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Introduction

1.1 Definitions

1.1.1 Computer integrated environments

A computer integrated environment (CIE) is used to establish an alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and integrate people whose cooperation is supported by computer networks. It is a manifestation of collaborative networks and a particular case of virtual organisation (VO) or virtual enterprise (VE).

Collaborative working using innovative CIE systems has become a reality as many activities in multidisciplinary work environments are performed with the stakeholders situated in discrete geographical locations. Such an information and communication technology (ICT) system helps to reduce fragmentation and enables the scattered professionals to communicate and collaborate virtually together in a synchronous or asynchronous manner.

The concept of CIE has been the subject of research for many years but the uptake of this technology has been very limited because of the development of the technology and its effective implementation. However, professionals and researchers have confirmed that networking, collaboration, information sharing and communication will be significantly more crucial and in demand in the future as conducting business in multidisciplinary and interdisciplinary environments will be essential for success and sustaining competitiveness. Subsequently, for successful development of the CIE technology as well as for the delivery and effective implementation of user-oriented systems, which require a correct balance between technology, process, organisation and people aspects, requirements engineering (RE) has become critically important. The specific features of CIEs or VEs can be summarised as follows:

- Boundary crossing
- Complementary core competencies

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- Geographical dispersion
- Complementary nature of the partners
- Participant equality
- Extensive use of information and communications technology.

Over the last couple of decades, there has been a major shift from an industrial economy to that of an information economy. This has led to an enormous increase in competitiveness among companies, and new technology is needed to help capitalise on the information economy. CIEs for VEs or VOs is a new and major trend in the cooperative business. CIE allows businesses to specialise and be flexible within their environments. In the past, this business model has been applied to outsourcing and supply chains, as well as to temporary consortia. Owing to the fact that the formation of these VEs is an intricate process, a new form of technological support has thus been developed. The most ambitious of the support systems actually intends to automate part of the creation process as well as the operation of these enterprises (Cardoso and Oliveira, 2005).

As with all types of enterprises, VEs present both benefits and challenges. Organisations can benefit from VEs through more economical connections with suppliers, greater opportunities to create revenue, more efficient operations and a reduction in administrative costs. The challenges facing VEs are inexperienced users, secured access, expense control and the level of integration and interoperability required to create a successful VE (Sun Microsystems, Inc., 2004).

Adopting VE enables a conventional organisation to accomplish tasks traditionally meant for an organisation that is much bigger, better resourced, and financially stable. One company having the technical capability, another with the right human skill set and a third with the solution, may come together to create a VE. For example, the current situation within the construction industry is that many projects are one of a kind and involve coordination between practitioners such as designers, engineers and suppliers. A typical construction project consists of a number of organisations and teams that are brought together for the duration of that particular project to form a so-called 'virtual enterprise'. This enterprise often contains units that are in different physical locations and use different computer platforms and have a need to work collaboratively and share the same project data (Faraj *et al.*, 2000). Some of the key benefits include, but are not limited to, the following:

- Emphasis on collaborative work for the construction stakeholders. The industry currently suffers from a considerable degree of fragmentation.

- Proposed new data exchange standards, such as Industry Foundation Classes (IFCs), for information exchange among the stakeholders.
- Proposed new construction processes, which eliminate non-value-adding activities.
- Provision of shared access to project information via integration over a central database or a communication layer. This prevents information duplication among stakeholders.
- Claims of providing savings in lifecycle project costs and time.
- Limited use in industry; thus there is little experience on their use.
- Provision of virtual reality (VR) functions and 4D simulations for decision-making processes for optimised solutions.

There have been extensive studies in the last decade such as ATLAS (Greening and Edwards, 1995), COMBINE (Augenbroe, 1995), RATAS (Björk, 1994), ICON (Aouad *et al*., 1994), COMBI (Scherer, 1995), OSCON (Aouad *et al*., 1997), OPIS (Froese and Paulson, 1994), SPACE (Alshawi *et al*., 1997), ToCEE (Amor *et al*., 1997) WISPER (Faraj *et al*., 2000), GALLICON (Sun *et al*., 2000), BIDSAVER (http://www.ceconsulting.it/ve/bidsaver.html), ALIVE (Chris *et al*., 2001), LEGAL-IST (www.legal-ist.org), ECOLEAD (Lavrac *et al*., 2005) in the area of CIE.

1.1.2 Requirements engineering

RE is a branch of systems engineering and it is related to the development of the technology and its effective implementation. That is to say, it helps to define what and how to develop, and when to implement the technology. RE is concerned with the goals, desired properties and constraints of complex systems such as the CIE systems that involve software systems, organisations and people.

Furthermore, it covers all activities related to the acquisition, specification and maintenance of requirements throughout the lifecycle of the software development projects. It also covers how requirements relate to business processes, work redesign, system and software architecture and testing and validation. This process is regarded as one of the most important aspects of building an information system as it is during this process that a decision is taken on what is to be built.

RE is also known as systematic requirements analysis (Wiegers, 2003). It is sometimes referred to loosely by names such as *requirements gathering*, *requirements capture*, or *requirements specification*. RE is critical to the success of a development project (Abran *et al*., 2005). Requirements must be actionable, measurable, testable, related

to identified business needs or opportunities and defined to a level of detail sufficient for system design.

Carr (2000) defined properties, attributes, services, function and behaviours as the requirements that are needed in a product to accomplish the goals and purposes of the system to be developed. RE is an iterative process by which the needs and requirements of individuals and groups significant to the product development are researched and identified. RE defines the following (Cooper *et al*., 1998):

- Customer, user and market requirements
- Design requirements
- Technical requirements.

Maguire (1996) emphasised that adopting a user-centred design process leads to more usable systems and products. It reduces the risk that the resulting system will under-deliver or fail. User-centred design implies the following:

- Early focus on users, tasks and environment
- Active involvement of users
- Appropriate allocation of function between user and system
- Incorporation of user-derived feedback into system design
- Iterative design whereby a prototype is designed