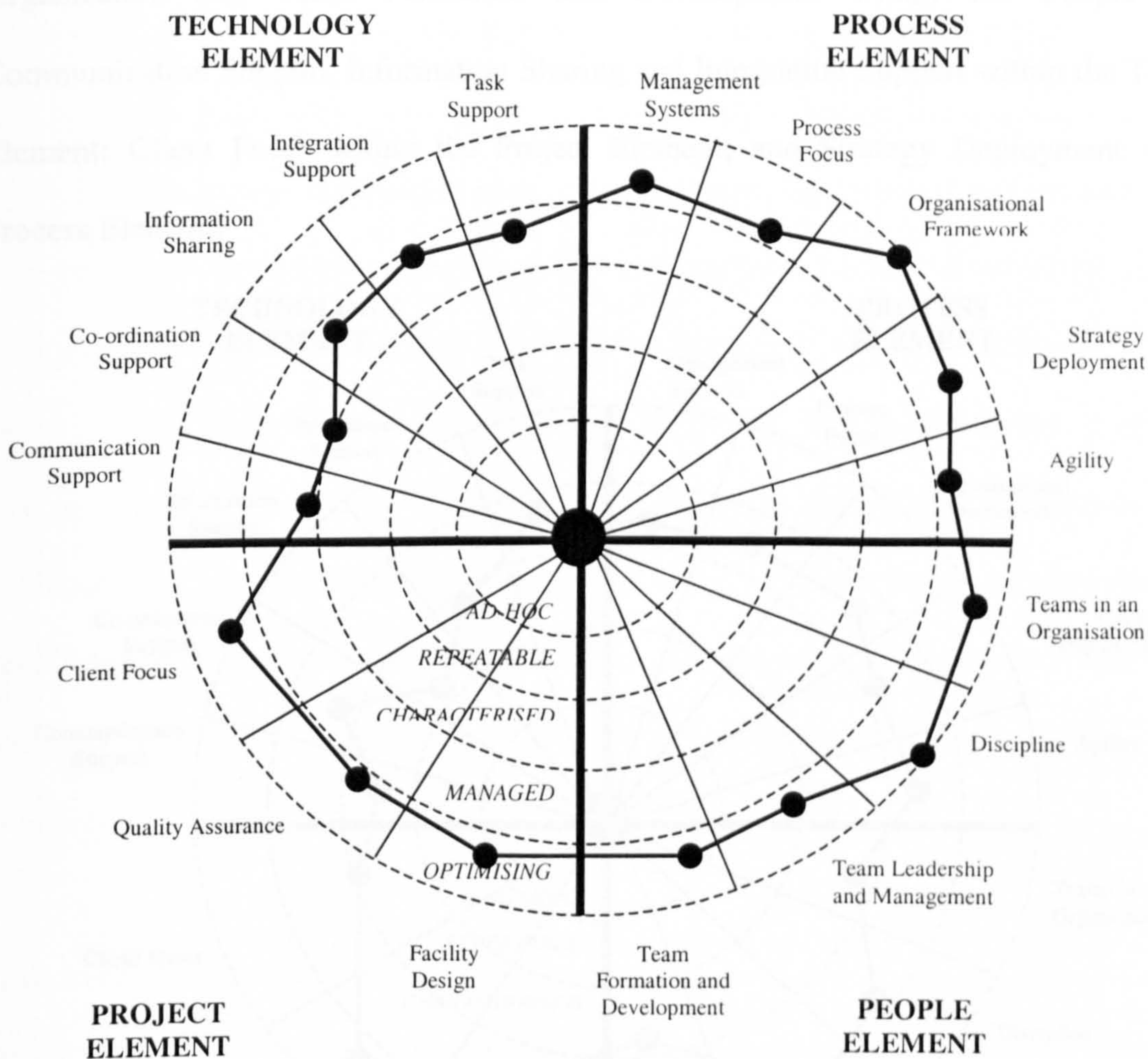


Figure 6.14: CE Readiness of Organisation M

### Case Study 5: Organisation N

Organisation N is a medium-sized design and build contracting organisation with over 2,000 employees and an annual turnover of £15-20m. The People Element is the most important and

the Technology Element the least important element from the organisation's point of view. The readiness assessment result is plotted on the BEACON Model diagram shown in Figure 6.15. It shows that two critical factors are at the 'Optimising level' while the rest are at the 'Managed level' with some of them are at the 'Characterised level'. This concludes that Organisation N is not ready to adopt CE and needs improvements in some of the critical factors within the elements. The areas, which need improvements, are Teams in an Organisation and Team Formation and Development within the People Element; Communication Support, Information Sharing and Integration Support within the Technology Element; Client Focus within the Project Element; and Strategy Deployment within the Process Element.

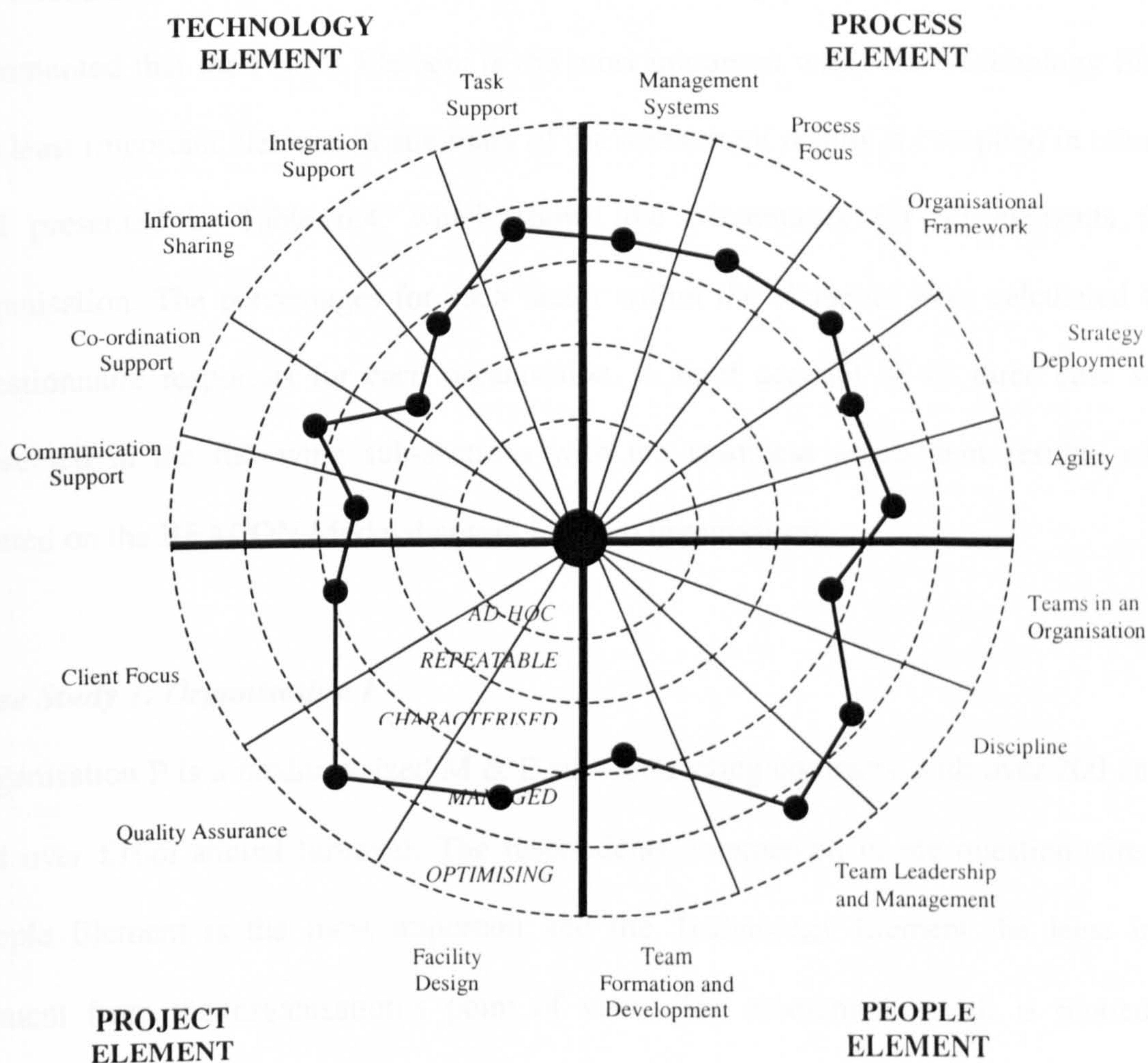


Figure 6.15: CE Readiness of Organisation N



### *6.3.4 Sub-Contracting Organisations*

This section focuses on the results of the case studies, which were carried out within sub-contracting organisations. Twelve sub-contracting organisations, ranging from small-sized to large, were sent the BEACON questionnaire. 25% of them responded and are referred to as Organisations P, Q, and R in this section. The assessment of sub-contracting organisations was important because they do most of the construction work on construction sites, and have multi-disciplinary and multi-skill teams for this purpose. Therefore, it was necessary to assess their readiness for collaborative and concurrent working practice. Most of the respondents commented that the People Element is the most important while the Technology Element is the least important element. A summary of the assessment results is compiled in tabular form and presented in Table 6.4, which shows the percentages for all elements for each organisation. The percentages for each factor within the elements were calculated from the questionnaire responses for each organisation. A brief account of all three case studies is presented in the following sub-sections with the readiness assessment results, which are plotted on the BEACON Model diagram for each organisation.

#### *Case Study 1: Organisation P*

Organisation P is a medium-sized M & E sub-contracting company with over 200 employees and over £16m annual turnover. The respondents commented in the questionnaire that the People Element is the most important and the Technology Element the least important element from the organisation's point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 6.16. This shows that Organisation P is mainly at the 'Managed level' except for some of the critical factors, which are at the 'Characterised

level'. This shows that Organisation P is not fully ready to adopt CE. The areas, which need attention, are Teams in an Organisation within the People Element; Task Support, Co-ordination Support, and Information Sharing within the Technology Element; and Strategy Deployment and Agility within the Process Element.

Table 6.4: A Summary of Readiness Assessment Results for Sub-Contracting Organisations

Elements	Organisations		
	Organisation P (%)	Organisation Q (%)	Organisation R (%)
<b>Process Element</b>	<b>Avg. 63.69</b>	<b>Avg. 93.96</b>	<b>Avg. 82.46</b>
Management Systems	73.08	96.15	80.77
Process Focus	65.38	96.15	86.54
Organisational Framework	70	87.5	87.5
Strategy Deployment	52.5	95	82.5
Agility	57.5	95	75
<b>People Element</b>	<b>Avg. 66.93</b>	<b>Avg. 91.2</b>	<b>Avg. 85.26</b>
Team Formation and Development	75	95	90
Team Leadership and Management	68.75	90.63	93.75
Discipline	71.88	100	90.63
Teams in an Organisation	52.08	79.17	66.67
<b>Project Element</b>	<b>Avg. 65.83</b>	<b>Avg. 98.32</b>	<b>Avg. 92.40</b>
Client Focus	61.38	97.73	88.64
Quality Assurance	75	100	96.88
Facility Design	61.11	97.22	91.67
<b>Technology Element</b>	<b>Avg. 50.71</b>	<b>Avg. 91.55</b>	<b>Avg. 86.08</b>
Communication Support	75	90	85
Co-ordination Support	27.78	97.22	91.67
Information Sharing	40.91	81.82	72.73
Integration Support	65.63	90.63	90.63
Task Support	44.23	98.08	90.38

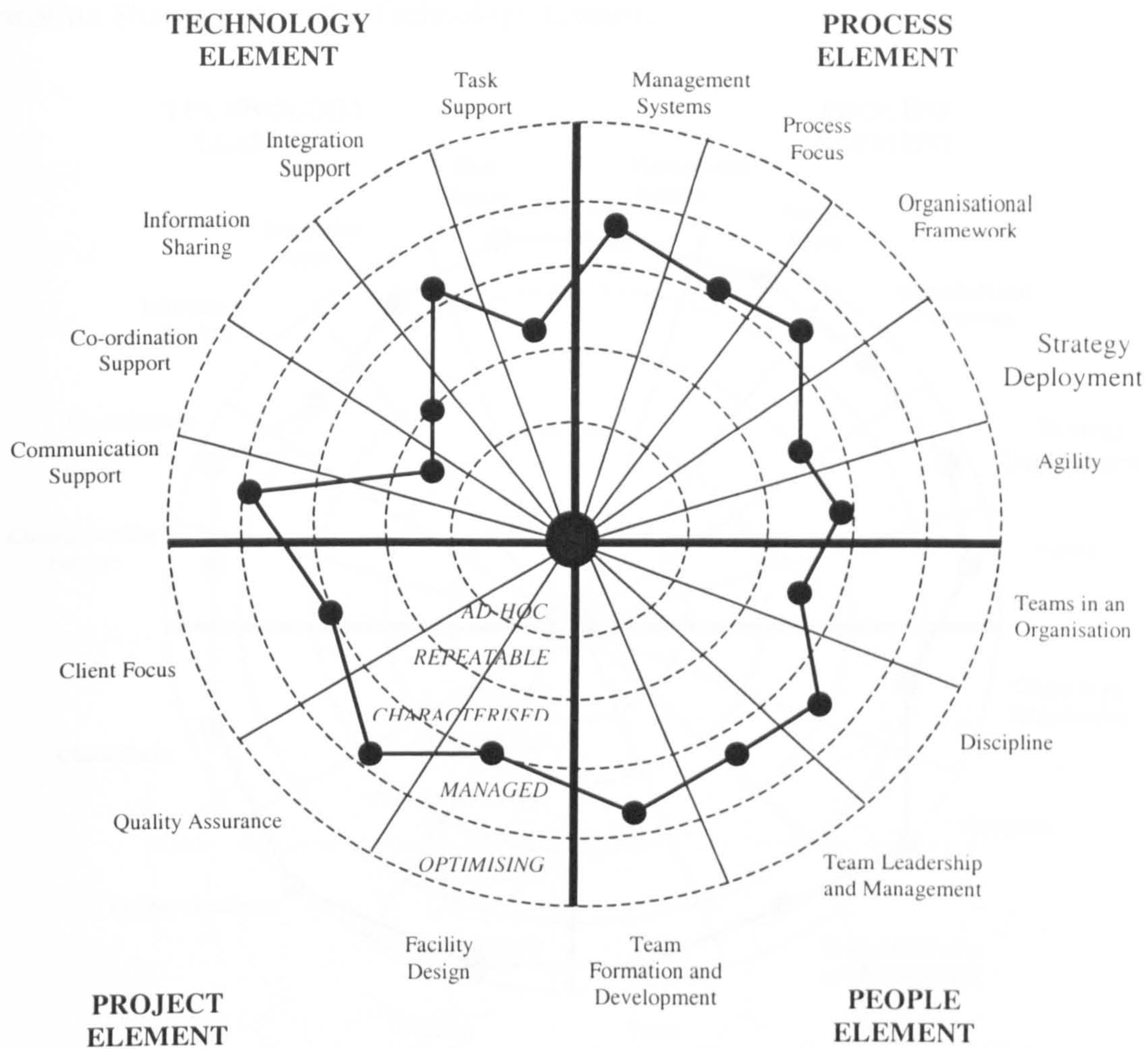


Figure 6.16: CE Readiness of Organisation P

### Case Study 2: Organisation Q

Organisation Q is also a medium-sized M & E sub-contracting company with over 450 employees and over £60m annual turnover. The organisation considers the Process Element the most important and the Technology Element the least important element. The assessment results are plotted on the BEACON Model diagram shown in Figure 6.17. The results show that the Organisation Q is generally at the 'Optimising level' except for a few critical factors, which are at the 'Managed level'. This suggests that Organisation Q is ready to adopt CE and may already have adopted CE in almost all of the critical factors within all elements. Areas

requiring minor improvements are Teams in an Organisation within the People Element, and Information Sharing within the Technology Element.

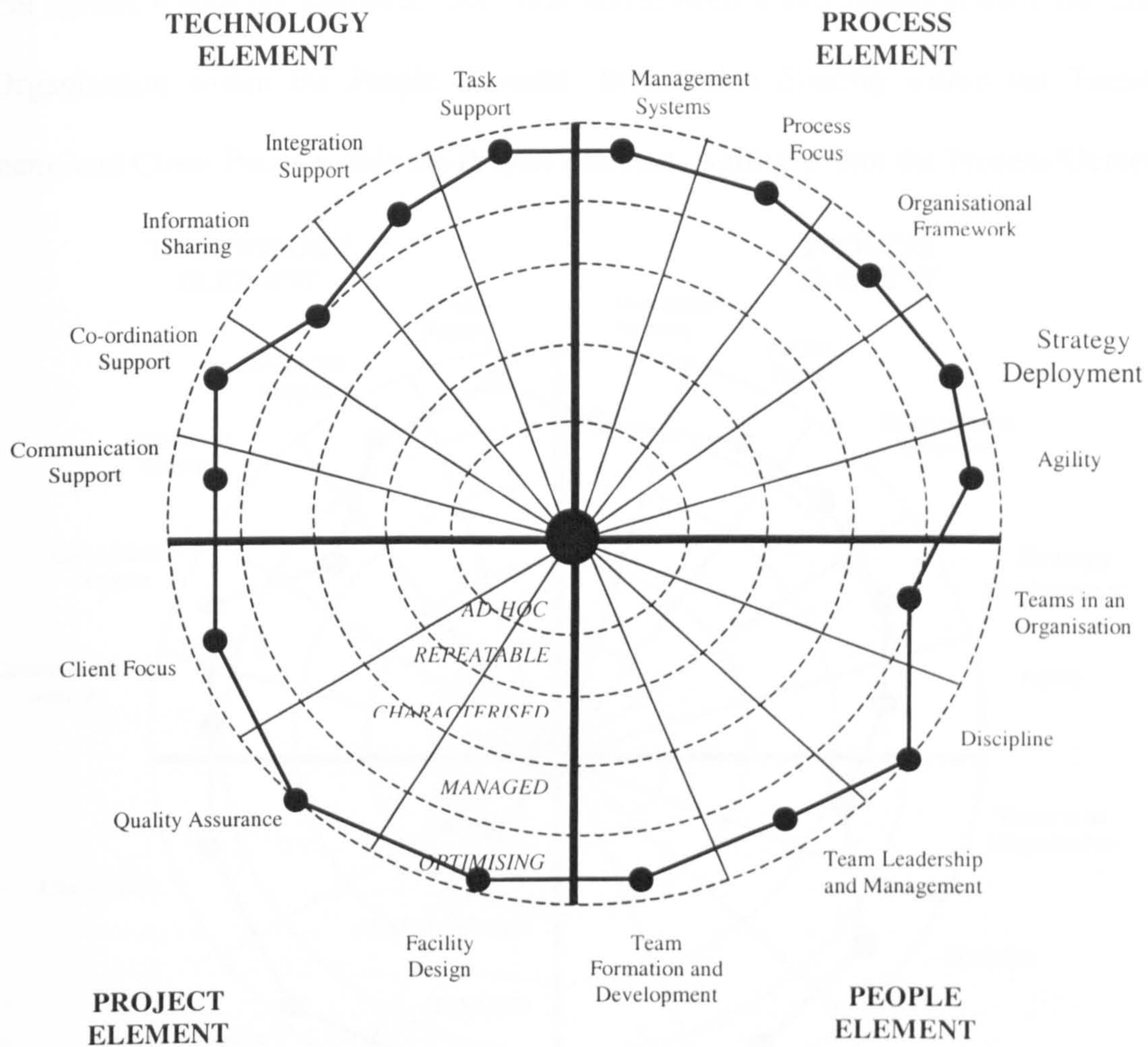


Figure 6.17: CE Readiness of Organisation Q

**Case Study 3: Organisation R**

Organisation R is a large contracting organisation with sub-contracting activities within housing, and property development and construction with over 3,500 employees and over £1.4b annual turnover. According to the information in the questionnaire, the People Element is considered the most important and the Technology Element the least important element from the organisation’s point of view. The readiness assessment results are plotted on the BEACON Model diagram shown in Figure 6.18. It shows that some critical factors are at the

‘Optimising level’ while the rest are at the ‘Managed level’. This concludes that the Organisation R is also ready to adopt CE and may have already adopted CE in some of the critical factors within the elements. The areas which need minor improvements are Teams in an Organisation within the People Element; Information Sharing within the Technology Element; and Client Focus within the Project Element, Agility within the Process Element.

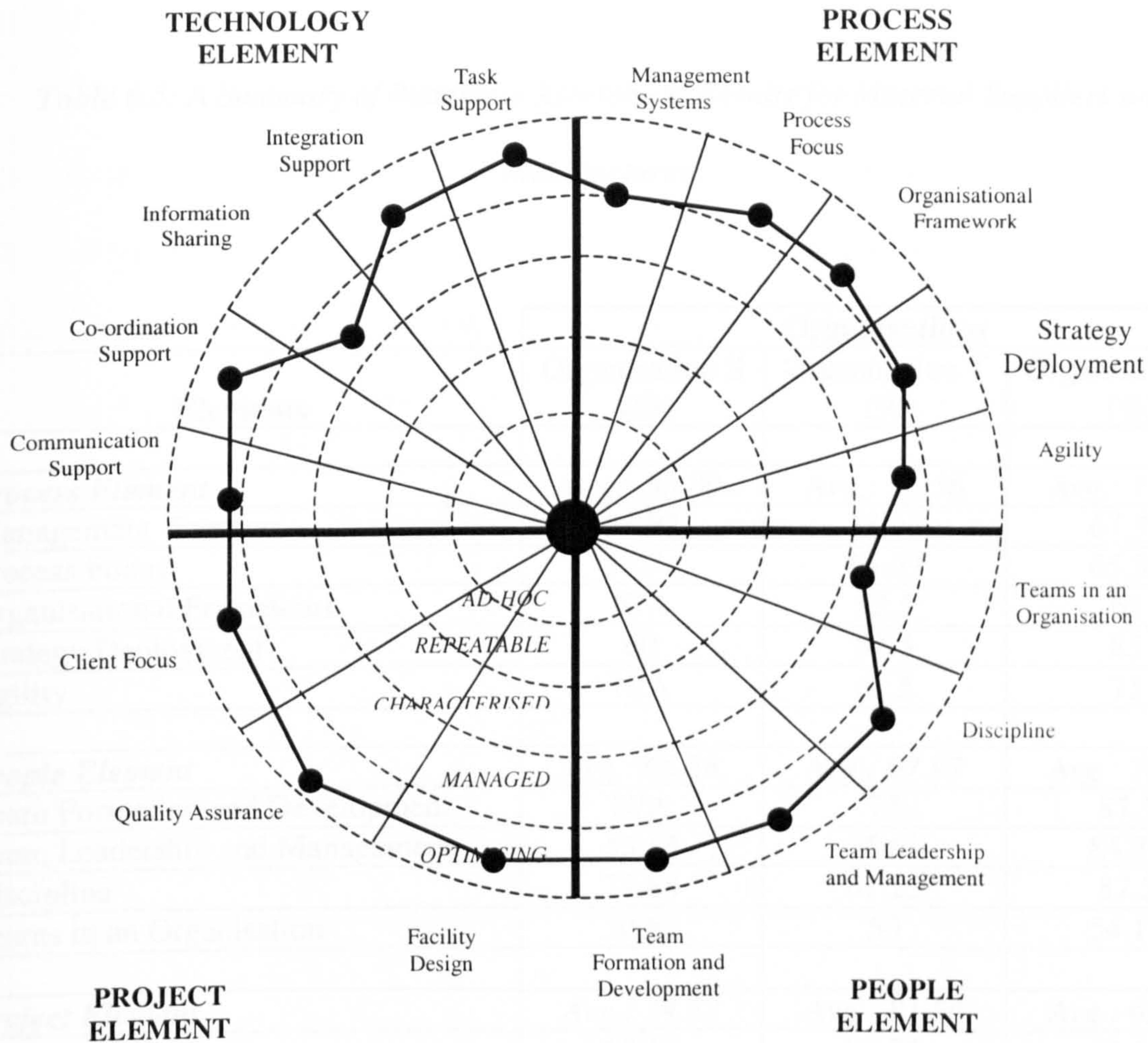


Figure 6.18: CE Readiness of Organisation R

### 6.3.5 Material Suppliers and Manufacturers

This section presents the results of the case studies, which were carried out within material suppliers and manufacturers’ organisations. Three organisations were selected randomly for

the case studies and are referred to as Organisations S, T, and U in this section. A summary of the assessment results is compiled in tabular form and presented in Table 6.5, which shows percentages of all Elements for each organisation. A brief account of all three case studies is presented in the following sub-sections with the readiness assessment results, which are plotted on the BEACON Model diagram for each organisation.

*Table 6.5: A Summary of Readiness Assessment Results for Material Suppliers and Manufacturers*

Elements	Organisations		
	Organisation S (%)	Organisation T (%)	Organisation U (%)
<b>Process Element</b>	<i>Avg.: 58.89</i>	<i>Avg.: 56.56</i>	<i>Avg.: 71.55</i>
Management Systems	58.93	38.64	67.37
Process Focus	57.74	66.67	65.38
Organisational Framework	N/A	52.5	65
Strategy Deployment	60	57.5	85
Agility	N/A	67.5	75
<b>People Element</b>	<i>Avg.: 65.28</i>	<i>Avg.: 67.97</i>	<i>Avg.: 78.39</i>
Team Formation and Development	N/A	75	87.5
Team Leadership and Management	53.13	65.63	84.38
Discipline	71.88	81.25	87.5
Teams in an Organisation	70.83	50	54.17
<b>Project Element</b>	<i>Avg.: 74.72</i>	<i>Avg.: 81.56</i>	<i>Avg.: 63.34</i>
Client Focus	68.18	86.36	63.64
Quality Assurance	81.25	75	62.5
Facility Design	N/A	83.33	63.89
<b>Technology Element</b>	<i>Avg.: 57.44</i>	<i>Avg.: 67.76</i>	<i>Avg.: 1.75</i>
Communication Support	75	90	2.5
Co-ordination Support	52.78	52.77	0
Information Sharing	54.85	77.27	0
Integration Support	46.88	68.75	6.25
Task Support	57.69	50	0

**Case Study 1: Organisation S**

Organisation S is a medium-sized supplier with around 220 employees and over £170m annual turnover. The respondents commented in the questionnaire that the People Element is the most important and the Project Element the least important element from the organisation’s point of view. The assessment results are plotted on the BEACON Model diagram shown in Figure 6.19. This shows that for the Process Element, Organisation S is somewhere between the ‘Characterised’ and ‘Managed levels’. For the People Element, the organisation is at the ‘Managed level’ except for the Team Leadership and Management factor, which is at the ‘Characterised level’. For the Project Element, one factor is at the ‘Optimising level’ while the other one is at the ‘Managed level’.

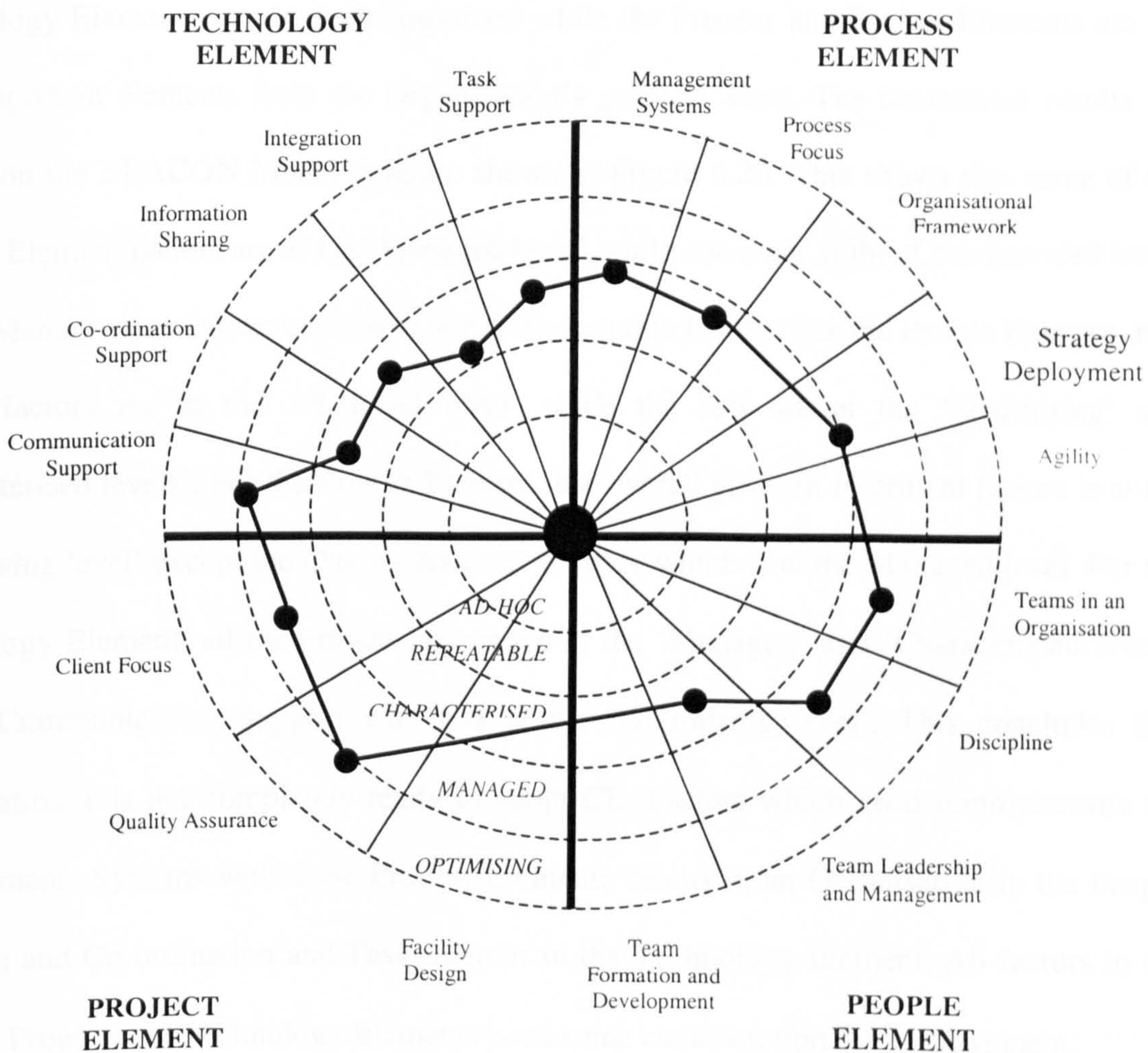


Figure 6.19: CE Readiness of Organisation S

For the Technology Element, all the factors are at the 'Characterised level' except for Communication Support, which is at the 'Managed level'. This concludes that Organisation S is not fully ready to adopt CE and some of the critical factors within all elements need attention. These include Team Leadership and Management in the People Element, and all factors within the Process and Technology Elements (except Communication Support).

### ***Case Study 2: Organisation T***

Organisation T is a small supplier and manufacturer with around 25 employees and with over £3.5m annual turnover. Responses to the questionnaire indicate that the People and Technology Elements are the most important while the Process and Project Elements are the least important elements from the Organisation's point of view. The assessment results are plotted on the BEACON Model diagram shown in Figure 6.20. This shows that some of the Process Element factors are at the 'Managed level' while some are at the 'Characterised level' except Management Systems which is at the 'Repeatable level'. For the People Element, two of the factors are at the 'Managed level' while the rest are at the 'Optimising' and 'Characterised levels'. For the Project Element, the overall position of critical factors is at the 'Optimising level' except the Quality Assurance factor which is at the Managed level. For the Technology Element, all the critical factors are at the 'Managed' and 'Characterised levels' except Communication Support which is at the 'Optimising level'. This concludes that Organisation T is not completely ready to adopt CE. Factors which need improvements are Management Systems within the Process Element; Teams in an Organisation in the People Element; and Co-ordination and Task Support in the Technology Element. All factors in the Process, Project, and Technology Elements need some consideration for improvement.



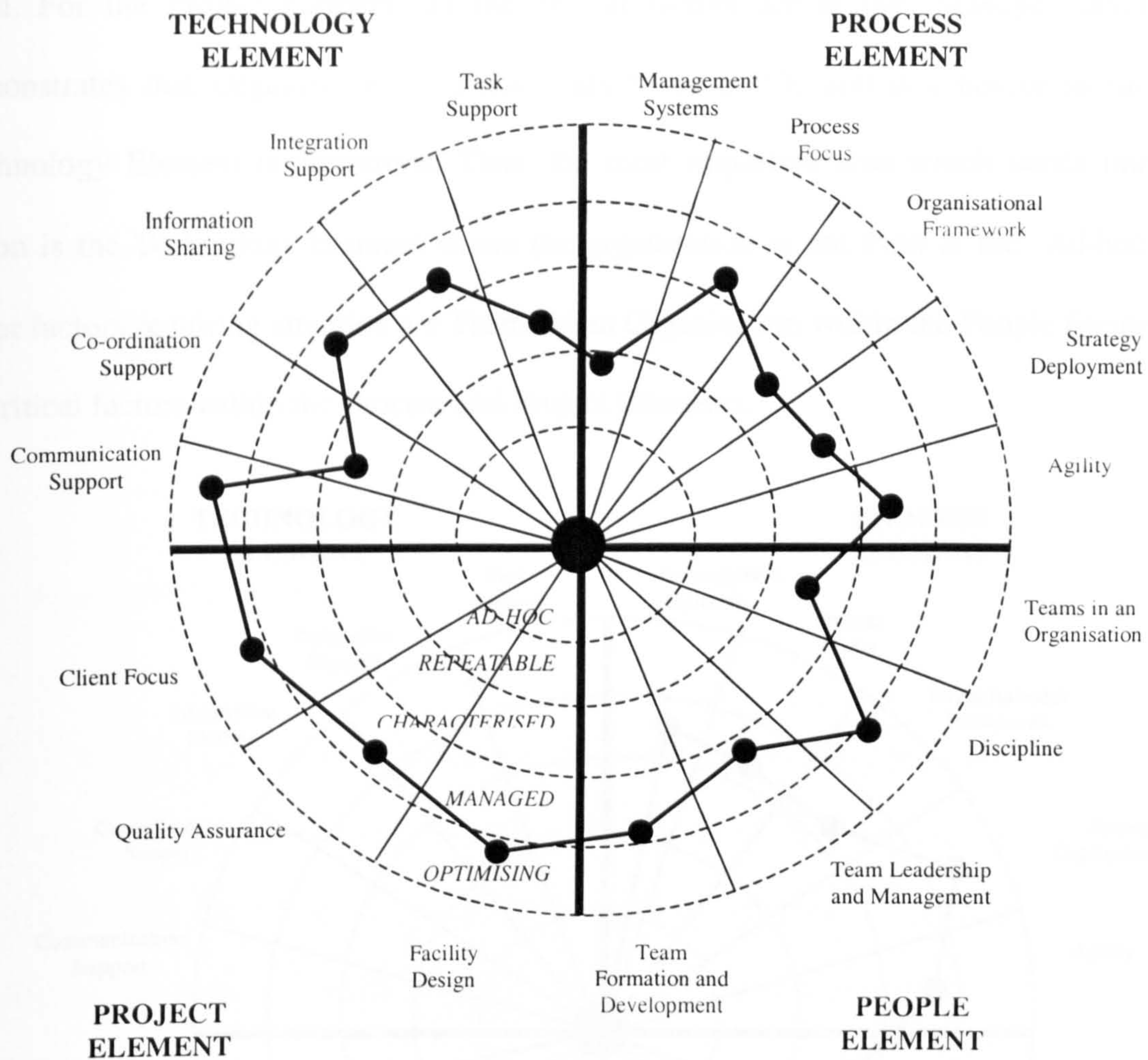


Figure 6.20: CE Readiness of Organisation T

### Case Study 3: Organisation U

Organisation U is a very small supplier with four employees and over £500k annual turnover. The organisation considers the People Element the most important and the Technology Element the least important element. The readiness assessment results are plotted on the BEACON Model diagram shown in Figure 6.21. It shows that Organisation U is very poor in the Technology Element – the percentages are so small that they are negligible on the diagram. For the Process Element, all critical factors are at the 'Managed level' except Strategy Deployment, which is at the 'Optimising level'. All the factors in the People Element are at the 'Optimising level' except Teams in an Organisation, which is at the Characterised

level. For the Project Element, all the critical factors are at the 'Managed level'. This demonstrates that Organisation U is not ready to adopt CE and is a novice as far as the Technology Element is concerned. Thus, the most important area which needs immediate action is the Technology Element where the organisation is not even at the 'Ad-hoc level'. Other factors requiring attention are Teams in an Organisation within the People Element; and all critical factors within the Process and Project Elements.

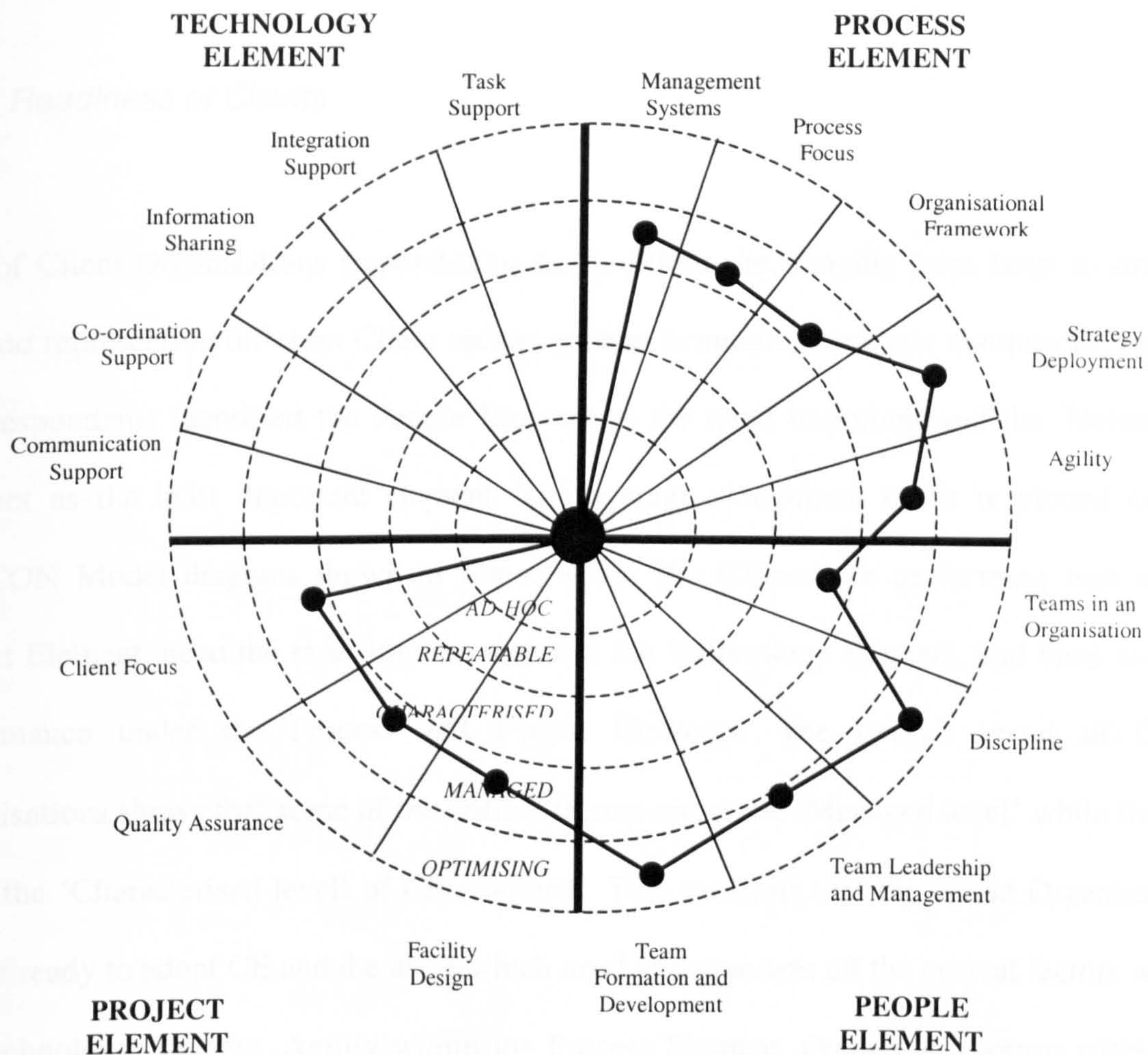


Figure 6.21: CE Readiness of Organisation U

## **6.4 Comparative Studies of the Results of Construction Supply Chain**

This section presents the average CE readiness assessment results for all the categories and include a comparative analysis. The average assessment results for each sector of the construction supply chain is compiled and presented in Table 6.6, with the composite BEACON Model diagram for each sector presented below.

### **6.4.1 Readiness of Clients**

33% of Client Organisations responded to the questionnaire, ranging from large to small in size and representing different Client sectors such as hospitals, academic institutions, etc. All four respondents identified the People Element as the most important and the Technology Element as the least important element. The average assessment result is plotted on the BEACON Model diagram shown in Figure 6.22. The Clients are performing best in the Project Element, need the most improvements in the Technology Element, and have average performance under the Process and People Elements. The overall result of Client Organisations shows that some of the critical factors are at the 'Managed level' while the rest are at the 'Characterised level' of CE readiness. This confirms that the Client Organisations are not ready to adopt CE and the areas which need attention are: all the critical factors within the Technology Element, Agility within the Process Element, Quality Assurance within the Project Element, and Teams in an Organisation within the People Element.

Table 6.6: Summary of the Readiness Assessment Results

Elements	Construction Supply Chain Participants				
	Clients (%)	Consultants (%)	Contractors (%)	Sub-contractors (%)	Material Suppliers & Manufacturers (%)
<b>Process Element</b>	<b>Avg.: 68.13</b>	<b>Avg.: 71.69</b>	<b>Avg.: 73.94</b>	<b>Avg.: 80.04</b>	<b>Avg.: 63.15</b>
Management Systems	66.13	71.64	77.31	83.33	54.98
Process Focus	70.36	66.83	70.38	82.69	63.26
Organisational Framework	68.33	68.75	78.00	81.67	58.75
Strategy Deployment	73.75	77.50	74.50	76.67	67.50
Agility	62.08	73.75	69.50	75.83	71.25
<b>People Element</b>	<b>Avg.: 68.56</b>	<b>Avg.: 75.39</b>	<b>Avg.: 78.81</b>	<b>Avg.: 81.13</b>	<b>Avg.: 71.88</b>
Team Formation and Development	70.42	71.88	76.50	86.67	81.25
Team Leadership and Management	81.25	75.78	81.88	84.38	67.71
Discipline	66.67	80.47	85.63	87.50	80.21
Teams in an Organisation	55.91	73.44	71.25	65.97	58.33
<b>Project Element</b>	<b>Avg.: 76.92</b>	<b>Avg.: 73.59</b>	<b>Avg.: 76.60</b>	<b>Avg.: 85.51</b>	<b>Avg.: 73.08</b>
Client Focus	80.89	65.91	69.09	82.58	72.73
Quality Assurance	69.79	81.26	86.26	90.63	72.92
Facility Design	80.09	73.61	74.44	83.33	73.61
<b>Technology Element</b>	<b>Avg.: 55.01</b>	<b>Avg.: 52.81</b>	<b>Avg.: 67.56</b>	<b>Avg.: 76.11</b>	<b>Avg.: 42.32</b>
Communication Support	57.92	60.63	64.50	83.33	55.83
Co-ordination Support	49.30	39.58	62.78	72.22	35.18
Information Sharing	55.69	50.00	70.00	65.15	44.04
Integration Support	55.76	48.44	69.38	82.30	40.63
Task Support	56.40	65.39	71.15	77.56	35.90

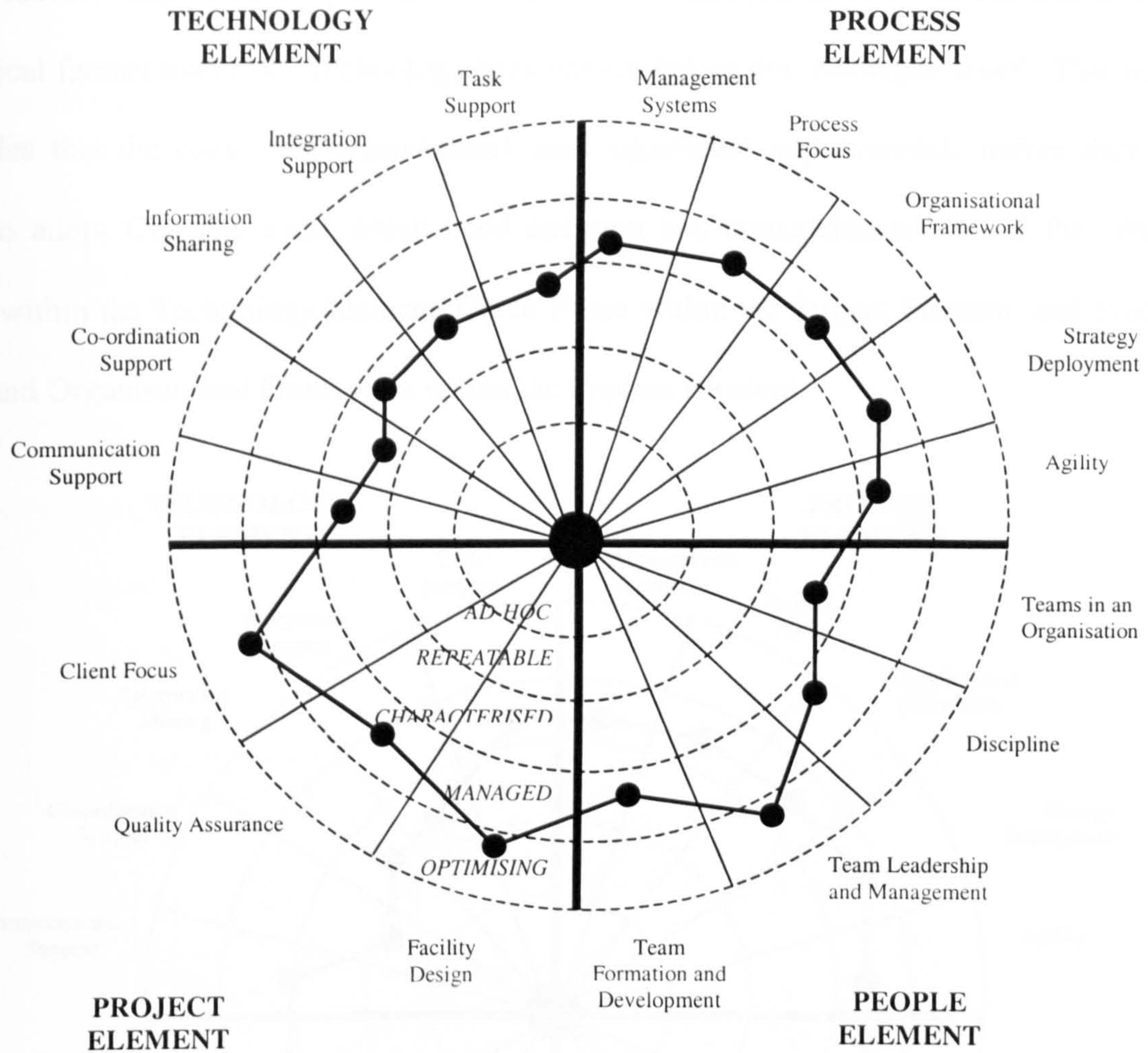


Figure 6.22: CE Readiness of Clients

#### 6.4.2 Readiness of Consultants

The response rate for consultants was the same as for Clients, that is four consulting Organisations out of twelve architecture and engineering consultants responded to the questionnaire. Most of the respondents stated that the People Element is the most important and the Technology Element the least important element for them. The average readiness assessment result for consultants is shown in Figure 6.23. This shows that consulting organisations are at the 'Managed level' except for some of the critical factors, which indicate the 'Characterised level' of the CE readiness for the organisations. Most of the critical factors

in the Process, People, and Project Elements are at the 'Managed level', whereas almost all of the critical factors under the Technology Element are below the 'Managed level'. This result concludes that the consulting organisations need significant improvements before they are ready to adopt CE. The areas which need attention and consideration are: all the critical factors within the Technology Element, Client Focus within the Project Element, and Process Focus and Organisational Framework within the Process Element.

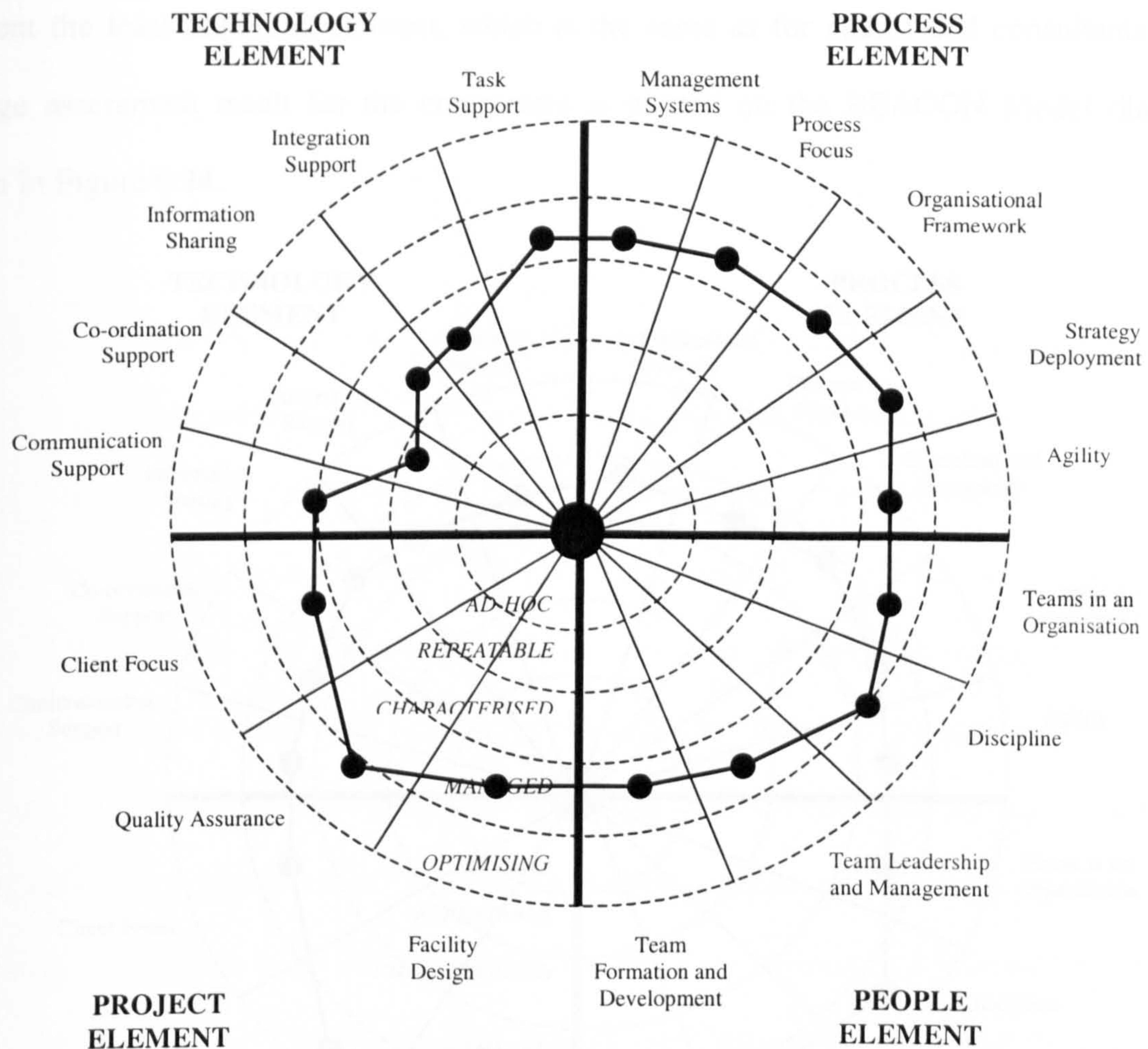


Figure 6.23: CE Readiness of Consultants

### 6.4.3 Readiness of Contractors

Five contracting organisations, ranging from medium-sized to large, responded to the questionnaire; this represents around 40% of the total number of questionnaires sent. Most of the respondents considered the People Element the most important and the Technology Element the least important element, which is the same as for clients and consultants. The average assessment result for the contractors is plotted on the BEACON Model diagram shown in Figure 6.24.

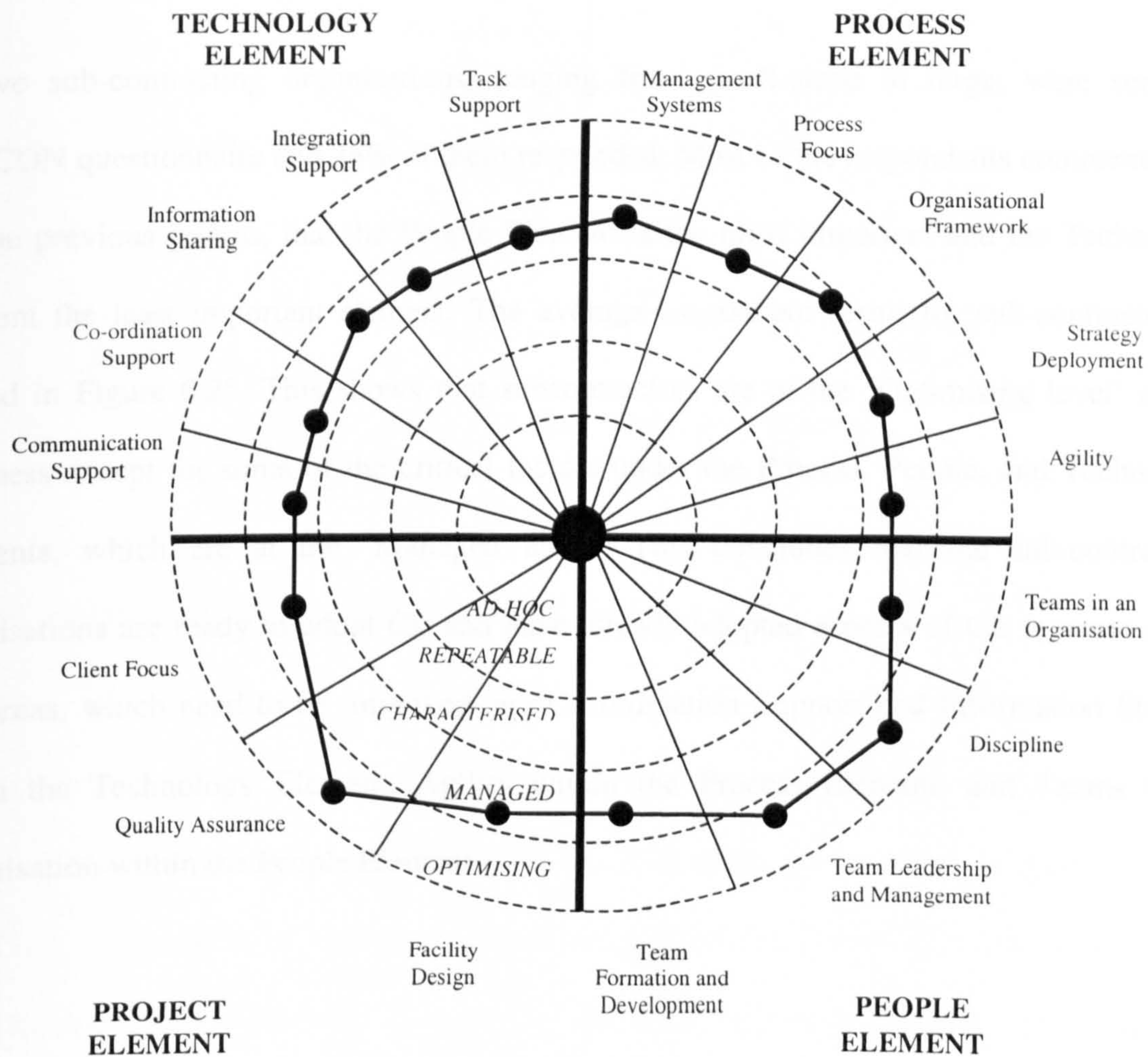


Figure 6.24: CE Readiness of Contractors

All the critical factors under the Process and Technology Elements are at the 'Managed level' of CE readiness whereas for the Project and People Elements, some of the critical factors are even at the 'Optimising level'. This concludes that the contracting organisations are ready to adopt CE and have already adopted aspects of CE in some of the critical factors within the Elements. The areas which need attention are Communication Support, and Co-ordination Support within the Technology Element, Client Focus within the Project Element, Agility within the Process Element, and Teams in an Organisation within the People Element.

#### *6.4.4 Readiness of Sub-contractors*

Twelve sub-contracting organisations, ranging from small-sized to large, were sent the BEACON questionnaire and 25% of them responded. Most of the respondents commented, as did the previous groups, that the People Element is the most important and the Technology Element the least important element. The average assessment result for sub-contractors is plotted in Figure 6.25. This shows that subcontractors are at the 'Optimising level' of CE readiness except for some of the critical factors under the Process, People, and Technology Elements, which are at the 'Managed level'. This concludes that the sub-contracting organisations are ready to adopt CE and have already adopted aspects of CE in some areas. The areas, which need to be improved, are Co-ordination Support and Information Sharing within the Technology Element, Agility within the Process Element, and Teams in an Organisation within the People Element.



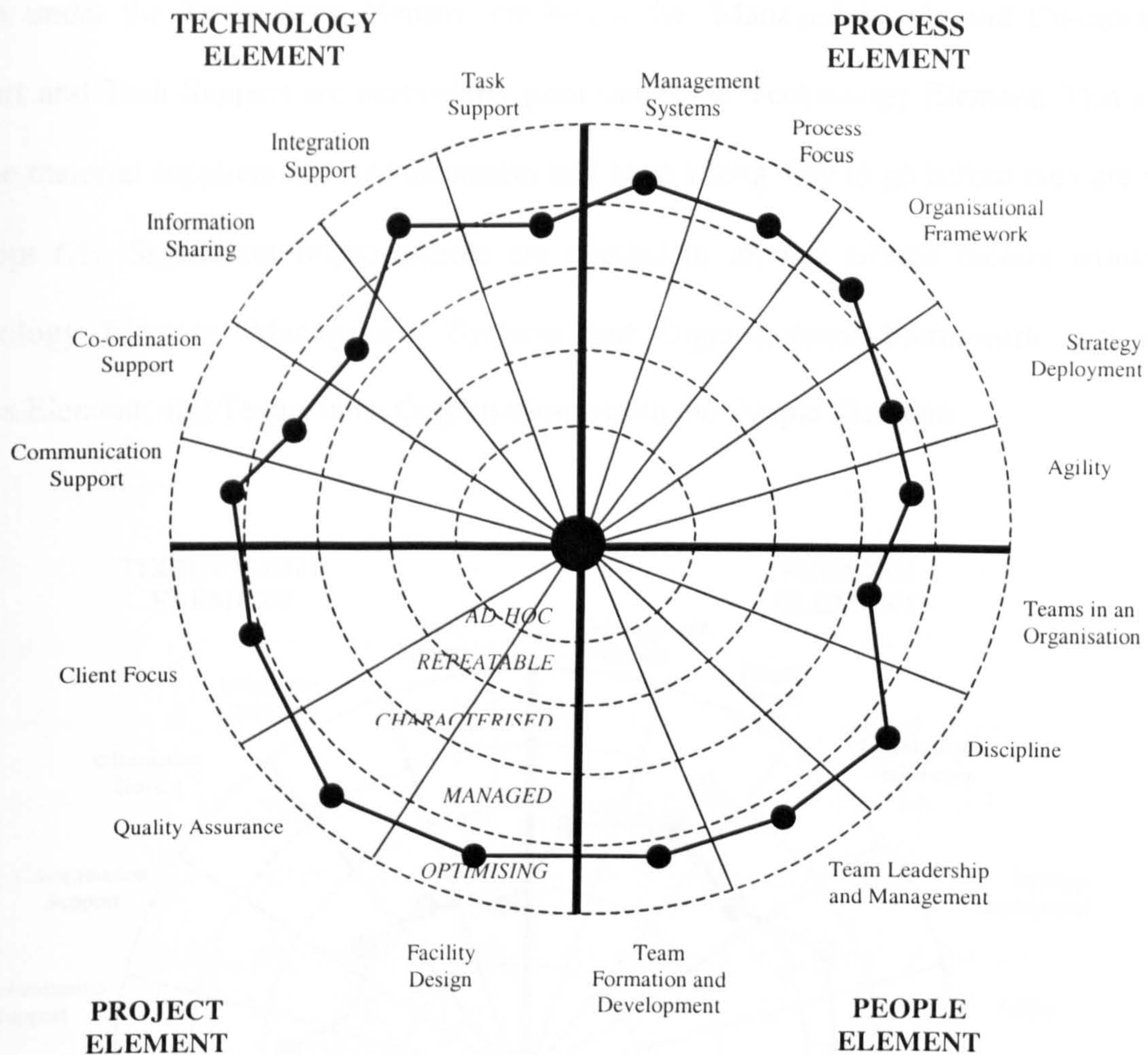


Figure 6.25: CE Readiness of Sub-contractors

#### 6.4.5 Readiness of Material Suppliers and Manufacturers

Three material suppliers and manufacturing organisations, ranging from medium to small-sized, responded to the questionnaire, which was 25% of the total number of questionnaires sent. Here again, most of the organisations considered the People Element as the most important and the Technology Element as the least important element. The readiness assessment results of the material suppliers and manufacturers are plotted on the BEACON Model diagram shown in Figure 6.26. It could be seen that almost all the critical factors under

the Process, People, and Project Elements are at the 'Managed level' whereas all the critical factors under the Technology Element are below the 'Managed level'; and Co-ordination Support and Task Support are particularly poor under the Technology Element. This shows that the material suppliers and manufacturers still have a long way to go before they are ready to adopt CE. Significant improvements are needed in all the critical factors within the Technology Element, Management Systems and Organisational Framework within the Process Element, and Teams in an Organisation within the People Element.

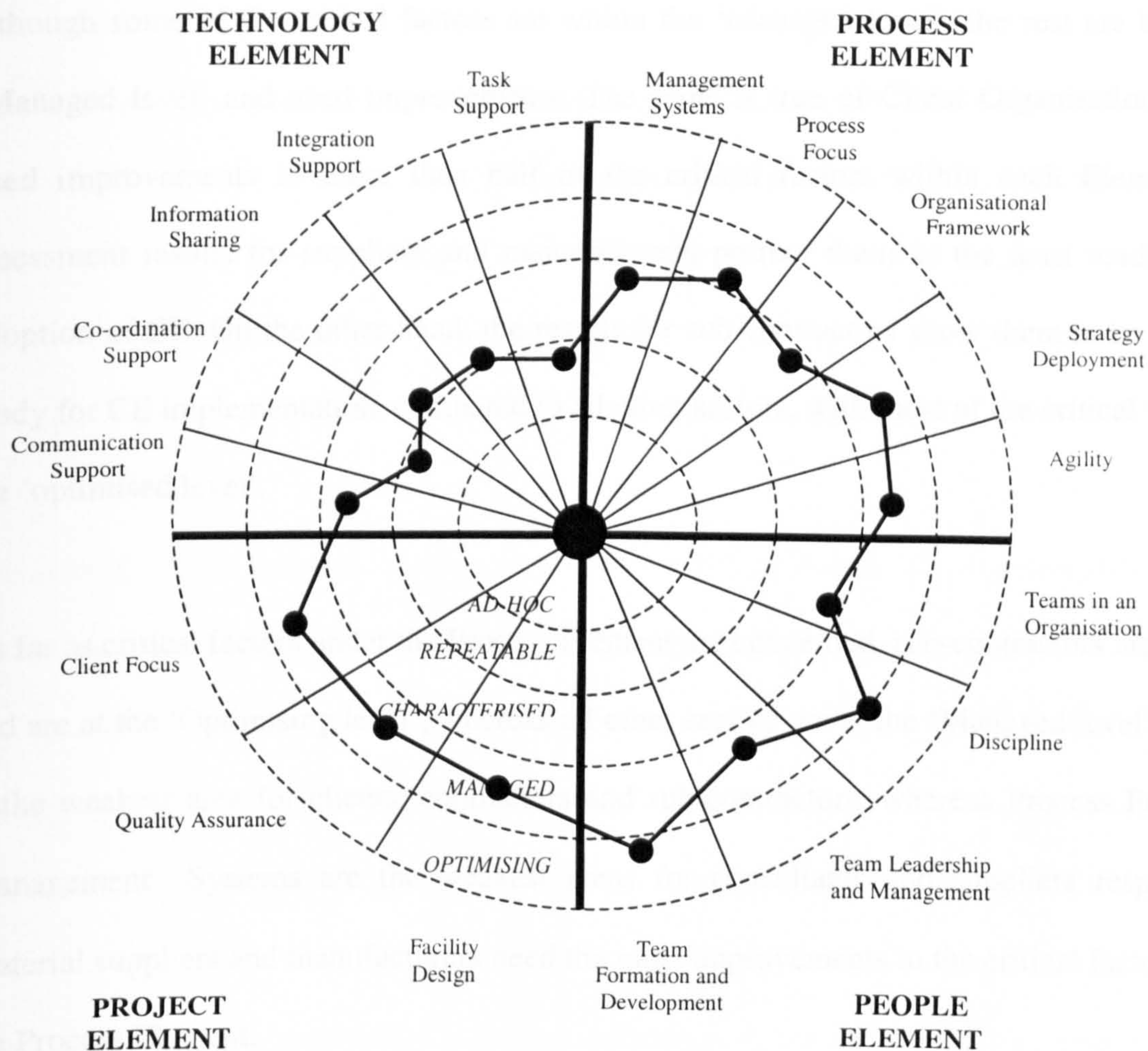


Figure 6.26: CE Readiness of Material Suppliers and Manufacturers

## **6.5 Discussion**

After analysing and comparing the results and background information from the readiness assessment case studies of the participating organisations within each category, it could be seen that the People Element is considered the most important Element and the Technology Element the least important element. Most of the contracting organisations are almost ready for concurrent engineering (CE) and most of the critical factors in each Elements are within the 'Managed level' of CE readiness. However, consulting organisations are not ready, although some of the critical factors are within the 'Managed level', the rest are below the 'Managed level' and need improvements. The same is true of Client Organisations, which need improvements in more than half of the critical factors within each Element. The assessment results for suppliers and manufacturers portray them as the least ready for the adoption of CE. On the other hand, the results for sub-contractors show them to be the most ready for CE implementation, compared to all other sectors, with most of the critical factors at the 'optimised level'.

As far as critical factors under the Process Element are concerned, sub-contractors are the best and are at the 'Optimising level', whereas all other sectors are at the 'Managed level'. Agility is the weakest area for clients, contractors and sub-contractors, whereas Process Focus and Management Systems are the weakest areas for consultants and suppliers respectively. Material suppliers and manufacturers need the most improvements to the critical factors under the Process Element.

Client Organisations need the most improvements within areas covered under the People Element whereas sub-contracting Organisations are performing well except for one factor,

that is Teams in an Organisation, which is also the weakest critical factor in all the other sectors. Overall, for the People Element, sub-contractors are at the 'Optimising level' and the rest are at the 'Managed level' of CE readiness.

All sectors seem to be performing well in the areas under the Project Element, specially sub-contractors, who are at the 'Optimising level' of the CE readiness while the rest are at the 'Managed level'. Client Focus seems to be the weakest area for all sectors except for the Client Organisations, which need the most improvements within the Quality Assurance factor.

Critical areas covered under the Technology Element need the most attention and consideration by all sectors, although contractors and sub-contractors are marginally better than others, being at the 'Managed level'. Clients, consultants, and suppliers are all at the 'Characterised level' and need considerable improvements in all areas under this Element. The weakest critical factor for all sectors is Co-ordination Support.

The overall results from the companies surveyed indicate that the construction industry, as a whole, still needs improvements in most of the critical areas in order to adopt CE effectively. Sectors, which seem to be ready for CE adoption are those, which are Client-Focused, have greater focus on monitoring and controlling of their project development process, and are continually improving their development processes and operations.

From the results of the readiness assessment undertaken, it appears that contractors and sub-contractors are in the best position to implement CE within their organisations. However, all sectors of the construction supply chain can use the BEACON Model not only for the purpose

of carrying out CE readiness assessment, but also as a tool for measuring their performance in the four critical elements – People, Process, Project, and Technology.

The methodology for carrying out the sample case studies was defined clearly in this chapter. This included the selection of sample companies, the assessment, and development of the results in the form of the BEACON Model diagram. This methodology can be now adopted for any further assessments within the construction industry using the BEACON Software, but the one thing, which would be different, is the selection of the companies. This is because the assessment could be carried out in the companies either considering CE implementation or willing to use the model as a performance measure.

On the basis of the feedback and comments supplied by the respondents, amendments and improvements could be made to the BEACON Model Questionnaire. For example, there is scope to reduce the overall length by eliminating closely related questions. Also, the system can be improved so that respondents are not required to complete inappropriate questions (e.g. clients need not complete the section on ‘Client Focus’). The BEACON Model Questionnaire is flexible and can readily incorporate these improvements.

The following are some of the limitations of the CE readiness assessment and its results:

- The assessment case studies were carried out within a limited number of companies in each sector of the construction industry. This was because of the difficulty in getting respondents to complete the questionnaire;

- Only one person in each organisation was assigned to fill in the assessment questionnaire because of the length of the questionnaire. However, they were given ample time to collect all the relevant information for their organisations;
- The selection of the companies for the assessment within each category of construction supply chain was random. The reason for the random selection was to get representative results. However, there is scope for a more comprehensive assessment involving a bigger sample of organisations; and
- There was no access to an existing or 'live' project organisation.

## **6.6 Summary**

This chapter has presented the details of the CE readiness assessment. It includes the objectives of the assessment; the assessment methodology adopted; assessment results for each sector of the construction supply chain; and a comparative study of these results. These were then followed by a discussion, which included the limitations of the assessment and its results. The following statements could be concluded on the basis of the assessment carried out as a part of the research project:

- The assessment results show that the People Element and Technology Element are respectively the most and least important elements for most of the organisations in all categories of the construction supply chain;
- Contractors and sub-contractors, in general, are ready to adopt aspects of CE within their organisations whereas clients, consultants, and suppliers & manufacturers are not yet ready to adopt CE;
- The overall results show that the construction industry, as a whole still needs improvements in most of the critical areas in order to adopt CE effectively;

- The industry needs appropriate guidelines for implementation of CE within the industry and also for improvements in the weaker areas identified in the assessment results;
- The BEACON Model can be successfully used as a CE readiness assessment tool for the construction industry;
- The BEACON Model can also be used as a useful tool for self-assessment on the four key Elements: Process, People, Project, and Technology for any organisation (in any sector) not necessarily considering the implementation of CE; and
- The readiness assessment of the construction supply chain, using the model, will enable the development of guidelines for the effective and more appropriate implementation of CE in construction.

The readiness assessment results will now be considered as the basis for the development of CE implementation strategies and considerations, which are presented in the next chapter.

## **Chapter 7: Formulation of Strategies for Concurrent Engineering Implementation**

This chapter discusses strategies and considerations for CE implementation based on the CE readiness assessment results. These strategies and considerations are presented under each of the four elements of the BEACON Model; Process, People, Project, and Technology. At the end of the chapter, the approach to a pilot CE implementation is also presented.

### **7.1 Importance of Strategy Formulation**

A strategy may be defined as a set of rules for guiding decisions in an organisation, which determines and reveals its objectives, purposes, or goals and presents the principal policies and plans for achieving those objectives (Carrillo, 2001). Having a strategy does not bring success to any organisation. If an organisation is competent and efficient, having a strategy would improve and enhance its flexibility and survival in a hostile environment, and encourage increased growth and profitability.

### **7.2 CE Implementation Strategies and Considerations for Construction**

The main objective of developing CE strategies and considerations is to engender improvements within construction organisations before and during CE implementation. Areas that need improvements can be identified from the CE readiness assessment results in the preceding chapter. The strategies and considerations highlighted will also



address other factors which cause changes within any organisation such as survival of the business; the need for a better, more efficient and more effective product/project development process; maintaining and enhancing the technical capability of the organisation; winning new businesses; requirement for increased profits; and responding to the changing business environment (Brooks & Foster, 1997). These strategies and considerations can then:

- Be used as a set of guidelines for pilot CE implementation;
- Act as a set of rules for guiding decisions relating to CE implementation;
- Help senior management in developing long-term CE implementation plans; and
- Help senior management to take CE related decisions, which determine and reveal objectives, purposes and goals, and produce the principal policies and plans for achieving those goals.

The strategies and considerations presented in this chapter are generic and could be used by any sector of the construction supply chain for CE implementation. Areas defined as weak for each sector in the previous chapter, should be given more attention while developing more specific considerations, as appropriate.

It should be noted that aspects covered within the migration paths for each of the critical factors are only examples of the full requirements. The considerations, which follow these migration paths, present the optimising maturity level of an organisation. An illustrative journey from ad-hoc to optimising maturity level for three of the critical factors is presented in Table 7.18.

### *7.2.1 Background*

The formulation of the strategies and considerations for CE implementation is based on the CE principles and success factors presented in Chapter 3, the results of the CE readiness assessment of the industry, and the lessons learned from similar studies carried out in other industry sectors in the form of benefits, and bottlenecks. The areas that are identified as weak from the results are then taken into account for the formulation of strategies and considerations. Strategies and considerations developed for CE implementation within other industry sectors, which could also be adopted for effective CE implementation in construction, are also presented. The following subsections present the generic CE implementation strategies and considerations for each of the four elements of the BEACON Model; Process, People, Project, and Technology. Each element discusses generic CE strategies and considerations under each critical factor, based on the readiness assessment results, for all sectors within the construction supply chain. The structure of the presentation comprises a tabular format followed by a discussion/description for each critical factor under each element. The tables show 'typical' characteristics of companies operating at an Ad-hoc level on the left and those operating at an Optimising level on the right. These summarise the key questions in the BEACON Model Questionnaire. Strategies and considerations for converting an organisation from Ad-hoc to Optimising maturity level are then presented in the following section for each critical factor.

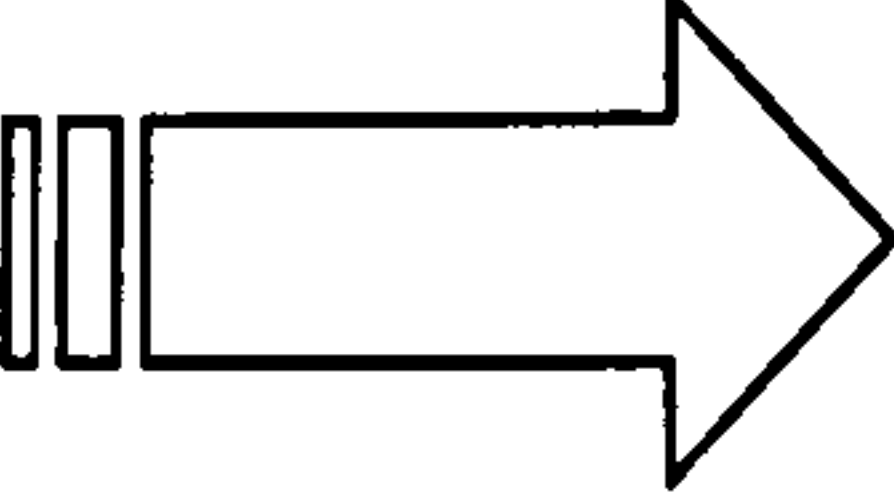
### 7.2.2 Process Element

The strategies and considerations, outlined in this section are for the improvement of the construction project development process and management systems within a construction organisation. These strategies are generic in nature, and applicable to all participants in the construction supply chain, and are outlined under each critical factor of the Process Element.

#### *Management Systems*

The migration path for the organisations moving from ad-hoc maturity level to optimising maturity level is shown in Table 7.1. The table summarises the key factors towards the improvement of management systems within the construction industry.

Table 7.1: Migration Path for Management Systems (Process Element)

<i>Ad-hoc Maturity Level</i>		<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li>❑ Poor project planning and management techniques</li> <li>❑ Non-reliable financial and accounting system</li> </ul>		<ul style="list-style-type: none"> <li>❑ Advanced project planning and management techniques</li> <li>❑ Strict financial and accounting system</li> </ul>

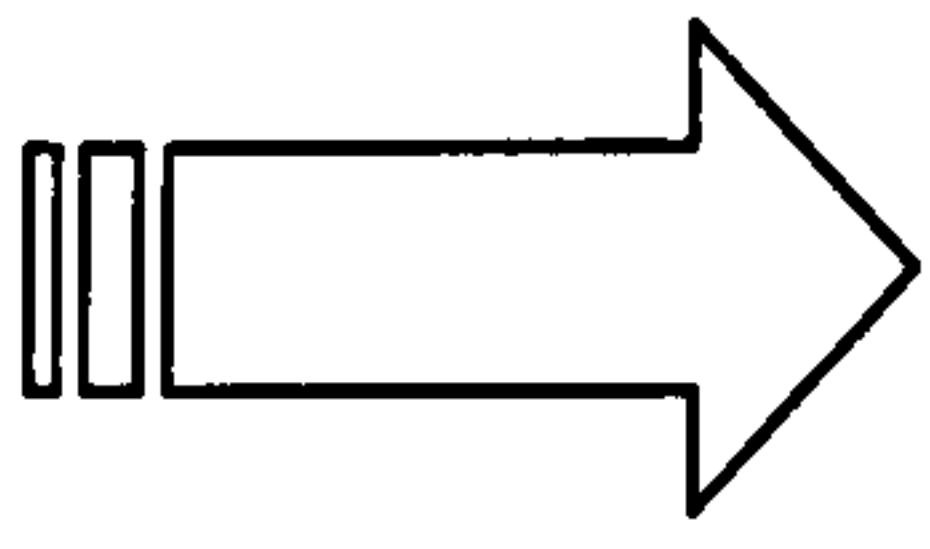
Planning and management of a project should be carried out such that project estimates and schedules are documented, and adequate resources are provided for the planning such as funding, technical expertise, etc. In order to achieve this, construction organisations should manage and monitor the activities and performance of contractors

and sub-contractors working on the project, and take corrective actions when actual results of any activity differ significantly. Another key issue related to the planning and project management is managing risks. Risk management plans should be prepared and a time margin for contingencies should be kept in the project schedules. Senior management of an organisation plays a vital role in improving project planning and management. They should review the project development activities of each project on a periodic basis, and conduct trade off studies to identify the risks associated with new technologies. They should also make sure that a standardised and reliable financial and accounting system is used for all projects.

***Process Focus***

The improvement path for the Process Focus critical factor is described in Table 7.2.

Table 7.2: Migration Path for Process Focus (Process Element)

<i>Ad-hoc Maturity Level</i>	<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li>❑ Non-documented project development process</li> <li>❑ No procedures for process evaluation</li> </ul>	<div style="text-align: center;">  </div> <ul style="list-style-type: none"> <li>❑ Fully documented Project development Process</li> <li>❑ Strict process evaluation and improvements</li> </ul>

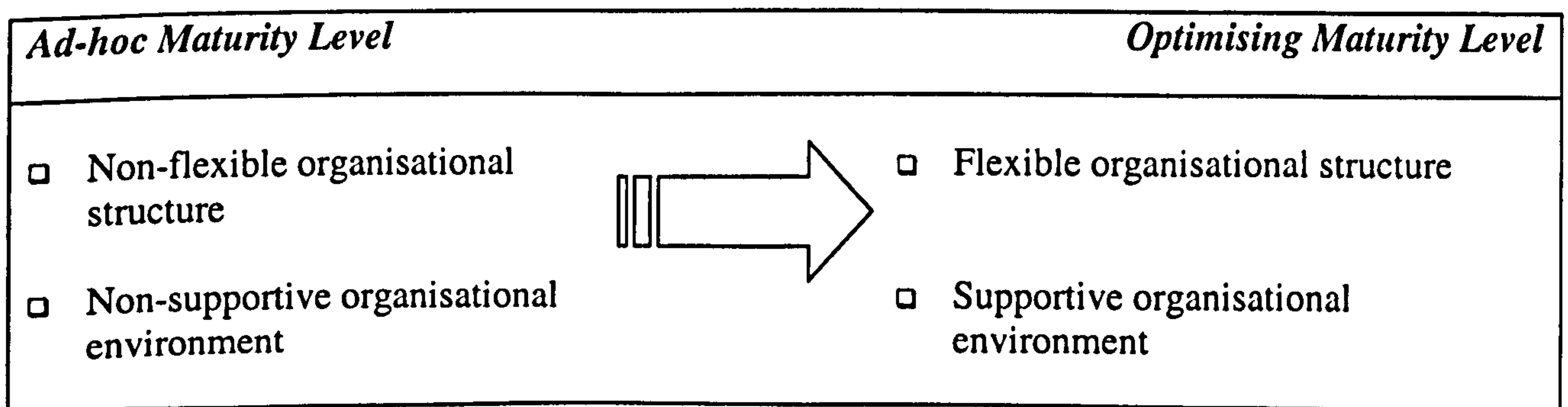
The project development process (PDP) should be documented and all the project participants should have access to these documents. The PDP documents should include the information on decisions made during the PDP and an established and documented project brief. Construction organisations should review their past decisions, experiences,

and knowledge, and make these available to the project participants. They should also evaluate the PDP of current projects periodically, and have a policy to monitor and control continuous improvements in the PDP. For this purpose, the organisations should delegate the task to an individual or a group, who is responsible for focusing on improvements. Another important area for improvement is project plans and activities. These should be developed and scheduled such that most of the processes and sub-processes are carried out as concurrently as possible. The construction organisations should also make sure that processes and activities are flexible enough to accommodate any changes related to the project.

### ***Organisational Framework***

The migration route for organisational framework towards the optimising maturity level is presented in Table 7.3.

Table 7.3: Migration Path for Organisational Framework (Process Element)



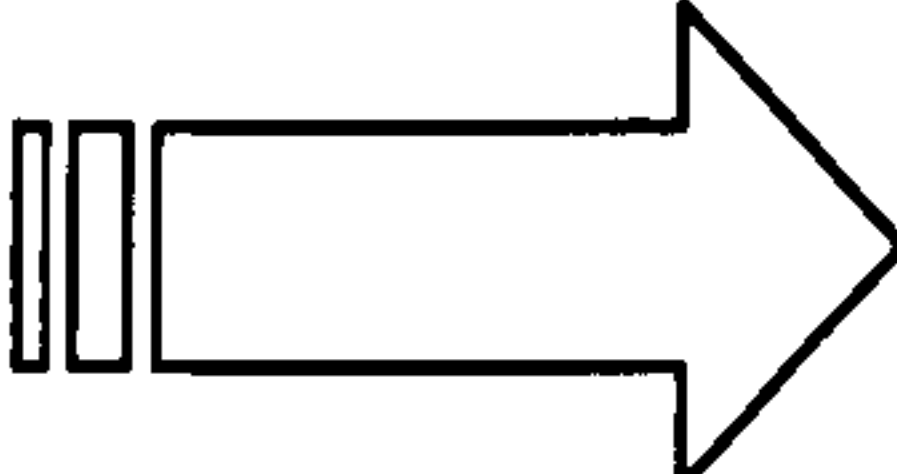
The organisational structure of construction organisations should be flexible enough to support a variety of project and process requirements, and support resolution of conflicts within their organisations. The structure should be flexible enough to support

individuals' preferred manner of working within the organisation, and respond to the changes in clients' requirements and the PDP. Another important area, which companies should address is setting up teams for identifying and preventing future problems related to the PDP, and for addressing clients' requirements. All project participants should make sure that the client is involved throughout the project development process. This involvement should be in the form of constant communication and co-ordination with the project development team (PDT), and continuous input and feedback throughout the process. Senior management's support is also vital in the development of organisational framework. They should make sure that crises do not disrupt the PDP, and problems faced during the PDP are monitored and resolved.

### ***Strategy Deployment***

The improvement path for Strategy Deployment is shown in Table 7.4.

Table 7.4 Migration Path for Strategy Deployment (Process Element)

<i>Ad-hoc Maturity Level</i>		<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li>❑ Poor business strategy</li> <li>❑ Poor senior management involvement</li> </ul>		<ul style="list-style-type: none"> <li>❑ Clear, consistent, and focused business strategy</li> <li>❑ Strong involvement of senior management for PDP</li> </ul>

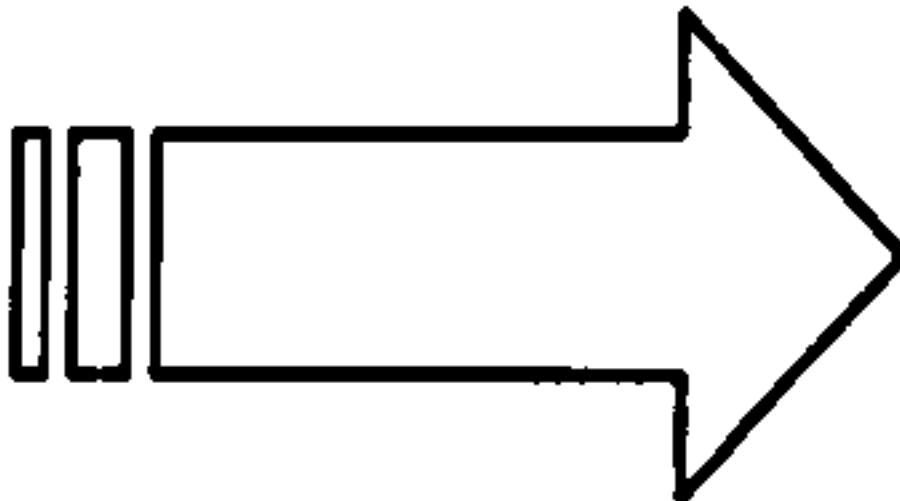
It is very important for construction organisations to have a clear business strategy for each project, and the strategy should be consistent with organisational business policy.

The strategy should focus on improvements within the organisation itself, the PDP of each project, and support resolution of issues at the lowest level within the organisation. Construction organisations should also have a strategy to reuse the company's assets and resources, and use past project information for new projects where appropriate. Human resource policies should support the business strategy, and should be improved continuously. Another important thing, which companies should make sure is formation of a team or group of people to address clients' requests, and that the problems faced during the PDP are monitored and resolved. The organisations should also make sure that changes in the clients' requirements are taken on board and information on past projects is used to plan for those changes within the PDP.

### ***Agility***

The Agility migration route for the organisations moving from ad-hoc maturity level towards optimising maturity level is shown in Table 7.4.

Table 7.5 Migration Path for Agility (Process Element)

<b><i>Ad-hoc Maturity Level</i></b>		<b><i>Optimising Maturity Level</i></b>
<ul style="list-style-type: none"> <li>❑ Non-flexible organizational structure</li> <li>❑ Poor maintenance of corporate memory</li> </ul>		<ul style="list-style-type: none"> <li>❑ Organisational structure is flexible enough to respond changes in PDP</li> <li>❑ Maintained corporate memory, and accessible to all members of PDT</li> </ul>

The organisational structure of construction organisations should be flexible to adapt and respond to any changes within an activity or a task of the PDP. The structure should

be flexible enough to support a variety of projects and processes, incorporate changes in the clients' requirements, and time to respond to these changes is improved throughout the PDP. Another important issue which construction organisations should focus on is the use of past project information on current tasks and activities where appropriate, and re-use of assets and resources for the new projects. In this regard, the management of the corporate memory of an organisation is very important. The corporate memory of a construction organisation should be maintained and accessible to all members of the PDT.

### *7.2.3 People Element*

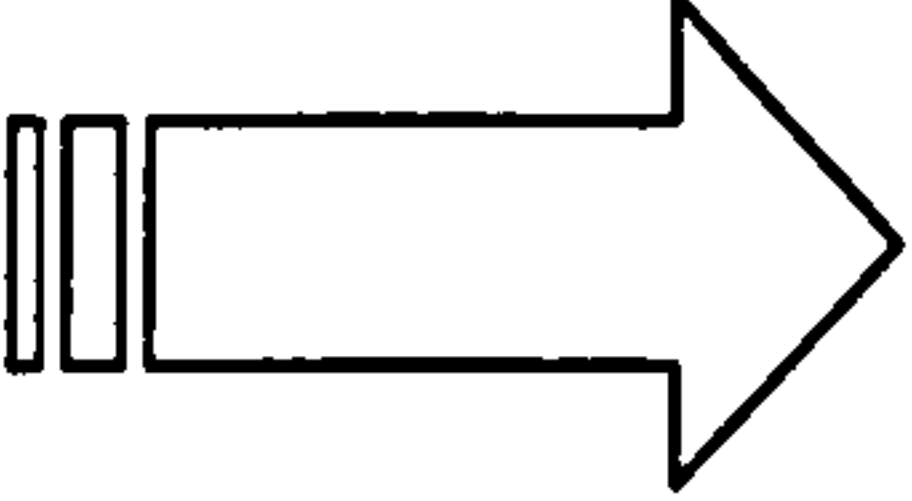
The strategies and considerations, presented in this sub-section are for the improvement of team performance and leadership within an organisation. These strategies and considerations are generic, and therefore, applicable to all sectors of the construction supply chain. These strategies are now summarised under each critical factor of the People Element.

#### *Team Formation and Development*

The improvement directions for Team Formation and Development is shown in Table 7.6.



Table 7.6 Migration Path for Team Formation and Development (People Element)

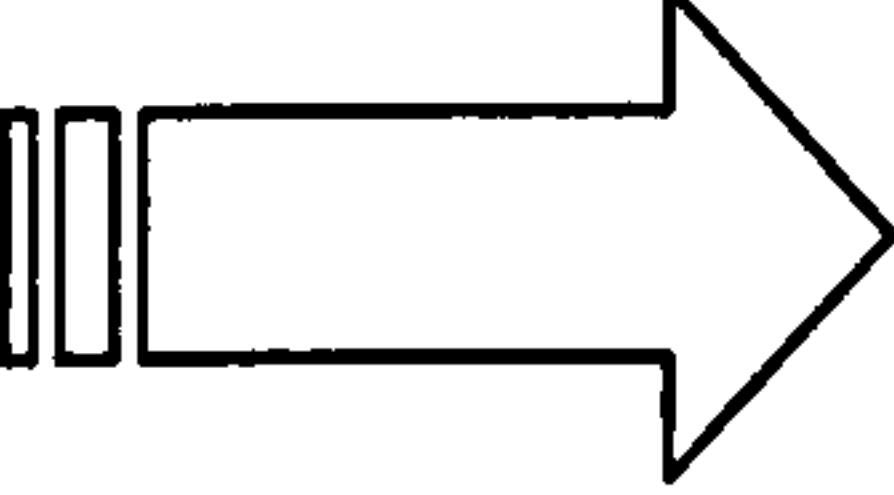
<i>Ad-hoc Maturity Level</i>	<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li>❑ Poor strategies for team formation and development</li> <li>❑ No interaction and no understanding of responsibilities</li> </ul>	<div style="text-align: center;">  </div> <ul style="list-style-type: none"> <li>❑ Strong strategies and policies for team development and training</li> <li>❑ Proper interaction among team members and clear understanding</li> </ul>

A project development team (PDT) should be formed in such a way that it has representation from all construction disciplines for a particular project. Similarly, each organisation should form a sub-team within their company, working on a specific project. Team members should be enthusiastic, specialised, and interact continuously with each other. Construction organisations should make sure that each team member clearly understands his/her responsibility, and shares the team's goals. Organisational policies should be formed such that it encourages teams to achieve their goals, and arrange training programmes for the team members in order to upgrade their skills and improve teamworking. The organisations should also make sure that adequate resources are available to carry out the training programmes, and that these programmes are evaluated for its effectiveness.

### ***Team Leadership and Management***

The development path for Team Leadership and Management from ad-hoc to optimising maturity level is shown in Table 7.7.

Table 7.7 Migration Path for Team Leadership and Management (People Element)

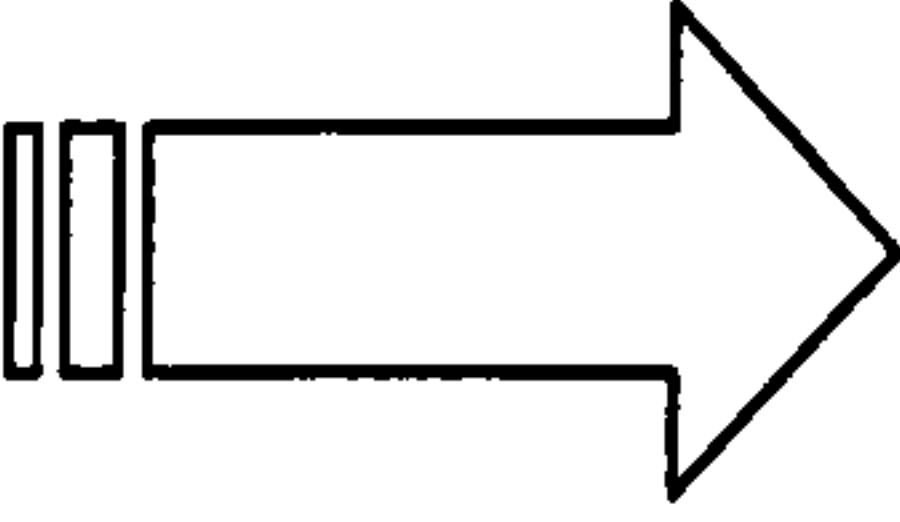
<i>Ad-hoc Maturity Level</i>	<i>Optimising Maturity Level</i>	
<ul style="list-style-type: none"> <li><input type="checkbox"/> Improper criteria for selecting a team leader</li> <li><input type="checkbox"/> No authority given to team leader</li> </ul>		<ul style="list-style-type: none"> <li><input type="checkbox"/> Strict criteria for team leader selection</li> <li><input type="checkbox"/> Team leader has full authority for project related decisions</li> </ul>

The team leaders for the PDT and sub-teams should be selected on the basis of their technical and managerial skills. Team leaders should be made accountable and responsible for the completion of project activities within the budget and on time. They should also be made responsible for controlling, organising, directing, and planning the activities of a project. Team leaders should be given authority to recruit new team members, and take final decisions for project-related issues within their teams. They should also consult with senior management of the organisations before taking any decision, and confirm that the senior management monitors the progress of both the PDT and the PDP.

### *Discipline*

The path towards optimising maturity level for the Discipline critical factor is shown in Table 7.8. This focuses on the disciplinary issues within an organisation.

Table 7.8 Migration Path for Discipline (People Element)

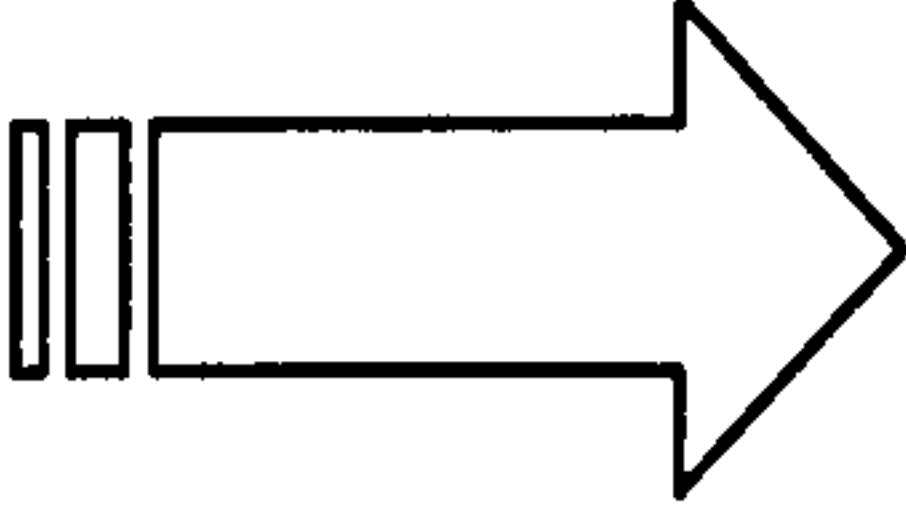
<i>Ad-hoc Maturity Level</i>		<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li><input type="checkbox"/> No disciplinary checks</li> <li><input type="checkbox"/> Team goals are never given priority</li> </ul>		<ul style="list-style-type: none"> <li><input type="checkbox"/> Strict disciplinary checks</li> <li><input type="checkbox"/> Priority is always given to team interests</li> </ul>

All members of teams should abide by the disciplinary rules and regulations, and should be committed to and share team rules. There should be an organisational commitment to deal with any disciplinary problems within the organisation. Another important area is team members' commitment. The team members should submerge their individual agenda and should operate in the best interests of the teams. They should also remain together when difficult issues and situations arise. On the other hand, senior management of the organisation should make sure that teams follow an established procedure to deliver value to their client, and also follow a set rules of behaviour for team meetings.

### ***Teams in an Organisation***

The migration path for Teams in an Organisation is shown in Table 7.9. This focuses on the main issues related to the management and empowerment of teams within the organisation.

Table 7.9 Migration Path for Teams in an Organisation (People Element)

<i>Ad-hoc Maturity Level</i>	<i>Optimising Maturity Level</i>	
<ul style="list-style-type: none"> <li>❑ No authority given to the teams</li> <li>❑ No organisational policies for team management</li> </ul>		<ul style="list-style-type: none"> <li>❑ Teams have been given full authority</li> <li>❑ organisational policies supports team development and management</li> </ul>

All teams working on a particular project should focus on their specific disciplinary tasks and activities, and have authority for technical and cost decisions. Teams should also have authority to reward their team members. Each team should make sure that it is easy for their team members to collocate, communicate and share information with each other. Another important area that should be given attention is measuring team performance. There should be organisational policies to measure team performance, support teamworking, and make each team accountable for achieving success with respect to their specific tasks. There should also be an organisational commitment to provide training to the team members, and plan and conduct peer reviews within the teams to improve performance.

#### *7.2.4 Project Element*

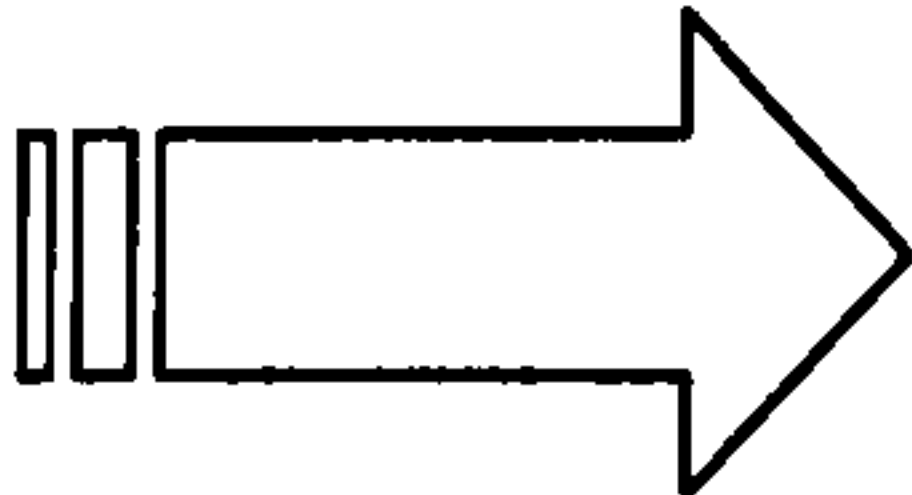
This section presents strategies and considerations for the improvement in clients' involvement within a PDP, facility design procedures, and quality related issues within a construction organisation. These strategies are generic in nature, and appropriate for

all sectors of the construction supply chain. They are outlined here under each critical factors of the Project Element.

***Client Focus***

The improvement path for Client Focus to move from ad-hoc to optimising maturity level is shown in Table 7.10. This presents the issues of client involvement within a project development process.

Table 7.10 Migration Path for Client Focus (Project Element)

<i>Ad-hoc Maturity Level</i>		<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li>❑ Client is not involved in a PDP</li> <li>❑ No priority is given to clients' requirements</li> </ul>		<ul style="list-style-type: none"> <li>❑ Client is constantly involved throughout a PDP as a PDT member</li> <li>❑ Prioritisation of all project decisions are based on clients requirements</li> </ul>

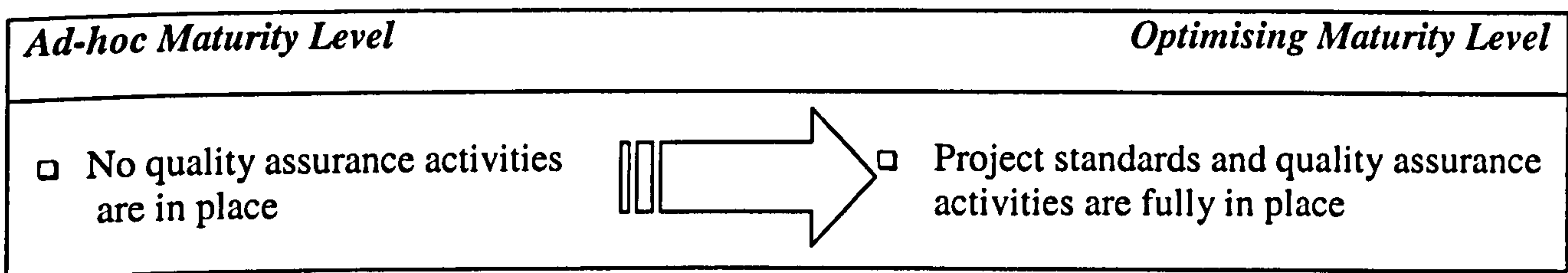
The client should be involved throughout the project development process (PDP) as a member of the project development team. Construction organisations should make sure that all team members clearly understand clients' requirements and a well-documented procedure is in place to gather these requirements. The organisations should also make sure that the prioritisation of all project decisions are based on clients' requirements, and these requirements are accessible to all team members at any time during the PDP. Clients' requirements should be addressed appropriately, disseminated properly to the concerned personnel, and accessible to all members of the teams. Another important point is that there should be procedures in place to evaluate how well the teams are

accommodating changes in clients' requirements, and whether the clients' requirements are met. Computer-based tools should be used to assist in eliciting and disseminating the clients' requirements, and to evaluate whether the clients' requirements are met.

***Quality Assurance***

The migration path from ad-hoc to optimising maturity level for Quality Assurance critical factor is shown in Table 7.11.

Table 7.11 Migration Path for Quality Assurance (Project Element)

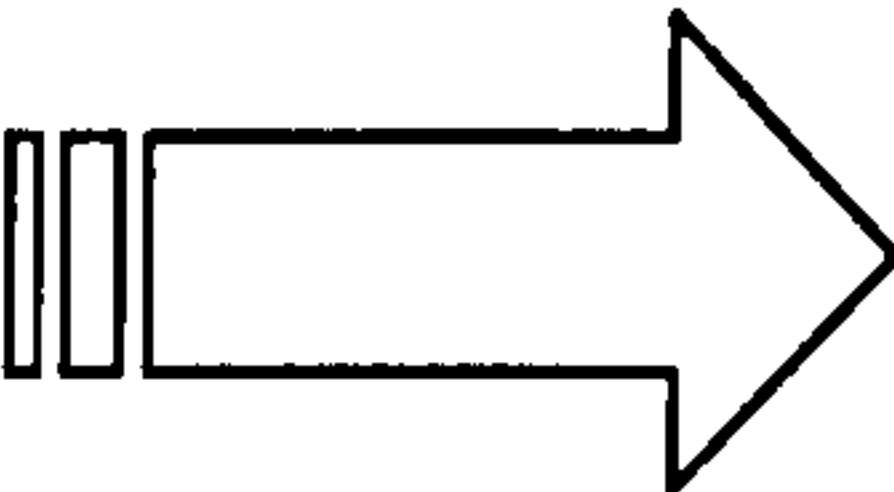


There should be quality management activities in place, which confirm that the project development process (PDP) comply with applicable procedures and standards. There should also be internally developed project standards, which are used during the design and construction phases of the PDP. These standards should be well established and recognised, and maintained and accessible to all team members. Another important issue, which an organisation should address, is ensuring that all changes and variations within the PDP are subjected to the quality assurance review and audit.

***Facility Design***

The improvement path for Facility Design from ad-hoc to optimising maturity level is shown in Table 7.12. This presents the key issues related to preliminary and final designs.

Table 7.12 Migration Path for Facility Design (Project Element)

<i>Ad-hoc Maturity Level</i>	<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li><input type="checkbox"/> Preliminary designs are never discussed</li> <li><input type="checkbox"/> Non-flexible facility design</li> </ul>	<div style="text-align: center; margin-bottom: 10px;">  </div> <ul style="list-style-type: none"> <li><input type="checkbox"/> Detailed discussion on preliminary designs</li> <li><input type="checkbox"/> Flexible facility design</li> </ul>

Preliminary designs and drawings of a facility should be prepared before entering into the final design and construction phases of a project. All members of the project development team (PDT) should analyse the preliminary design, and give comments and suggestions on how to overcome any downstream problems. Another important area is client satisfaction. There should be an organisational policy to ensure that the client is satisfied with the facility design, and that the design is flexible enough to address changes in clients' requirements. Construction organisations should also make sure that relevant past designs are consulted, and recognised design approaches are adopted to develop the current project's design. The design of the facility should be developed in such a way that it encourages repetitive and standard procedures of construction to reduce complexity during construction phase. The facility design should be accessible to all members of the PDT and should also be maintained electronically if possible.

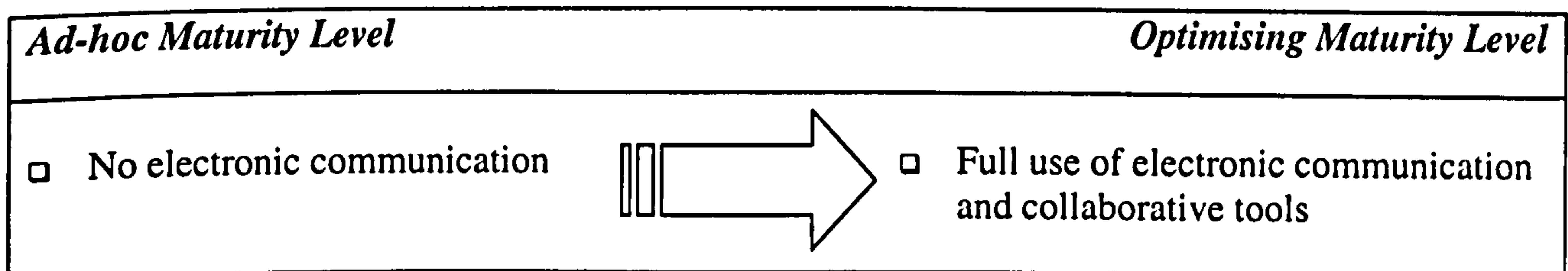
### 7.2.5 Technology Element

The strategies and considerations, presented in this sub-section are for the improvement of technological tools within an organisation to support communication, co-ordination, and information sharing. These strategies and considerations are general, and appropriate to all participating construction organisations. These strategies are now summarised under each critical factors of the Technology Element.

#### *Communication Support*

Table 7.13 shows the migration path for Communication Support from ad-hoc to optimising maturity levels.

Table 7.13 Migration Path for Communication Support (Technology Element)



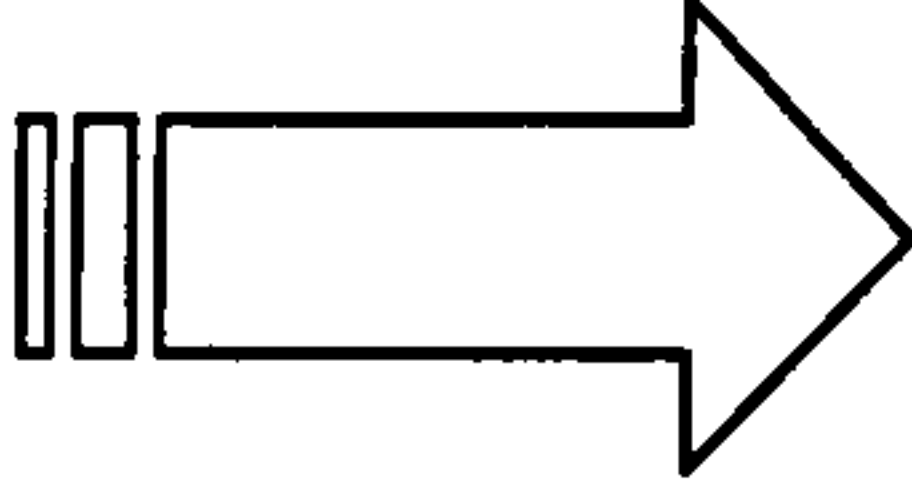
Construction organisations should make sure that all the team members are connected to each other in a network, and electronic mail facility is also available. All team members should be connected to each other such that they are able to share project data over the network, and are also be able to exchange graphics, voice and video files over the network. It is also important that organisations encourage their staff to take full



advantage of electronic communication and collaboration. Computers should also be used for virtual meetings and communication between PDT members as often as face-to-face meetings.

***Co-ordination Support***

Table 7.14 Migration Path for Co-ordination Support (Technology Element)

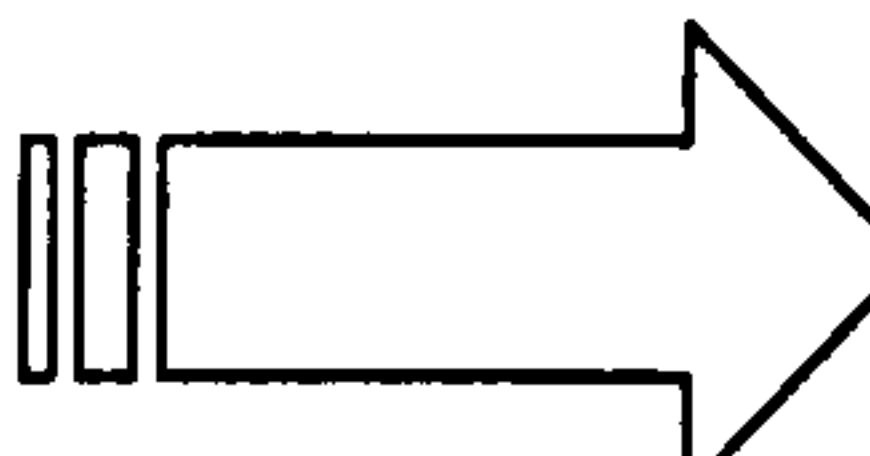
<i>Ad-hoc Maturity Level</i>		<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li>❑ Improper co-ordination among Team Members</li> <li>❑ No system available to support project monitoring</li> </ul>		<ul style="list-style-type: none"> <li>❑ Full co-ordination among teams and team members</li> <li>❑ Sophisticated systems available to support project monitoring</li> </ul>

The improvement route for Co-ordination Support from ad-hoc to optimising maturity level is shown in Table 7.14, showing the key issues related to co-ordination among the team members. Project data should be available electronically to all the project development team (PDT) members. For this purpose, a central project model should be used, which facilitates full co-ordination among all the teams involved on a project. On the other hand, there should be a system in place, which supports project management, conflict recognition and resolution, negotiation, trade-off within the organisations, and monitoring of the PDT. Versions of the computer tools and software should also be strictly enforced.

***Information Sharing***

Table 7.15 shows the key changes in moving to an optimising maturity level for the Information Sharing critical factor. This focuses on the information management and sharing issues within an organisation.

Table 7.15 Migration Path for Information Sharing (Technology Element)

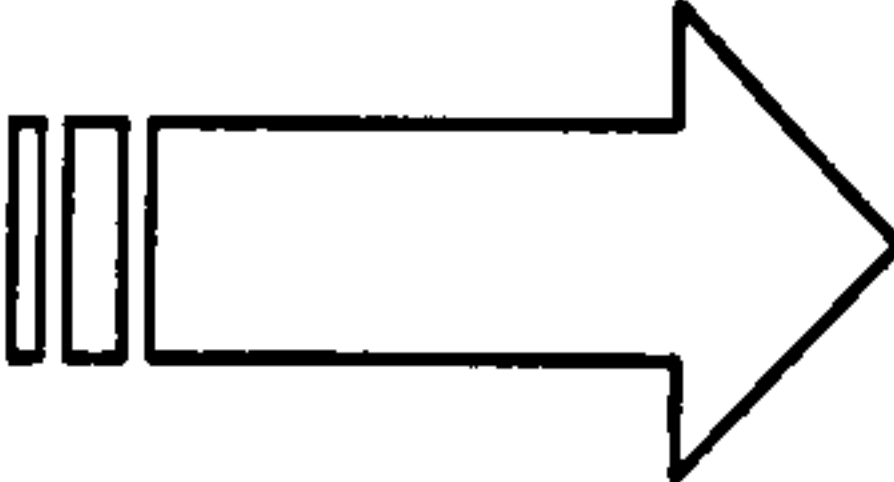
<i>Ad-hoc Maturity Level</i>	<i>Optimising Maturity Level</i>	
<ul style="list-style-type: none"> <li><input type="checkbox"/> Project information is not managed electronically</li> <li><input type="checkbox"/> Non-availability of multimedia technology</li> <li><input type="checkbox"/> No internet and intranet</li> </ul>		<ul style="list-style-type: none"> <li><input type="checkbox"/> Information required for the PDP is managed electronically</li> <li><input type="checkbox"/> Multimedia technology is exploited</li> <li><input type="checkbox"/> Internet and intranet facilities are available</li> </ul>

Construction organisations should ensure that the information required for the project development process is accessible in an electronic form to all members of the project development team. Advantage should also be taken of multimedia technology while sharing information including texts, graphics, images, voice and video files. Another important areas is use of Inter- and Intra- nets. Construction organisations should promote the use of Intranet and Internet for sharing information among team members, and ensure that there are appropriate communication systems available and in use to link up with other disciplines and organisations.

***Integration Support***

The transition of Integration Support from ad-hoc to optimising maturity level is shown in Table 7.16, highlighting the key issues related to integration among the team members.

Table 7.16 Migration Path for Integration Support (Technology Element)

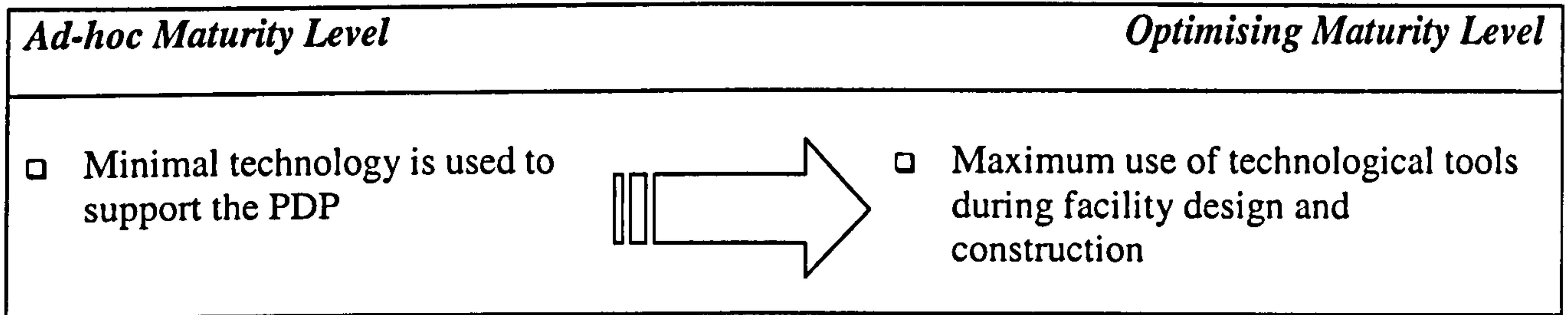
<i>Ad-hoc Maturity Level</i>		<i>Optimising Maturity Level</i>
<ul style="list-style-type: none"> <li><input type="checkbox"/> None availability of shared integrated model</li> <li><input type="checkbox"/> Computer systems are not linked to each other</li> </ul>		<ul style="list-style-type: none"> <li><input type="checkbox"/> A shared integrated information model is in place</li> <li><input type="checkbox"/> Computer systems are linked to each other to minimise re-entry and errors</li> </ul>

All the computer systems within an organisation should be linked to each other to minimise re-entry and errors. They should also be linked to their most frequent business partners. Construction organisations should make sure that all the members of the project development team are virtually integrated through a shared integrated information model, which is updated throughout the project development process (PDP). All the members should also be able to access this model and share information throughout the PDP.

***Task Support***

The migration path for Task Support critical factor towards the optimising maturity level is shown in Table 7.17.

Table 7.17 Migration Path for Task Support (Technology Element)



CAD and simulation tools should be used while facility design is developed. Other computer-based tools should also be available for collaborative working, and accessing applicable historical design information. These technological and task support tools should be evaluated to determine their effectiveness in terms of quality, productivity, cost, time, etc. Another important area is organisational policy. There should be an organisational policy to make and follow a plan for managing and improving technology. There should also be a policy in place within the organisations to assess and select new technological advancement, and task support tools such as plant and equipment, computer hardware and software, etc. against their needs.

Aspects covered within the migration paths for each of the critical factors (see Tables 7.1 – 7.17) are only examples of the full requirements. A step-by-step migration from ad-hoc to optimising maturity level for three of the critical factors, which have been selected randomly, is presented in Table 7.18.

Table 7.18: Step-by-step Migration Path from Ad-hoc to Optimising Maturity Levels

Maturity Levels	Critical Factors		
	Process Focus	Client Focus	Teams in an Organisation
<i>Ad-hoc</i>	Ill-defined procedures and controls. Management of the project development process is not applied consistently in projects.	Informal interaction with the client is observed.	Confused and disordered teams that do not understand their assignment nor how to operate effectively.
<i>Repeatable</i>	Standard methods and practices are used for monitoring the project development process.	Interaction with the client is structured but it is only at the inception of the project.	There are barriers to communicate within the project development team.
<i>Characterised</i>	The project development process is well characterised and reasonably well understood.	Most individuals are well aware of client's requirements but client is not involved in the process.	Teams may struggle and fall apart as conflicts are addressed but a team begins to respect individual differences.
<i>Managed</i>	A series of organisational and the process improvements have been implemented.	Client is involved throughout the process.	The project development team accomplishes work, and addresses the conflicts.
<i>Optimising</i>	The project development process is not only characterised and understood but is also quantified, measured, and reasonably well controlled. Tools are used to control and manage the process.	Client is a part of project development team from inception and all project decisions are prioritised based on client's needs.	Team performance is regularly measured, and performance measures are continuously validated.

### *7.2.6 Summary*

This section has presented the generic strategies and considerations for CE implementation within the construction industry. The strategies are intended to enable construction organisations to improve in each of the critical factors of the BEACON model, thereby enhancing their readiness to implement CE. These strategies and considerations may now be used for a pilot CE implementation, followed by a full-scale implementation.

## **7.3 Towards Pilot CE Implementation**

### *7.3.1 Introduction*

After the development of CE implementation strategies and considerations, the next step is to apply these strategies to a pilot project in order to introduce and implement CE. Plans should be made accordingly, milestones should be identified in the plans, budgets should be allocated, and performance metrics should be established.

A prime objective of pilot projects is to start to do things differently. Pilots can be used to test a combination of the people, process, project and technology (P<sup>3</sup>T) and to confirm the expected levels of benefit. Part of the preparation for the pilots can involve (Brooks & Foster, 1997):

- Selecting the pilot project;
- Mobilising the pilot team;

- Facilitating the pilot project;
- Auditing the progress and outcome; and
- Selecting and mobilising the teams, and training them in the new way of working together, with relevant techniques such as process modelling, milestone planning, team-working, and problem solving.

Creating a supportive team environment is critical to the success of CE. The multi-disciplinary team should have a clear contract, negotiated up-front. The benefit of having an explicit contract and mode of working is that everyone has clear expectations of the project and one another (Evans et al., 1994). The management team must sign up to the savings and drive the pilot project to realise the changes and improvements in performance.

These pilots help to introduce the new way of working, generate benefits, and will enable the benefit estimates to be refined. A key role for the management team will be to run and support these pilots and to transfer the lessons learnt. They must also propagate the changes in P<sup>3</sup>T across other projects and the organisation. Therefore, selection of a pilot work activity, teams and relevant change mechanisms are critically important, especially for the early projects where resistance to change is greater. Other benefits of using pilot projects are (Brooks & Foster, 1997):

- Clearly defined areas of real project work;
- Packages of work that management team members need;
- Links to a benefit area;
- Sponsored and supported by management team member(s);

- Measurable (by having clear and meaningful metrics);
- Undertaken by a selected and trained team; and
- A test-bed for new ways of working involving changes in approach to people, process, project and technology.

### 7.3.2 Key Issues

The following are some of the key issues, which must be kept in mind while undertaking CE implementation on a pilot project (Brooks & Foster, 1997; Evans et al., 1994; Tucker & Leonard, 1994):

- Awareness training to strengthen the aims of the initiative, to build an environment of trust and to set the terms of reference of the CE team must be introduced from the beginning and continue throughout the project;
- Similarly, the choice of pilot projects is vital because early success is needed to support the long-term success of the whole project;
- A clear demonstration of senior management's commitment is to set up a steering committee and appoint a CE champion, who are responsible for driving the change through the organisation and providing direction;
- CE must be implemented in a progressive manner. The initiation of one or two CE pilot projects, to show product development success, prior to expanding it to the whole organisation, is extremely common for CE implementation within any organisation; and
- The most important issue is making sure that all the above-mentioned CE strategies and considerations are taken into account for successful pilot CE implementation.



### *7.3.3 CE Champion and CE Steering Committee*

In order to facilitate CE implementation, CE agents should be appointed by senior management to assist them in driving and monitoring the changes brought on by CE. These agents are often internal to the organisation in the form of a CE Champion and a CE Steering Committee.

#### *Champion*

The CE Champion is a member of the management team and plays a key role. He/she must be a senior person committed, and responsible for, achieving the change outcome and gaining the targeted benefits. He/she should support the team's desire to work in a new way, and ensure that the team receives support, training, and on-going facilitation. He/she should be prepared to defend or protect the team and their radical approach in the face of pressures from the rest of the conventional organisation. He/she should communicate and promote the new way of working within his/her own organisations (Brooks & Foster, 1997).

#### *Steering Committee*

The CE Steering Committee sets a clear performance target for the team, which is aggressive yet achievable. This indicates to the team WHAT they must achieve. The team must then decide HOW it is to be achieved through the development of a detailed project plan (Evans et al., 1994).

### 7.3.4 CE Teams and CE Team Leader

Senior management must ensure that the CE team is clear and confident about its role and responsibilities. If the CE team feels that their superiors support them, then they will feel greater ownership for their project tasks. This is especially important during the early creative stages of product development when the product specification is being defined and project plans are being produced.

A team leader for a pilot is responsible for the technical deliverables of the project and has been trained with the team in the appropriate change mechanisms and the CE principles. Typical roles and responsibilities of Team Leader include (Evans et al., 1994; Brooks & Foster, 1997):

- To manage the team decision making process without making team decisions;
- To ensure the project plan reflects reality and urgency;
- To listen, involve, and communicate internally and externally; and
- To give guidance and support to team members.

According to Tucker & Leonard (1994), the team leader should co-ordinate the activities of all the departments, and arbitrate in any conflicts that arise. Therefore, it is more important for the leader to have strong interpersonal and diplomatic skills, rather than a high degree of technical ability. The leader would also need a significant degree of authority and autonomy.

The team leader should be given full control over who should constitute the team members. This is because of his prior knowledge of people within the company. Because of the very aggressive time scales for the project, people have to be chosen on the basis of who has the best access to the information and technical resources needed to make the project work. The possession of the necessary technical expertise is taken as an unavoidable requirement.

The team meetings are an ideal vehicle to ensure co-ordination, but occasionally problems arise which need urgent attention. In such situations, the team members should approach the team leader, who would take remedial steps as he sees fit. The choice of team leader also needs careful consideration, because he/she is the one who naturally interfaces with all parties.

### *7.3.5 Conclusions*

Pilot projects are successful when:

- A CE team has been given ownership of the project;
- There is effective and efficient communication between teams and team members;
- All the key issues related to the CE implementation are addressed using simple but proven techniques; and
- There is a vision that learning to manage a CE implementation is best achieved by actually doing it.

Importance should therefore be attached to the way in which integrated product development activities are managed after the initial pilot CE project(s). It is important that the organisational structure and the business processes, which run through it, go together with CE working practices.

For the expansion of CE implementation, the pilot project should be completed, reviewed and lessons learnt, which should then be carried forward to subsequent CE implementation projects. The changes made during the CE implementation process, which are very important, should be transferred by using formal and informal internal learning processes such as project reviews, seminars, workshops, etc.

#### **7.4 Summary**

This chapter has presented considerations and strategies for CE implementation within the construction industry. This presentation refers to the need of a readiness assessment prior to the CE implementation within an organisation in order to derive the strategies and considerations for CE implementation, and to identify the areas requiring improvements. The chapter has outlined the generic CE implementation strategies and considerations under each of the four elements of the BEACON Model; the Process, People, Project, and Technology. Towards the end of the chapter, the strategy for CE implementation within a pilot project was presented in order to introduce CE within the organisation. It is also important to share the lessons learnt from CE implementation in the other industries and try to overcome identified problems and bottlenecks during CE implementation within the construction industry.

The next chapter will present the summary and conclusions of the whole project, identify limitations, and present recommendations for CE implementation for construction organisations based on the above mentioned strategies and consideration.

## **Chapter 8: Summary and Conclusions**

This chapter summarises the whole project, evaluates it against the original aims and objectives, presents the conclusions drawn from the research, outlines recommendations to the construction industry, and states the limitations of the research. It also covers recommendations for future work.

### **8.1 Summary**

This section presents the original aim and objectives of the project and compares it with the work carried out through out the project. This is followed by a summary of the work done during the research period.

#### ***8.1.1 Aim and Objectives of the Research***

The original aim and objectives of the research are reproduced here:

##### **Aim**

The aim of the research project was to explore the development of a tool which could be used to investigate the readiness of the construction industry to improve its project delivery process through the implementation of Concurrent Engineering (CE), and formulate strategies for the effective implementation of CE within the industry.

## Objectives

The specific objectives of the research project were as follows:

- 1) To review the implementation of CE in other industry sectors (e.g. manufacturing, shipbuilding, offshore, software engineering, etc.) with a view to identifying the critical success factors, best practice, the technical and socio-cultural barriers, and generic cross-sectoral benefits.
- 2) To investigate existing tools and metrics for assessing the readiness assessment of organisations for CE implementation.
- 3) To assess the readiness of the construction industry for CE implementation by using the tool resulting from objective 2).
- 4) To develop strategies and considerations for enhancing the construction industry's efficiency and competitiveness through the implementation of CE.

This project has examined CE implementation in other industries such as manufacturing, software engineering, etc. and identified the critical success factors, best practice, the technical and socio-cultural barriers, and generic cross-sectoral benefits. It has also reviewed and compared the CE readiness assessment tools and models used in other industries and came up with a specific CE readiness assessment tool, called the 'BEACON Model' for the construction industry. It was then used to assess the construction supply chain including clients, consultants, contractors, sub-contractors, and material suppliers and manufacturers. The results of the assessment informed the development of CE implementation strategies and considerations for the construction industry.

### *8.1.2 General Summary*

This thesis provided an introduction to the subject matter in the first chapter, defined the aim and objectives of the project, justification for the research, and the sources of data for the research project.

The research methodology was then described, which included the use of both quantitative and qualitative procedures and methods (also called triangulation method). The methodology adopted for each task carried out during the project was also described in detail. This included literature review on Concurrent Engineering (CE), comparison of CE Readiness Assessment tools and models, development of the BEACON Model and its associated questionnaire, and prototype software, assessment methodology, case studies and results, and development of CE implementation strategies.

The thesis also presented a discussion that was based on a literature review on CE readiness assessment, its application to other industries, and current tools used to carry out the readiness assessment. It discussed the definition of CE, CE implementation, CE readiness assessment, and associated criteria, introduced available readiness assessment tools and models briefly, and examined their appropriateness for the construction industry.



The comparison showed that all the available tools were developed to assess the CE implementation process and the readiness to adopt CE for organisations in either the manufacturing or software industry, and there is a need of a tool which checks the readiness of construction organisations. Therefore, a new CE readiness assessment model – the BEACON model - for the construction industry and some of its major features were presented. The benefits of the model and its associated questionnaire were also discussed.

The development of a prototype software programme for the BEACON Model was also discussed; this included the objectives for developing an electronic version of the BEACON Model. Details of the system architecture, the implementation environment, and system development using MS Access and MS Excel were described. The thesis also demonstrated how the software works and generates the assessment results, identified some of the key benefits of the software, and proposed possible improvements.

The thesis also presented the case studies conducted within the construction supply chain using the BEACON model. It presented the outcomes of the case studies and identified the areas which needed to be improved. Conclusions were also presented such as: ‘the BEACON model can be successfully used as a CE readiness assessment tool for the construction industry’, and ‘it can also be used as a useful tool for self-assessment on the four key Elements: Process, People, Project, and Technology even for organisations not necessarily considering the implementation of CE’.

Considerations and strategies for CE implementation within the construction industry, based on the CE readiness assessment of the industry, were presented in the later part of the thesis. These were outlined with respect to each of the four elements of the BEACON Model. The strategy for CE implementation within a pilot project was described in reasonable detail.

Finally, the summary and conclusions of the whole project are presented in this chapter. Limitations, recommendations and further work with respect to the research topic are also presented below.

## **8.2 Conclusions**

This research project investigated the readiness of the construction industry to improve its project delivery process through CE implementation. The following conclusions can be drawn from the research:

- On the basis of intense literature review and lessons learnt from other industries, it could be concluded that the introduction of CE within the construction industry has the potential to contribute towards client satisfaction by improving quality, adding greater value, reducing cost, reducing construction schedules, and overcome its current problems;
- CE implementation efforts within other industry sectors clearly conclude that it is necessary to carry out CE readiness assessment of an organisation before CE implementation so as to ensure that maximum benefits are achieved. Thus this

project views the development of a tool to assess the readiness of the construction industry as very important;

- In order to assess the construction industry, a specific CE readiness assessment model was required because existing models are not appropriate for the construction industry in their present form;
- The BEACON Model, developed specifically for construction organisations, can be successfully used as a CE readiness assessment tool for the construction industry. This is based on its use within different sectors of the construction supply chain as a part of this research project;
- The results of the assessment show that large companies are better prepared to implement CE than medium-sized companies, which need improvements in many key areas. This may be because of the availability of more resources;
- The assessment results show that the People Element is the most important element for most of the organisations in all sectors of the construction supply chain, and the Technology element is the least important to most organisations. Interestingly, the Technology element also came out as the weakest element from the assessment results and requires attention and improvement in all sectors of the construction supply chain;
- From the results of the readiness assessment conducted as a part of this research project, it is evident that contractors and sub-contractors are more ready to adopt aspects of CE within their organisations than clients, consultants, and suppliers & manufacturers;

- Using the model to assess the construction supply chain, and lessons learnt from other industry sectors have enabled the development of strategies and considerations for the effective and more appropriate implementation of CE in construction;
- The overall readiness assessment results show that the construction industry, as a whole, still needs improvements in most of the critical areas in order to adopt CE effectively;
- The BEACON model can act as a useful tool for self-assessment on the four key elements: Process, People, Project, and Technology (P<sup>3</sup>T) for construction organisations not considering the implementation of CE; and
- The developed strategies and considerations for CE implementation have the potential to lead towards better, more effective, and more efficient implementation of Concurrent Engineering within the construction industry.

### **8.3 Limitations**

The CE readiness assessment case studies were carried out within a limited number of companies in each sector of the construction industry. A random sample was used to ensure that the results would be indicative of the industry's readiness. More representative results may be obtained by involving a substantially larger number of organisations.

Another limitation in the research was its scope, which did not include the actual CE implementation to a construction project by using the developed strategies and

considerations. This could be done by a follow-on project, although would be very difficult to convince construction project teams to fully implement CE on a live project.

#### **8.4 Recommendations and Further Work**

This section presents recommendations to the industry and researchers, and outlines possible further work. The further work is divided into three sections: BEACON Model and prototype software, CE readiness assessment, and CE in construction.

Further work on improving the BEACON Model and prototype software includes the evaluation of the model itself on a periodic basis in order to modify it according to changes within the construction industry. Refinement of the prototype software is essential, if it has to be used on professional basis. This could be achieved by implementing it using a programming language such as Visual Basic to make it more user-friendly, and including new tools and facilities. On the other hand, modifications could also be made to make the model and prototype software flexible enough for use within other industry sectors or other countries.

The user-interface of the BEACON Model software could be developed to simplify the input of information by personnel within an organisation. This could also allow for input by multiple users within the same organisation. Another key development would be to make the system fully Web-based so that it is accessible to members of a

distributed/virtual project team. A report generation facility could also be implemented, which would be able to provide intelligent advice to organisations based on their readiness assessment results.

A more cost effective and efficient methodology could be developed for assessing an organisation. The current approach is somewhat time consuming. It is also important to have established and developed procedures, which could enable organisations and/or project teams to benchmark their performance against the results for award-winning projects and/or teams.

As far as CE implementation within the construction industry is concerned, there is a need to investigate the most appropriate mechanism for engaging the whole construction supply chain in the implementation. The study undertaken has demonstrated that if certain sections of the supply chain are weak in any of the critical areas, then the full benefits of CE cannot be realised.

Given the importance of the People Element in the BEACON Model, it is necessary for a detailed study to be undertaken on the human and organisational barriers and enablers for CE implementation in the construction industry. On the other hand, there is also a need to look at the Technology Element in the model in order to devise appropriate mechanism to improve this area within the construction industry.

## **8.5 Closing Remarks**

The effective implementation of CE within the construction industry could bring about those benefits, which have been realised by other industry sectors such as manufacturing and software engineering. The research documented in this thesis has identified a key step towards CE implementation within the industry, that is, readiness assessment, which has been successfully used in other industries prior to CE adoption. The main contribution of the research is the development of a CE readiness assessment model for the construction industry (the BEACON Model) and its use to assess the construction supply chain. This resulted in the formulation of strategies and considerations for CE implementation within the construction industry. Construction organisations should adopt these to improve their business processes generally and to facilitate the implementation of CE. The future of the BEACON Model and its associated prototype software is bright.

## References

Ainscough, M. S. and Yazdani, B. (1999), "Concurrent Engineering within British Industry", *Proceedings of Advances in Concurrent Engineering (CE99)*, Bath, UK, 443-448.

Al-Ashaab, A. and Molina, A. (1999), "Concurrent Engineering Framework: A Mexican Perspective", *Proceedings of Advances in Concurrent Engineering (CE99)*, Bath, UK, 435-442.

Anumba, C. J. Bouchlaghem, N. M. & Whyte, J. (2000), "Perspectives on an Integrated Construction Project Model", *International Journal of Cooperative Information Systems*, Vol. 9, No. 3 (2000), pp. 283 – 313.

Aouad, G.; Cooper, R.; Kagioglou, M.; Hinks, J. and Sexton, M. (1998), "A Synchronised Process/IT Model to support the co-maturation of processes and IT in the Construction sector", *Time Research Institute*, University of Salford.

Bergman, L. and Ohlund, S. (1995), "Development of an Assessment Tool to Assist in the Implementation of Concurrent Engineering", *Proceedings of Conference on Concurrent Engineering: A Global Perspective*, 1995, 499-510.

Britton, C. and Doake, J. (1996), *Software System Development: A Gentle Introduction*. McGraw-Hill, London, 1996.



Brookes, N. J.; Backhouse, C. J. and Burns, N. D. (2000), "Improving Product Introduction Through Appropriate Organisation: The Development of the SIMPLOFI Positioning Tool", *Proceedings of Institution of Mechanical Engineers*, Vol. 214, Part B, Journal of Engineering Manufacture, 339-364.

Brooks, B. M. and Foster, S. G. (1997), "Implementing Concurrent Engineering", *Concurrent Engineering – The Agenda for Success*, Medhat, S. (Ed.), Research Studies Press Ltd.

Broughton, T. (1990), "Simultaneous Engineering in Aero Gas Turbine Design & Manufacture", Proceedings of the 1<sup>st</sup> International Conference on CE, 4-5 December 1990, London, pp. 25-36.

Bryman, A. and Cramer, D. (1990), "Quantitative Data Analysis for Social Scientist", Routledge, London.

Carnduff, T.; Miles, J.; Gray, A.; Santoyridis, I. and Faulconbridge, A. (1997), "Case Adaptation and Versioning in Concurrent Engineering", *Concurrent Engineering in Construction: Proceedings of 1<sup>st</sup> International Conference*, Anumba, C. J. & Evbuomwan, N. F. O. (Eds.), IStructE, London, 3 – 4 July 1997, 45 – 54.

Carrillo, P. M. (2001), "Mergers and Acquisitions in the Construction Industry: An Exploratory Study", *PhD Thesis*, Department of Civil & Building Engineering, Loughborough University.

CERC Report (1993), "Final Report on Readiness Assessment for Concurrent Engineering for DICE", *Submitted by: CE Research Centre, West Virginia University*, June 1993.

CERC Technical Report (1992), "Process Issues in Implementing Concurrent Engineering", *Submitted by: CE Research Centre, West Virginia University*, October 1992.

Chen, G. (1996), "The Organisational Management Framework for Implementation of Concurrent Engineering In the Chinese Context", *Advances in Concurrent Engineering, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering: Research & Applications*, University of Toronto, Canada, 26-28 August 1996, 165-171.

CIRIA Report (1999), "Standardisation and pre-assembly: Adding Value to Construction Projects", CIRIA Report No. 176, 1999, CIRIA, London.

Componation P. J. and Byrd Jr., J. (1996), "A Readiness Assessment Methodology for Implementing Concurrent Engineering", *Advances in Concurrent Engineering, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering:*

*Research & Applications*, University of Toronto, Ontario, Canada, 26-28 August 1996, 150-156.

CONCUR (1999), Web Page of the CONCUR Project : <http://ivope.ivo.fi/concur>.

Constable, G. (1994), "Concurrent Engineering – Its Procedures and Pitfalls", *Measurement + Control*, Vol. 27, Oct. 1994, pp. 245-247

Creswell, J. W. (1994), "Research Design: Qualitative and Quantitative Approaches", Thousand Oaks, SAGE Publications, California & London.

Crow, K. A. (1994), *Building Effective Product Development Teams*, DRM Associates, 1994.

Dainty, A. R. J.; Bagilhole, B. M. and Neale, R. H. (1997), "Analytical Strategies of Dealing with Qualitative Data in Construction Management Research", Proceedings of 13<sup>th</sup> ARCOM Conference 1997, Vol.2, pg. 491-500.

Dann, Z.; Poolton, J.; Barclay, I. and Holroyd, P. (1996), "Benchmarking CE Best Practices: Development of a Framework", *Advances in Concurrent Engineering*, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering: Research & Applications, University of Toronto, Ontario, Canada, 26-28 August 1996, pp.181-186.

de Graaf, R. and Sol, E. J. (1994), "Assessing Europe's Readiness for Concurrent Engineering", *Proceedings of Conference on Concurrent Engineering: Research & Application*, 1994, 77-82.

de Graaf, R.; Wognum P. M.; Stoeten, B. J. B. and Kerkhof M. (1996), "PMO-RACE: A Combined Method for Assessing Organisations for CE", *Advances in Concurrent Engineering, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering: Research & Applications*, University of Toronto, Ontario, Canada, 26-28 August 1996, pp.113-120.

Deasley, P and Lettice, F (1997), "A Concurrent Engineering Approach to Construction: Learning from Cases in Manufacturing Industry", *Concurrent Engineering in Construction, Proceedings of 1<sup>st</sup> International Conference on Concurrent Engineering in Construction*, Anumba, C. J. & Evbuomwan, N. F. O. (Eds.), The Institution of Structural Engineers, London, 3 & 4 July 1997, pp. 269-305.

Denzin, N. K. (1978), "The Research Act: A Theoretical Introduction to Sociological Methods", 2<sup>nd</sup> ed., McGraw-hill, New York.

Duke, A. K. and Anumba, C. J. (1997), "Enabling Collaboration for Virtual Construction Project Teams", *Concurrent Engineering in Construction: Proceedings of 1<sup>st</sup> International Conference*, Anumba, C. J. & Evbuomwan, N. F. O. (Eds.), IStructE, London, 3 – 4 July 1997, 163 – 172.

Egan, J. (1998), "Rethinking Construction", *Report of the Construction Task Force on the Scope for Improving the Quality and Efficiency of UK Construction Industry*, Department of the Environment, Transport and the Regions, London.

Evans, S.; Lettice, F. and Palminder, S. (1994), "Concurrent Engineering – Key Implementation Issues", *Advances in Agile Manufacturing*, pg. 89-92.

Evbuomwan, N. F. O. and Anumba, C. J. (1998), "An Integrated Framework for Concurrent Life-cycle Design and Construction", *Advances in Engineering Software*, 1998, Vol. 5, No. 7-9, 587-597.

Finnemore, M. and Sarshar, M. (2000), "Linking Construction Process Improvement to Business Benefit", *Proceedings of the Bizarre Fruit 2000 National Conference of Postgraduate Research in the Built and Human Environment*, Salford, UK, 9-10 March 2000, 94-106.

Hills, P. (1992), "Simultaneous Engineering", A seminar on Simultaneous Engineering, organised by the Management and Design Division, Institution of Electrical Engineers, Savoy Place, London, 8 Oct 1992.

Holmes, G. (1994), "Putting Concurrent Engineering into Practice", *World Class Design to Manufacture*, Vol. 1, No. 5, 1994, pp. 38-42, MCB University Press.

Johansson, C. ; Legge, D. and Wappling, A. (1999), "Concurrent Engineering in the Supply Chain", Proceedings of Advances in Concurrent Engineering (CE99), Bath, UK, pg. 51-56.

Kamara J. M. and Anumba, (2001), "ClientPro: A Prototype Software for Client Requirements Processing in Construction", *Advances in Engineering Software*, 32 (2001), 141-158

Kamara J. M, Anumba C. J. and Evbuomwan N. F. O. (1997), "Considerations for the Effective Implementation of Concurrent Engineering in Construction", Concurrent Engineering in Construction, Anumba C. J. & Evbuomwan N. F. O. (Eds.), Institution of Structural Engineers, London, July 1997, pp 33-44.

Kamara, J. M.; Anumba, C. J. and Evbuomwan, N. F. O. (2000), "Developments in the Implementation of Concurrent Engineering in Construction", *International Journal of Computer Integrated Design and Construction*, Vol.2, No.1, February 2000, 68 – 78.

Keppel,G. (1991), "Design and Analysis: A Researcher's Handbook", 3<sup>rd</sup> ed., Englewood Cliffs, Prentice Hall, NJ.

Khalfan, M. M. A., 2000, *First Year PhD Research Report on the 'BEACON' project*, Department of Civil & Building Engineering, Loughborough University, UK.

Khalfan, M. M. A. and Anumba, C. J. (2000a), "Readiness Assessment for Concurrent Engineering in Construction", *Proceedings of the Bizarre Fruit 2000 National Conference of Postgraduate Research in the Built and Human Environment*, Salford, UK, 9-10 March, 2000, 42-54.

Khalfan, M. M. A. and Anumba, C. J. (2000b), "Implementation of Concurrent Engineering in Construction - Readiness Assessment", *Proceedings of the Construction Information Technology 2000 Conference*, Reykjavik, Iceland, 28 – 30 June 2000, Vol. 1, 544-555.

Khalfan, M. M. A. and Anumba, C. J. (2000c), "A Comparative Review of Concurrent Engineering Readiness Assessment Tools and Models", *Concurrent Engineering 2000 (CE 2000) Conference*, Lyon, France, 17–20 July 2000, 578-585.

Khalfan, M. M. A.; Anumba, C. J. & Price, A. D. F. (2000), "Improving the Construction Project Development Process through Integration and Concurrent Engineering", *Proceedings of COBRA 2000 Conference organised by RICS Research Foundation*, Greenwich (London), UK, 30 August - 1 September 2000, pp. 208-215.

Khalfan, M. M. A.; Anumba, C. J. and Carrillo, P. M. (2001a), "An Investigation of the Readiness of Contractors for the Implementation of Concurrent Engineering in Construction", *Proceedings of the First International Conference of Postgraduate Research in Built and Human Environment*, University of Salford, UK, 15-16 March 2001, 1-13.

Khalfan, M. M. A.; Anumba, C. J. and Carrillo, P. M. (2001b), "Readiness Assessment of Construction Clients for Concurrent Engineering Implementation", *Proceedings of 1<sup>st</sup> International Conference of Architecture, Engineering & Construction*, Loughborough University, 18-20 July 2001 (in press).

Khalfan, M. M. A.; Anumba, C. J.; Siemieniuch, C. E. and Sinclair, M. A., (2001), "Readiness Assessment of the Construction Supply Chain – A Necessity for Concurrent Engineering in Construction", *European Journal of Purchasing and Supply Management*, Volume 7, Issue 2, Spring 2001, 141-153.

Kwak, Y. H. and Ibbs, C. W. (1997), "Project Management Process Maturity (PM)<sup>2</sup> Model", <<http://www.ce.berkeley.edu/~yhwak/pmmaturity.html>>

Latham, M. (1994), "Constructing the Team", *Final Report on Joint Review of Procurement and Contractual Agreements in the UK Construction Industry*, HMSO, London.

Lee, R. J. V. and Young, R. I. M., (1994), "Design for Manufacture: An approach to Software Support in a Concurrent Engineering Environment", *Proceedings of Factory 2000, 4th International Conference on Advanced Factory Automation*, York, 1994, 593-600.



Love, P. E. D. and Gunasekaran, A. (1997), "Concurrent Engineering in the Construction Industry", *Concurrent Engineering: Research & Applications*, Vol.5, No.2, June 1997, 155-162.

Martin, A. and Evans, S. (1992), "Project Planning in a Concurrent Engineering Environment", *Proceedings of 3rd International Conference on Factory 2000*, York, UK, July 1992, 298-303.

Muya, M.; Price, A. D. F. and Thrope, A. (1999), "Contractors' Supplier Management", *Proceedings of a Joint Triennial Symposium, Cape Town, 5-10 September 1999*, Vol. 2, pp. 632-640.

NCE web site:<http://www.nceplus.co.uk/nce/companydirectory/asp/index.asp>

Paul, J. and Burns, C. (1997), "Implementing a Business Process Re-engineering Programme", *Concurrent Engineering – The Agenda for Success*, Medhat, S. (Ed.), Research Studies Press Ltd.

Prasad, B. (1997), "Seven Enabling Principles of Concurrency and Simultaneity in Concurrent Engineering", *Concurrent Engineering in Construction*, Proceedings of 1<sup>st</sup> International Conference organised by The Institution of Structural Engineers Informal Study Group on Computing in Structural Engineering, 3 & 4 July 1997, London, pp.1-12.

Rezgui, Y.; Cooper, G.; Yip, J. and Brandon, P. (1997), "Construction Collaborative Engineering in a Concurrent Multi-actor Environment", *Concurrent Engineering in Construction: Proceedings of 1<sup>st</sup> International Conference*, Anumba, C. J. & Evbuomwan, N. F. O. (Eds.), IStructE, London, 3 – 4 July 1997, 183 – 194.

Sharon, A. (1992), "The Biggest Bottlenecks in concurrent engineering", IFIP working conference on Manufacturing in the Era of Concurrent Engineering, Herzlyia, Israel 13-15 April 1992, Halevi, G. & Weill, R. D. (Eds.), Elsevier science publisher, BV (North-Holland) pp. 5-13.

SPICE Questionnaire (1998), *Key Construction Process Questionnaire*, Ver. 1.0, Salford University, July 1998.

Sya, C. S. (1997), "Concurrent Engineering: Key Issues in implementation and practice", *Concurrent Engineering in Construction*, Proceedings of 1<sup>st</sup> International Conference organised by The Institution of Structural Engineers Informal Study Group on Computing in Structural Engineering, 3 & 4 July 1997, London, pp.13-21.

Tesch, R. (1990), "Qualitative Research: Analysis Types and Software Tools", Falmer, London.

Thamhain, H. J. (1994), "Concurrent Engineering: Criteria for Effective Implementation", *Industrial Management*, Vol. 36, No. 6, Nov./Dec. 1994, pp. 29-32.

ToCEE (1997), ToCEE European Project for Concurrent Engineering, *ToCEE Information Document*, 1997.

Tummala, V. M. R.; Chin K. S. and Ho S. H. (1996), "Assessing Success Factor for Implementing CE: A Case Study in Hong Kong Plastic Products Industry Using AHP", *Advances in Concurrent Engineering, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering: Research & Applications*, University of Toronto, Ontario, Canada, 26-28 August 1996, pp.395-402.

Wailles, M. K.; Tizani, W.; Nethercot, D. A. and Smith, N. J. (1997), "The Integration of Tools for Concurrent Design and Fabrication of Steel Structures", *Concurrent Engineering in Construction: Proceedings of 1<sup>st</sup> International Conference*, Anumba, C. J. & Evbuomwan, N. F. O. (Eds.), IStructE, London, 3 – 4 July 1997, 100 – 108.

Winner, R. I.; Pennell, J.P.; Bertrend, H.E. and Slusarczuk, M. M. G. (1988), "The Role of Concurrent Engineering in Weapons System Acquisition", *IDA Report R-338*, Institute for Defence Analyses, Alexandria, VA.

Wognum P. M.; Stoeten, B. J. B., Kerkhof M and de Graaf, R. (1996), "PMO-RACE: A Combined Method for Assessing Organisations for CE", *Advances in Concurrent Engineering, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering: Research & Applications*, University of Toronto, Ontario, Canada, 26-28 August 1996, pp.113-120.

Yin, R. K. (1989), *Case Study Research: Design and Methods*, Applied Social Research Methods Series, Vol. 5, Sage Publications, 1989.

Young, R. I. M. (1999), "Organisational Issues in Concurrent Engineering", Department of Manufacturing Engineering, Loughborough University, Lecture Notes, Section 2, pp. 8 – 15.

## **Bibliography**

Amor, R. and Anumba, C. J. (1999), "A Survey and Analysis of Integrated Project Databases", *In Proceedings of Concurrent Engineering in Construction*, Bath, UK, September 1999, pp. 217-227.

Anon (1993), "CIMOSA: Open Systems Architecture for CIM "(2nd ed.), Commission of the European Communities, Scientific & Technical Communications Unit, DG XIII, Luxembourg.

Anumba, C. J. (1996), "Functional Integration in CAD Systems", *Advances in Engineering Software*, Vol. 25, pp. 103-109.

Anumba, C. J.; Baron, G. and Duke, A. (1997), "Information and communication technologies to facilitate Concurrent Engineering in Construction", *BT Technical Journal*, July 1997, Vol.15, No.3, pp.199-207.

Anumba, C. J., Baron, G. and Evbuomwan, N. F. O, "Communications Issues in Concurrent Life-Cycle Design and Construction", *BT Technology Journal*, Vol. 15, No. 1, 1997, pp. 209-216.

Anumba, C. J. and Duke A. (1997), "Structural Engineering in Cyberspace: Enabling Information and Communication Technologies", *The Structural Engineer*, Vol. 75, No.15, August 1997, pp 259-263.

Anumba, C. J. and Evbuomwan, N. F. O., "A Conceptual Model for Construction Clients' Requirements Processing", *Computing in Civil Engineering: Proceedings of the third ASCE Congress*, Anaheim, California, June 17-19, 1996, 431-437.

Anumba, C. J. and Evbuomwan, N. F. O. (Editors), 1997, "Concurrent Engineering in Construction", Proceedings of 1<sup>st</sup> International Conference organised by The Institution of Structural Engineers Informal Study Group on Computing in Structural Engineering, 3 & 4 July 1997, London.

Anumba, C.J.; Evbuomwan, N.F.O. and Kamara, J.M (1997), 'The Principles and Applications of Concurrent Engineering' *University of Teeside Technical Report No. 97/1*

Anumba, C. J., Kamara, J. M. and Evbuomwan, N. F. O., "Encapsulating the 'Voice of the Customer' in Construction Projects", *Proceedings of the 12th ARCOM Conference*, Sheffield Hallam University, 11-13 September, 1996, pp. 170-179.

Anumba, C. J.; Kamara, J. M. and Evbuomwan, N. F. O. (1997), "Construction in the UK Petrochemical Industry – Aspects of Concurrent Engineering Practices", Proceedings of the 1997 4<sup>th</sup> Congress on Computing in Civil Engineering, 16-18 June 1997, in *Journal: Computing in Civil Engineering*, ASCE, New York, pp.114-121.

Anumba C.J and Newnham L. (1998) "Towards the use of Distributed Artificial Intelligence in Collaborative Building Design", Proceedings of First International Conference on New Information Technologies for decision Making in Civil Engineering, Miresco, E. T. (Ed.), Montreal, Canada, 11-13 Oct. 1998, pp. 413-424.

Anumba, C. J.; Siemieniuch, C. E. and Sinclair, M. A. (1999), "Supply Chain Implications of Concurrent Engineering", International Journal of Physical Distribution and Logistics Management, (in press).

Backhouse, C. J. & Brookes, N. J. (Editors), 1996, "Concurrent Engineering – What's Working Where", The Design Council, Gower.

Bergring J. and Andersin H., "Design performance measurement systems for improving the visibility of the concurrent engineering process," Concurrent Engineering: Research and Applications Conference, 1994, Pittsburgh, PA, August 1994, p.61-68.

Bordass, B. and Leaman, A. "From Feedback to Strategy", Paper presented at, Buildings in Use '97, Commonwealth Institute, London, February 25, 1997.

Buchanan, D. and Huczynski, A. (1991), Organisational Behaviour, pp. 453, 532-534, Prentice Hall International, UK

Camp R. C. (1989), "Benchmarking: The Search for Industry Best Practices that Leads to Superior Performance", Quality Press.

Cockshaw, A., "The Partnership Approach", Redefining the Design Team, Discussion Meeting, Interdisciplinary Design for the Built Environment, The Royal Academy of Arts, Burlington House, Piccadilly, London, 16 October, 1995, pp. 8-10.

Creswell, John W. (1994), Research Design: Qualitative and Quantitative Approaches, Thousand Oaks, SAGE Publications, California & London.

Crowley, A. J.; Watson, A. S. and Christodoulakis, D. (1997), "From data exchange to information sharing", Concurrent Engineering in Construction, Proceedings of 1<sup>st</sup> International Conference organised by The Institution of Structural Engineers Informal Study Group on Computing in Structural Engineering, 3 & 4 July 1997, London, pp.,131-140.

Davis, T. (1993), "Effective supply chain management", Sloan Management Review, Summer, pp.35-46.

de Graaf, R. (1996), "Assessing Product Development, Visualising Process & Technology Performance with RACE".

de Graaf, R and Kornelius, L (1996), "Inter-organisational CE: A Case Study in PCB Manufacturing", Computers in Industry, Vol.30, No.1, 1996, pp.37-47.



de Graaf, R. and Muller, P.C. (1995), "NewProd and RACE: Complementary Tools for Diagnosing & Improving New Product Development Performance", Proceedings of ISPIM Conference 1995, Rome.

Dong, J. (1995), "Organisation Structures, Concurrent Engineering, and Computerized Enterprise Integration", Concurrent Engineering Research and Applications, Vol.3, No. 3, pp167 - 173

Edum-Fotwe, F. T.; Thorpe, A. and McCaffer, R. (1999), "Organisational Relationships within the Construction Supply-Chain", Proceedings of a Joint Triennial Symposium, Cape Town: 5-10 September 1999, Vol. 1, pp. 186-194.

Ekvall, G. (1993), "Creativity in Project Work: a longitudinal study of a product development project", Creativity and Innovation Management, 2(1), pp.17-26.

Evans, S. (1991), "Changing your Way to a Better Business", Engineering Computers, May 1991, pp. 12-17.

Evbuomwan, N. F. O. and Anumba, C. J. (1996), "Towards an Integrated Engineering Design Environment", Information Representation and Delivery in Civil and Structural Engineering Design, Kumar, B. and Retik, A. (Eds.), Civil-Comp Press, pp. 127-134.

Evbuomwan N. F. O. & Anumba, C. J., "A Software Architecture for Concurrent Life-Cycle Design and Construction", *Computing in Civil Engineering, Proceedings of the Third ASCE Congress held in Anaheim, California*, June 17-19, 1996, pp. 424- 430.

Evbuomwan, N. F. O & Anumba, C. J., "Towards a Concurrent Engineering Model for Design-and-Build Projects", *The Structural Engineer*, Vol. 74, No. 5, 1996, pp. 73-78.

Evbuomwan, N. F. O., Sivaloganatham, S. and Jebb, A. (1994), "A state of the art report on concurrent engineering", in Paul, A.J. and Sobolewski, M. (eds.), 'Proceedings of the 1st International Conference on Concurrent Engineering, Research and Applications', pp 35-44

Fellows, R. and Liu, A. (1997), "Research Methods for Construction", Blackwell Science, Oxford.

Fernie, S.; Root, D. and Thorpe, A. (1999), "Supply Chain Management – Theoretical Construct for Construction", *Information and Communication in Construction Procurement*, CIB W92 Procurement System Symposium, Serpell, A. (Ed.), Pontificia Universidad Catolica de Chile, 2000, pp. 541-556.

Fojt, M. (1996), "Briefings. Supplier alliance: Chrysler-MAGANA International", *Logistics Information Management*, Vol. 9, No. 5, pp.55-56.

Gu, P. and Kusiak, A. (1993), "Concurrent Engineering: Methodology and Applications", Elsevier, Amsterdam & London.

Hannus, M.; Huovila, P.; Lahdenpera, P.; Laurikka, P. and Seren, K (1997), "Methodologies for Systematic improving of Construction Processes", Concurrent Engineering in Construction, Proceedings of 1<sup>st</sup> International Conference organised by The Institution of Structural Engineers Informal Study Group on Computing in Structural Engineering, 3 & 4 July 1997, London, pp.55-64.

Harding, J. A. and Popplewell, K. (1996), "Driving Concurrency in a Distributed CE Project Team: A Specification for an Engineering Moderator", International Journal of Production Research, Vol. 36, No.3, pp. 841-861.

Henry, R. M. (1993), "Role of Advanced Computer Technology in Construction Industry", Journal of Computing in Civil Engineering, Vol. 8, No. 3, July 1994.

Holberton, S. (1991). "Let's do this in stages". Financial Times, London.

Jones, G., George, J. and Hill, C. (1998), *Contemporary Management*, pp 53-54, 233-259, McGraw-Hill, USA

Kamara, J. M., Anumba, C. J. and Evbuomwan, N. F. O., "The Importance of Client Requirements Processing in Concurrent Engineering", *7th International Conference on Flexible Automation and Intelligent Manufacturing*, Middlesbrough, 25-27 June, 1997.

Kamara, J. M.; Anumba, C. J. and Evbuomwan, N. F. O. (1998), "Tools for Client Requirements Processing in Construction Life-Cycle Design and Construction", in Horvath, I. and Taled-Bendiab, A. (Editors.), 2<sup>nd</sup> International Symposium on Tools and Methods for Concurrent Engineering, 21-23 April, Manchester, UK, pp. 73-83.

Kamara, J. M.; Anumba, C. J. and Evbuomwan, N. F. O. (2000), "Developments in the Implementation of Concurrent Engineering in Construction", International Journal of Computer Integrated Design and Construction, Vol.2, No.1, Feb. 2000, pp.68 – 78.

Kusiak, A. (Ed.), 1993, "Concurrent Engineering: Automation, Tools, and Techniques", Wiley, New York & Chichester.

Laudon, K. C. and Laudon, J. P. (1996), "Management Information Systems: Organisation and Technology", 4<sup>th</sup> ed., Prentice Hall, New Jersey.

Laudon, K. C. and Laudon, J. P. (1998), "Management Information Systems: New Approaches To Organisation And Technology", 5th ed. Prentice Hall, New Jersey.

Love, P. E. D.; Gunasekaran, A. and Li, H. (1998), "Concurrent Engineering: A Strategy for Procuring Construction Projects", International Journal of Project Management, Dec. 1998, Vol.16, No.6, pp.375-383.

Medhat, S. (Ed.) (1997), "Concurrent Engineering: The Agenda for Success", Research Studies Press Ltd., UK.

Melham A (1999), "Intelligent Agents", Available at Construction-IT web site:  
<http://www.construct-it.salford.uk>

Melling, T. ; Lomax, J. ; Cather, H. and Koshal, D. (1996), "The Use of Simulation Techniques in the Implementation of Concurrent Engineering in Small to Medium Sized Enterprises", Advances in Concurrent Engineering, Proceedings of 3<sup>rd</sup> ISPE International Conference on Concurrent Engineering: Research & Applications, University of Toronto, Ontario, Canada, 26-28 August 1996, pp. 352-359.

Miah T., Carter C., Thorpe A., Baldwin A. and Ashby S. (1998), "Wearable Computers - An Application of BT's Mobile Video System for the Construction Industry", BT Technology Journal, Vol. 16, no. 1, Jan 1998.

Mintzberg, H. (1979), The Structuring of Organisations, pp 2, 6, 9-11, 65-68, 181-183, Prentice Hall, New Jersey

Munn, P. & Drever, E. (1995), "Using Questionnaires in Small-Scale Research: A Teacher's Guide", Scottish Council for Research in Education, Edinburgh.

Naoum, S. G. (1998), "Dissertation Research and Writing for Construction Students", Butterworth-Heinemann, Oxford.

Nicholas, J. M. (1994), "Concurrent Engineering: Overcoming Obstacles to Teamwork", *Production & Inventory Management Journal* - Third Quarter, pp18 - 22

Parsaei, H. and Sullivan, W. G. (Ed.) (1993), "Concurrent Engineering – Contemporary Issues and Modern Design Tools", 1<sup>st</sup> ed., Chapman & Hall, London.

Pearson, J. N. and Ellram, L. M. (1995), "Suppliers Selection and Evaluation in Small versus Large Electronics Firms", *Journal of Small Business Management*, January 1997, Vol. 33, pp. 53-65.

Peppard, J. (1993) "IT Strategy for Business", Pitman, London.

Prasad, B. (1995), "Is Planning a Strategic Requirement for CE Success?", *Concurrent Engineering: Research and Application*, Vol. 3, NO. 3, 1995.

Prasad, B. (1996), "Concurrent Engineering Fundamentals Vol.1: Integrated Product and Process Organization", Upper Saddle River, Prentice Hall, NJ.

Prasad, B. (1997), "Concurrent Engineering Fundamentals Vol.2: Integrated Product Development", Upper Saddle River, Prentice Hall, NJ.

Rawcliffe and Randall (1989), "CE Applied to an SDIO Technology Programme", AAIA/ADP/NSIA, First National TQM Symposium, 1989.

Roger, A. S. (1994), "Virtuosi – Virtual Reality Support for Groupworking", BT Technology Journal, Vol. 12, No. 3, July 1994.

Rogers, P. "The Client and the Design Team", Redefining the Design Team, Discussion Meeting, Interdisciplinary Design for the Built Environment, The Royal Academy of Arts, Burlington House, Piccadilly, London, 16 October, 1995, pp. 11-13.

Sako, M. (1992), "Prices, Quality and Trust – Inter-firm Relations in Britain and Japan", Cambridge University Press.

Schermerhorn, J. (1993), Management for Productivity, pp 271-290, 311-315, 670-671, Wiley, New York

Schrijver, R & de Graaf, R (1996), Development of a tool for benchmarking for CE, Concurrent Engineering: Research & Applications, Vol.4, No.2, 1996, pp.159-170.

Scott, W. R. (1992), Organisations, Rational, Natural and Open Systems, pp. 88-90, Prentice Hall Inc., New Jersey

Senior, B. (1997), Organisational Change, pp. 7-9, 56-58, 87-88, 222-223, Pitman, London

Segars, A. H. and Grovers, V. (1996), "Designing Company-wide Information System", Long Range Planning, Vol. 29, No. 3, pp. 381-392.

Siemieniuch, C. E. and M. A. Sinclair (1999). "Implications Of The Supply Chain For Role Definitions In Concurrent Engineering." International Journal of Human Factors in Manufacturing, (in press).

Siemieniuch, C. E., M. A. Sinclair, et al. (1997). "Supply chains in the fast-moving consumer goods industry", 13th Triennial Congress of the International Ergonomics Association - IEA'97, Tampere, Finland, June 29 - July 4th 1997, Finnish Institute of Public Health.

Sinclair, M. A. (1990). "Subjective assessment", Evaluation of human work, Wilson, J. R. and Corlett E. N. (Ed.), London, Taylor & Francis: 58-88.

Sinclair, M. A. and C. E. Siemieniuch, (1995). "A Discussion of Simultaneous Engineering and the manufacturing supply chain, from an Ergonomics Perspective." International Journal of Industrial Engineering, 16(4-6): 263-282.

Software Process Maturity Questionnaire, CMM, Ver. 1.1, April 1994.

Spekman, R. E. ; Kamauff Jr., J. W. and Myhr, N. (1998), "An empirical investigation into supply chain management – A Perspective on Partnerships", International Journal of Physical Distribution and Logistics Management, Vol. 28, No. 8, 1998, pp 630-650.



Schrijver, R & de Graaf, R (1996), "Development of a tool for benchmarking for CE",  
Concurrent Engineering: Research & Applications, Vol.4, No.2, 1996, pp.159-170.

Software Process Maturity Questionnaire, CMM, Ver. 1.1, April 1994.

Stecher, Brian M. & Davis W. Alan, (1987), "How to Focus an evaluation", Newbury  
Park, SAGE, California.

Sudman, Seymour & Bradburn, Norman M. (1982), "Asking questions", Jossey-Bass,  
San-Francisco & London.

Sudweeks, F. and Allbritton, M. (1996), "Working Together Apart: Communication and  
Collaboration in a Network Group", Proceedings of 7<sup>th</sup> Australasian Conference of  
Information Systems, Vol. 2, pp. 701-712.

Thorpe A., Baldwin A., Cater C., Leever D. and Madigan D. (1995), "Multimedia  
Communications in Construction", In Proceedings of the Institution of Civil Engineers,  
1995, vol. 108, issue 1.

Tonarelli, P.; Ferries, B. ; Delaporte, J. L. and Tahon, C. (1995), "Technical and  
Economic Design Support System in Construction within the context of Concurrent  
Engineering", Building Research and Information, Nov.- Dec. 1995, Vol.23, No.6,  
pp.324-339.

Towill, D. R. (1996), "Time Compression and Supply Chain Management – A Guided Tour", Supply Chain Management, Vol. 1, No. 1, pp. 15-27, MCB University Press Ltd.

Tucker, D. E. & Leonard, R. (1994), "Overcoming the Cultural Barriers to Implementing Concurrent Engineering", Advances in Agile Manufacturing, pp. 67-70.

Usher, John M.; Roy, Utpal & Parsaei, Hamid (Editors), 1998, "Integrated Product & Process Development – Methods, Tools and Technologies", John Wiley & Sons Inc., USA.

Watson, G. H. (1993), "Strategic Benchmarking: How to Rate your company's Performance against the World's Best", John Wiley and Sons, Inc.

Zhang, D. and Zhang, H. C. (1995), "Concurrent Engineering : An Overview from Manufacturing Engineering Perspectives", Concurrent Engineering Research and Applications, Vol. 3, No.3, pp 221 – 231.

## Appendix 1

### *BEACON Model Questionnaire*

## **BEACON Model Questionnaire**

(Version 1.0, May 2000)

The BEACON model is designed to assess the readiness of a construction organisation for the adoption of Concurrent Engineering<sup>1</sup> (CE). The questionnaire assesses the organisation under four key elements, which are Process, People, Project and Technology.

The questionnaire itself is sub-divided into five sections. The first section (section A) collects background information for administrative purposes only. The rest of the sections (i.e. section B, C, D and E) cover the four elements of the model.

Please answer all questions and tick only one box for each question. If there is any question, which is not applicable to your organisation, then please state this in the comments area against that question and do not tick any of the boxes. Your answers will be held in strict confidence. Please go through first to Appendix B for important definitions.

A combined assessment result, in the form of a radial plot on the BEACON model (see Appendix A) and a brief commentary on areas for improved organisational effectiveness, will be sent to you shortly.

Thank you for your kind assistance in participating in this assessment.

Malik M. A. Khalfan

PhD. Research Student @

**Department of Civil and Building Engineering,**

Loughborough University, Loughborough University,  
Leicestershire, LE11 3TU  
United Kingdom.

---

<sup>1</sup> According to Winner et al. (1988), Concurrent Engineering is a “...systematic approach to integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life-cycle from conception through disposal, including quality, cost, schedule, and user requirements.”

## **Section A: Background Information**

Name & Location of the Organisation: \_\_\_\_\_

\_\_\_\_\_

Your Name (optional): \_\_\_\_\_

Current Job Title: \_\_\_\_\_

Job Description: \_\_\_\_\_

\_\_\_\_\_

Type of your Organisation (e.g. Design Consultant, Contractor, etc.): \_\_\_\_\_

\_\_\_\_\_

Total No. of Employees: \_\_\_\_\_

Annual Turnover: \_\_\_\_\_

Any Speciality within Construction Industry  
(e.g. Housing, Commercial Sector, etc.): \_\_\_\_\_

\_\_\_\_\_

Date: \_\_\_\_\_

Contact Details (optional):

Phone: \_\_\_\_\_ Fax: \_\_\_\_\_

E-Mail: \_\_\_\_\_

Rank the 4 Key Elements of the Model (with 1 for the most important) from your organisation's point of view.

- |              | <i>Rank</i> |
|--------------|-------------|
| • Process    | _____       |
| • People     | _____       |
| • Project    | _____       |
| • Technology | _____       |

## Section B: Process Element

### **B1. Management Systems**

The purpose of assessing the Management Systems is to ensure that the management systems are designed and implemented to enable project teams to be successful in their objectives, and are improved continuously through feedback and periodic reviews. Management systems include planning, scheduling, controlling and tracking of a project development process, resource planning, contract management, performance measurement, financial accounting system, risk management, contingencies plans etc.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. Project estimates and schedules are documented for use in controlling and tracking a Project Development Process (PDP).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Adequate resources are provided for planning any project (e.g. funding, experienced individual etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Project Development Team (PDT) keeps time margin in the schedules for contingencies.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. There is an organisational policy for managing contracts and sub-contracts.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. The activities and performance of contractors and sub-contractors are reviewed on both periodic and event-driven basis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Similar resource allocation procedures are followed within the organisation for each project (e.g. allocation is based on the level of technical difficulty to each activity of any project etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. It is possible to carry out an analysis of the impact of resource allocation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. A standardised and reliable project financial accounting & management system is used on all projects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. The project financial accounting & management system is integrated with an overall project management system.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. A risk management plan is prepared for each project, which is used to monitor the project development process and quantify project risk factors.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
11. Trade-off studies are conducted to identify the risks associated with new technologies.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12. Corrective actions are taken when actual results differ significantly from project plans.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
13. Senior management reviews activities used for planning any project on both periodic and event-driven basis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Section B: Process Element

### **B2. Process Focus**

The aim of checking the Process Focus is to verify that the project development process is documented and flexible enough to adapt to changes in the client's requirements, personnel etc. It ensures that the process is evaluated and improved periodically through analysing the past decisions and reusing past processes.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. The Project Development Process (PDP) is documented.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. The process documentation is kept in electronic form, and is accessible to the Project Development Team (PDT) members.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Similar processes are used on different construction projects (i.e. process reuse).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. Past decisions are analysed to discover lessons learnt, which can help to improve the PDP continually.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. Procedures are used to evaluate and improve the PDP periodically.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Data is collected to measure the effectiveness of the PDP.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. There is an individual or a group responsible for focusing on improving the project development process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. The PDP is flexible such that it is adaptable to changes (e.g. changes in projects, personnel, client's requirements etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. The critical process activities are identified at the beginning of the PDP.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. The critical process parameters are identified at the beginning of the PDP.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
11. The critical process parameters are continuously modified to optimise cost, quality and time.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12. Processes and sub-processes are carried out as concurrently as possible.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
13. Non-value adding processes are eliminated from the PDP whenever possible.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section B: Process Element

### **B3. Organisational Framework**

The objective of evaluating the Organisational Framework is to confirm that there are organisational policies which assist in controlling and monitoring of a project development process, and support teams to do resources allocation, conflict resolution, and improve individual and team performance.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. A documented project brief is established at the beginning of each project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. The activities for managing and updating the project brief are subjected to quality assurance review.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. There are organisational policies, which assist the monitoring and controlling of continuous improvements in management systems and technology.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The organisation analyses the value added by each project development activity.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. There are policies, which support the teams to do resource allocation and trade-offs (resources such as budget, labour etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. There is adequate organisational support to resolve conflicts within the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. The organisational environment supports individuals to perform different jobs.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. The organisational environment supports members of a project development team and sub-teams to work as individuals, or as a group, and transitions between these two types of working.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. The organisational environment supports each individual's preferred manner of working.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. The organisational structure is flexible and supports a variety of project and process requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



## Section B: Process Element

### **B4. Strategy Deployment**

The purpose of assessing the Strategy Deployment is to ensure that the business strategy is clear, consistent, and focuses on the improvement of a project development process. It also ensures that teams are set up to address client's requests, and to identify & prevent future problems.

	Always	Most of the Time	Sometimes	Rarely	Never	Comments
1. The senior management has a clear business strategy for each project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. The strategy is consistent with organisational business policy.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. The strategy focuses on the improvement of the project development process of each project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The strategy encourages people to resolve issues at the lowest appropriate level of the organisation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. The human resource policies support the strategy and are improved continuously.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Teams involve few members to identify and prevent future problems related to the project development process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. Teams are set up to address client's requests regarding the project development process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Senior Management focuses on the improvement of management systems of each project within the organisation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. Senior management ensures that any crisis will not disrupt the project development process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. The problems faced during the project development process are monitored until they are resolved.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## Section B: Process Element

### **B5. Agility**

The aim of evaluating the Agility is to confirm the ability of an organisation to respond gracefully to changes in a project development process, and making sure that the assets are reused. It also evaluates whether the corporate memory of the organisation is maintained and made available to all members of the project development team and sub-teams.

	Always	Most of the Time	Sometimes	Rarely	Never	Comments
1. Documented procedures are used for ensuring that the organisation can respond to changes in the project development process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. The time to respond to the changes in client requirements is improved for new projects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Each sub-team concurrently makes trade-off decisions in response to the changes in the client's requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The project development process is flexible enough to incorporate changes in the client's requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. The project development process documentation is maintained electronically and accessible to all members of the team.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. The project development process documentation includes information on the decisions made during the process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. A corporate memory of the organisation is maintained.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. The corporate memory is made available to all members of the project development team.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. Assets and resources are re-used for new projects (e.g. machinery, facility design, construction tools and material, computers etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. The project development team makes use of past project information (e.g. design, trade studies, construction constraints, etc.) to plan for changes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section C: People Element

### ***C1. Team Formation and Development***

The basic purpose of assessing the Team Formation & Development is to confirm whether the organisation has strategies for team formation and development, and is arranging training sessions for team members to upgrade their technical skills. It also assesses whether each member of the project development team and sub-teams understands his/her responsibilities, has common purpose, and interacts with others on continuous basis.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. The Project Development Team (PDT) is formed in such a way that it has representation from each sub-teams (e.g. design team, M & E team, Q/S team etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. The PDT and sub-teams are comprised of individuals who are enthusiastic and specialised in their respective field.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. All members of the teams continually interact rather than just at key decision points.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. Each team member clearly understands his/her responsibilities.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. There is a common purpose within the teams for a specific project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Organisational policies encourage the teams to achieve different goals.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. There is an organisational policy to arrange training programmes for the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Adequate resources are available to implement the training programme (e.g. funding, appropriate training facility etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. All the members of the teams receive regular training to upgrade their technical skills and improve their teamworking.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. Team training is evaluated for its effectiveness.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section C: People Element

### **C2. Team Leadership and Management**

The objective of evaluating the Team Leadership & Management is to ensure that selection of team leaders is on the basis of their technical and managerial skills. It also ensures that the team leaders are responsible for the completion of a project and have authority to enlist new members and take team related decisions.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. Team leaders of a Project Development Team (PDT) and sub-teams are selected on the basis of their technical and managerial skills.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Team leaders are responsible and accountable for the completion of the tasks and activities on time and within the budget.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Team leaders have the authority to enlist new team members.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The leader of the PDT works as a project manager and is responsible for controlling, organising, directing and planning a Project Development Process (PDP).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. Team leaders take final decisions for all the project and team-level issues.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Team leaders consult senior management before taking any team-level decision.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. Senior management monitors progress of both the PDP and the PDT.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Senior management attempts to resolve issues at the lowest appropriate level of the organisation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Section C: People Element

### ***C3. Discipline***

This is intended to verify that all members of a team abide by the disciplinary rules and regulations, and are committed to and share team rules. It ensures that team members submerge their individual agendas and stick together when difficult issues arise.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. All members of teams abide by the disciplinary rules and regulation set by the organisation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. All members of the teams (including team leaders) are committed to and share team rules.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Members submerge their individual agendas and operate in the best interests of the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The team members stick together even when difficult issues arise.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. Team meetings follow a set of rules of behaviour.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. There is an organisational commitment to deal with disciplinary problems promptly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. There is an established grievance procedure.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Senior management ensures that the project team follows established procedures to deliver value to the client.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## Section C: People Element

### **C4. Teams in an Organisation**

This checks the extent to which there are diverse disciplines and specialist groups working as sub-teams. It ensures that the teams have authority and can easily communicate with each other. It also ensures that there are policies to measure team performance and to plan and conduct peer-reviews within the teams.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. There are diverse disciplines and specialist groups within the organisation, which work as sub-teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. The sub-teams focus on their specific disciplinary tasks and support the project development team.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. The teams have the authority for technical and cost decisions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The teams have the authority to reward their team members.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. There are rewards for acting as a team member instead of looking out for individual interests.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. It is easy for members of the teams to collocate.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. It is easy for the teams to communicate and share information with each other.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Each team is accountable for achieving success with respect to a specific project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. There are organisational policies to measure team performance and support teamwork.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. The performance of the teams is crucial to an individual's career success.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
11. There is an organisational commitment to provide adequate and specific training to individuals to perform their roles within the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12. There is an organisational policy to plan and conduct peer reviews within the teams to eliminate defects from an activity output early and efficiently.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section D: Project Element

### **D1. Client Focus**

The Client Focus factor ensures that the client is a part of the project development team throughout the design and construction phases of the facility. It also ensures that all project decisions are prioritised based on client's needs, and all members of the teams understand the client's requirements and respond appropriately to changes in client's requirements.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. The client is continuously involved throughout a Project Development Process (PDP) as a member of a Project Development Team (PDT).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Well-documented procedures and guidelines are followed in gathering the requirements from the client.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. All members of the PDT and sub-teams clearly understand the client's requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The prioritisation of all project decisions is based on the client's requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. Similar guidelines are followed throughout the organisation for interacting with the client.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Computer-based tools are used to assist in eliciting and disseminating requirements from clients.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. The teams can access the client's requirements at any time during the project development process.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. The teams respond appropriately to changes in client's priorities.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. Procedures are used to evaluate how well the team is accommodating new client priorities.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. Procedures are used to evaluate whether the client's requirements are met.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
11. Computer-based tools are used to assist in evaluating whether the client's requirements are met.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section D: Project Element

### **D2. Quality Assurance**

The objective of checking the Quality Assurance is to confirm that project standards and quality assurance activities are adopted and maintained. It also confirms that there are policies to ensure required project quality and analyse feedback from the construction site.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. Internally developed project standards used during both design and construction phase of a project are well established and well recognised.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Project standards are maintained and accessible to all the members of the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Quality Assurance (QA) activities, which confirm that a completed project and its process comply with applicable procedures and standards, are used.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. All changes and variations to a project are subjected to QA review and audit.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. There is an organisational policy to ensure required project quality by implementing quality management techniques.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Methods are used to ensure the required quality of materials before construction, for every project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. There are standard methods for collection and analysis of site failure data for feedback to the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. There are procedures available to check progress of project development process against quality, cost, time, and specification on both periodic and event-driven basis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



## Section D: Project Element

### **D3. Facility Design**

The aim of the Facility Design factor is to verify that preliminary designs of the facility are prepared and discussed before entering into the final design and construction phases and relevant past designs are also consulted and used to design the current facility. It also ensures that the design of the facility is flexible enough to address any changes, and encourages repetitive and standard construction procedures.

	Always	Most of the Time	Sometimes	Rarely	Never	Comments
1. Key interfaces during the Project Development Process (PDP) are strategically defined at the beginning of a project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Preliminary designs and drawings of a facility are prepared before entering into the final design and construction phases of a project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. All the members of a Project Development Team (PDT) analyse the preliminary design and give comments and suggestions on how to overcome any downstream problems, and that it confirms to the client's requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. There is an organisational policy to ensure that the client is satisfied with the preliminary design of the facility.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. Relevant past designs are consulted and reviewed to develop the current project design and drawings.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. The facility design is flexible enough to address changes in the client's requirement.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. Design approaches (such as standardisation, modularization etc.) are adopted for the facility design.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. The facility design encourages repetitive and standard procedures of constructing an element to reduce complexity during the construction phase.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. The facility design is not only maintained in the form of drawings on sheets but also in an electronic form.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Section E: Technology Element

### ***E1. Communication Support***

Communication Support is concerned with ensuring that the interaction between team members by electronic mean and all team members are connected to each other in a network. It also explores the extent to which team members use e-mail facilities, exchange project data over a network, and use computers for virtual meetings and interaction.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. All members of the teams are connected to each other in a network while working on the same project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Electronic mail capabilities are used by each individual to communicate.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. All members of the Project Development Team (PDT) and sub-teams exchange project data over the network.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. It is possible for members of the teams to share application programmes over the network.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. It is possible to exchange graphics, voice, still video, and real-time video files related to the project over the network.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Communication within and between the teams is via computer.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. Computer tools are used for better interaction between the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Systems exist within the organisation, which support person-to-person, person-to-computer, and computer-to-computer interaction.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. The network used for communication is very transparent.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. Computers based virtual meetings and interaction between PDT members take place as often as face-to-face meetings.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section E: Technology Element

### **E2. Co-ordination Support**

The aim of evaluating the Co-ordination Support is to confirm that the project data is available electronically in the form of central project model, which facilitates co-ordination of all members of teams. It ensures the availability of systems that are used to support project monitoring, conflict recognition, resolution, negotiation, and trade-offs among the teams.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. Project data is electronically available to all the project development team members.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Project workflow is managed on the network (e.g. electronic work orders etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. Tools and methods are used, which support sub-teams to carry out trade-off analysis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. A central project model is used to facilitate co-ordination of all the teams involved on a project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. A system is used for each project, which automatically updates the workflow and project data as activities are completed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. There are systems available within the organisation, which are used for supporting conflict recognition, resolution, negotiation, and trade-off among the teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. Computer-based tools are used to support the monitoring of a project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Tools used for project monitoring are continuously assessed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. Version control is strictly enforced for each project to ensure easy exchange of and access to project workflow and data.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section E: Technology Element

### **E3. Information Sharing**

This seeks to verify that the information required for the project development process is accessible in electronic form and is managed by an appropriate data base management system. It ensures that the advantage of multimedia technology is taken, master model of resource information is also used, and full corporate memory of relevant project information and decisions is maintained.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. The information required for the project development process is accessible in an electronic form to all members of a project development team.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. All information in electronic form is managed by an appropriate Data Base Management System (DBMS).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. There are IT systems available, which provide an integrated database view to the users.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The information sharing services take advantage of multimedia technology.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. The project information is stored as text, graphics, images, voice, and video files.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. A comprehensive master model of the project development process exists and is used for all projects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. A master model of organisational resource information is used for all projects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. Full corporate memory of relevant project information and decisions is maintained.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. A company intranet accessible to all staff is maintained.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. Use is made of the Internet for project communication.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
11. Appropriate communication systems are used to link up with other disciplines and organisations.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section E: Technology Element

### ***E4. Integration Support***

The aim of evaluating the Integration Support is to confirm that all members of teams are integrated through a shared integrated information model and all members of the teams use a common operating system. It also confirms that data translation techniques are used, and data exchange standards are supported.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. The organisation uses computers with a common operating system for all projects (e.g. UNIX, Macintosh, Windows, etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Members of the Project Development Team (PDT) and sub-teams are virtually integrated through the shared integrated information model, which is up-dated throughout a Project Development Process (PDP).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. The organisation's computer systems are linked together to minimise data re-entry and errors.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. The organisation has an approach to support standards for data exchange.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. All members of the PDT access data through a shared integrated information model.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. Data translation techniques are used while accessing data through the shared integrated information model.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. There are systems available to assist in translating data within the organisation as well as used when eliciting data from an outside source.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. The IT systems used by team members can be linked to those of the organisation's most frequent business partners.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Section E: Technology Element

### **E5. Task Support**

The purpose of assessing the Task Support is to ensure that CAD, simulation tools, and past design information are effectively used for facility design. It also ensures that available technology is improved and task support tools are evaluated to determine their effect on a project.

	Always	Most of the Time	Some-times	Rarely	Never	Comments
1. Systems exist within the organisation, which give historical design information applicable to the on-going project during its design phase.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2. Computer Aided Design (CAD) and simulation tools are used to check the constructability and sustainability of a project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3. CAD and visualisation tools are used to prepare design of the facility according to the client's requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4. CAD tools are used to permit an interactive and optimal design of the project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5. Computer-based tools are utilised for collaborative work during a Project Development Process (PDP).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6. There is an organisational policy to make and follow a plan for managing technology.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7. Senior management focuses on the improvements of the available technology (e.g. computers, site plants and equipment etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8. There is an organisational method for assessing new technology to assist in selection of technology for the PDP.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9. Task support tools used during the PDP (such as plant and equipment, computer software & hardware etc.) are the latest in their respective technologies.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
10. There are systems within the organisation (such as Intelligent Agents), which inform automatically to all the members of a project development team if there are any changes in the PDP (e.g. changes in facility design, client's requirements, resource allocation etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
11. There are tools, which utilise quantitative as well as qualitative information to assist decision-making.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

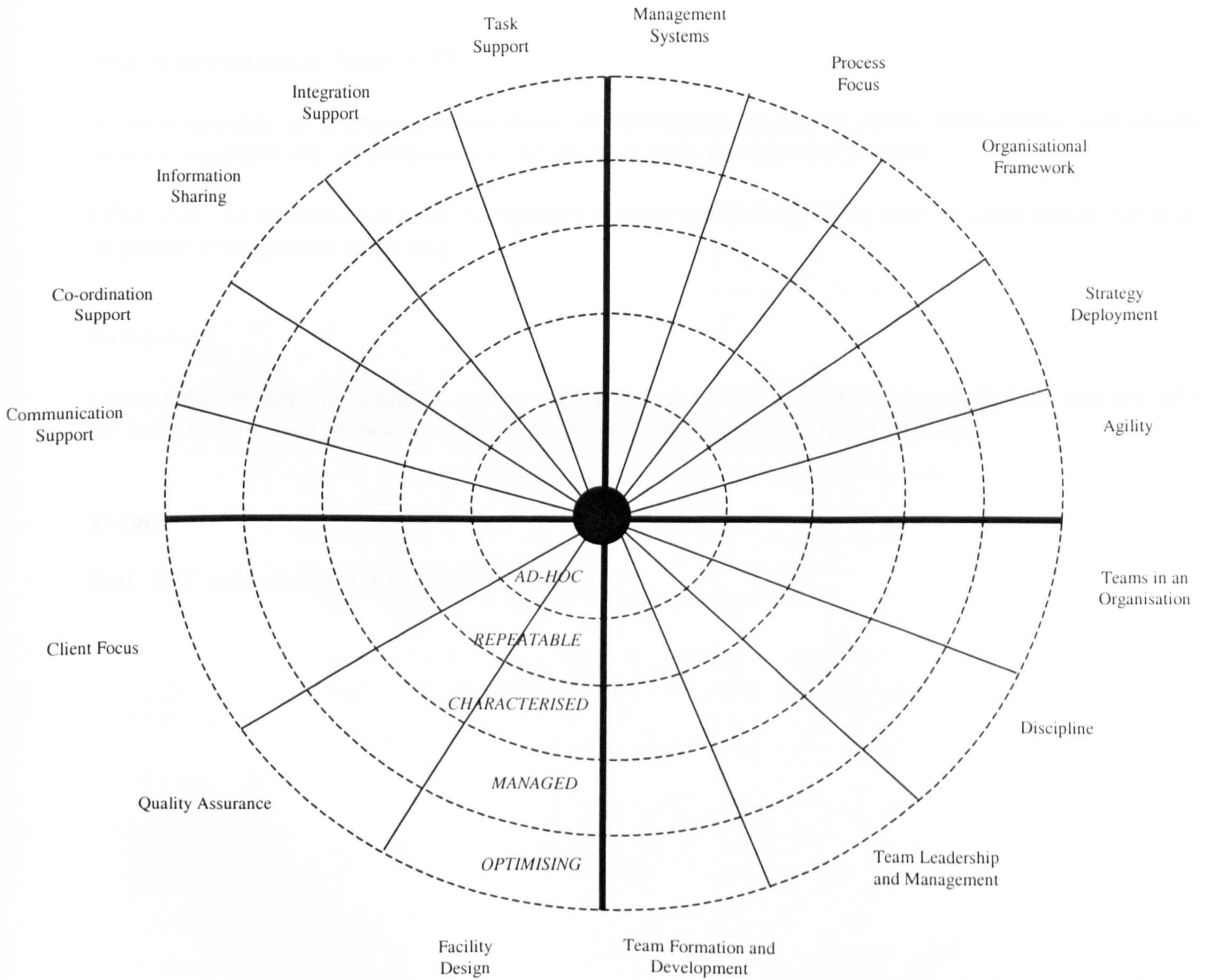
## Section E: Technology Element

	Always	Most of the Time	Some-times	Rarely	Never	Comments
12. Task support tools are evaluated to determine their effect on the project (e.g. quality, productivity, reduction in cost and time etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
13. The organisation adopts internal data exchange standards for every project.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**TECHNOLOGY ELEMENT**

**PROCESS ELEMENT**



**PROJECT ELEMENT**

**PEOPLE ELEMENT**



***Project Development Process (PDP):***

The whole process including both design and construction phases of a facility development.

***Project Development Team (PDT):***

A team consists of a representative from all disciplines including client, consultants, contractors, material suppliers etc. and responsible for whole project development process.

(This team can be termed as inter-disciplinary team or multi-disciplinary team or cross-functional team or project management team etc.)

***Sub-teams:***

Diverse disciplines and specialist groups are termed as sub-teams that are responsible for one task of a project like Q/S team or design team. All sub-teams have representation in a PDT.

***Teams:***

Both PDT and sub-teams are termed as teams.

## Appendix 2

### *A Sample Covering Letter for the Assessment Survey*

7<sup>th</sup> September 2000

Dear Sir/ Madam

I (Malik Khalfan, PhD Research Student) am conducting a survey questionnaire to assess the performance of the UK construction industry. The questionnaire is basically associated with a model called "BEACON" Model, which is developed by me and my supervisor Dr Chimay Anumba as part of my research.

A copy of the questionnaire is enclosed with this letter and I want someone within your organisation either from senior or middle management to fill this in and send it back to me when he/she gets it completed. It is estimated that it will take not more than 45 minutes to complete.

I can imagine the workload within your organisation and I will highly appreciate and remain grateful to you for helping me in my research by completing the questionnaire. I can assure you that the responses will be treated in the strictest confidence and will be used for academic purposes only.

Thank you for your time and I will be very happy to send you a summary of the results when they are ready. Please try to complete this questionnaire and send it back to me on address mentioned below by 22<sup>nd</sup> September 2000.

Thanks once again.

Yours Sincerely

Malik Khalfan

Department of Civil & Building Engineering,  
Loughborough University, Loughborough, Leics.  
LE11 3TU

Tel: 01509-263171 Ext. 4140

E-mail: M.M.A.Khalfan@lboro.ac.uk

## Appendix 3

### *Publications from the Research*

- **Innovation Award (Best Research Paper) by CIOB, March 2001.**
  
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M., *An Investigation of the Readiness of the Construction Industry for Concurrent Engineering*, Presentation on 19<sup>th</sup> April 2001, Chartered Institute of Building (CIOB), London, UK.**  
  
(see web-site: <http://www.ciob.org.uk/ps/documents/psKhalfan.pdf>).
  
- **Refereed Journal Papers**
  
- **Khalfan, M. M. A.; Anumba, C. J.; Siemieniuch, C. E. & Sinclair (2001), M. A., *Readiness Assessment of the Construction Supply Chain – A Necessity for Concurrent Engineering in Construction*, European Journal of Purchasing and Supply Management, Volume 7, Issue 2, Spring 2001, pp. 141-153.**
  
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001), *Development of a Readiness Assessment Model for Concurrent Engineering in Construction*, Benchmarking: An International Journal, Volume 8, Issue 3, 2001, pp. 223 - 239.**
  
- **Anumba, C. J.; Baugh, C. & Khalfan, M. M. A., *Organisational Structures to Support Concurrent Engineering in Construction*, Journal of Industrial Management and Data Systems (in press).**

- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M.,** *Applicability of Existing Concurrent Engineering Readiness Assessment Methods to the Construction Industry*, *Concurrent Engineering: Research & Application Journal* (under review).
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M.,** *BEACON: A Readiness Assessment Model for Concurrent Engineering in Construction*, *Journal of Construction Engineering & Management*, ASCE, (under review).
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M.,** *How Collaborative Is Your Organisation?*, *Journal of Municipal Engineering* (under review).
- **Refereed Conference Papers**
  - **Khalfan, M. M. A. & Anumba, C. J. (2000a),** *Readiness Assessment for Concurrent Engineering in Construction*, *Proceedings of the Bizarre Fruit 2000 National Conference of Postgraduate Research in the Built and Human Environment*, University of Salford, UK, 9-10 March 2000, pp. 42 – 54.
  - **Khalfan, M. M. A. & Anumba, C. J. (2000b),** *Implementation of Concurrent Engineering in Construction - Readiness Assessment*, *Proceedings of the Construction Information Technology 2000 Conference*, Reykjavik, Iceland, 28 – 30 June 2000, Vol. 1, pp. 544-555.

- **Khalfan, M. M. A. & Anumba, C. J. (2000c), *A Comparative Review of Concurrent Engineering Readiness Assessment Tools and Models*, Concurrent Engineering 2000 (ISPE/CE2000) Conference, Lyon, France, 17 – 20 July 2000, pp. 578 – 585.**
- **Khalfan, M. M. A.; Anumba, C. J. & Price, A. D. F. (2000), *Improving the Construction Project Development Process through Integration and Concurrent Engineering*, Proceedings of COBRA 2000 Conference organised by RICS Research Foundation, Greenwich (London), UK, 30 August - 1 September 2000, pp. 208 – 215.**
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001a), *An Investigation of the Readiness of Contractors for the Implementation of Concurrent Engineering in Construction*, Proceedings of the 1<sup>st</sup> International Conference of Postgraduate Research in Built and Human Environment, University of Salford, UK, 15-16 March 2001, pp. 1 – 13.**
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001b), *Readiness Assessment of Construction Clients for Concurrent Engineering Implementation*, Proceedings of 1<sup>st</sup> International Conference of Architecture, Engineering & Construction, Loughborough University, 18-20 July 2001, pp. 389 – 400.**
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001c), *Investigation of Consultants' Readiness for the Implementation of Concurrent Engineering in Construction*, CD ROM Proceedings of Concurrent Engineering 2001 (ISPE/CE2001) Conference, Anaheim, CA, USA, 29 July – 1 Aug., 2001, pp. 384 - 393.**

- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001d), *The BEACON Model: Concurrent Engineering Readiness Assessment Tool for the Construction Industry*, Online Proceedings of IEPM 2001 Conference, Aug. 20-23, 2001, Quebec City, Canada (see web site: <http://iepm.centor.ulaval.ca/>).**
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001e), *An Investigation of the Readiness of Material Suppliers and Manufacturers for the Implementation of Concurrent Engineering in Construction*, Proceedings of COBRA 2001 Conference organised by RICS Research Foundation, Glasgow, UK, 3 - 5 September 2001, Vol. 2, pp. 478 – 489.**
- **Khalfan, M. M. A.; Anumba, C. J. & Carrillo, P. M. (2001f), *Concurrent Engineering Readiness Assessment of Sub-contractors within the UK Construction Industry*, Proceedings of 17<sup>th</sup> ARCOM Conference, University of Salford, 5 -7 Sept. 2001, Vol. 2, pp. 741 – 750.**
- **Other Outputs/Recognition**
  - An Invitation for a Research Paper for 'International Journal of Computer Applications in Technology'.
  - An Invitation for a Book Chapter for 'Concurrent Life Cycle Design and Construction'.
  - Research Focus Article: 'How Ready is your Organisation for Collaborative Working?'
  - First-year-PhD-Report on 'BEACON Model', Sept. 2000.
  - Three-month-PhD-Report on 'CE Critical Success Factors', Jan. 2000.
  - Summary paper of three-month-PhD-report: 'Critical Success Factors for Concurrent Engineering Implementation – Lessons for Construction'.

- Khalfan, M. M. A. (2000), *Improving Business Performance in Construction through Integration & Concurrent Engineering*, Business Information Systems 2000 Conference, Poznan, Poland, 12-13 April 2000 (accepted as a student paper, but not published in the proceedings).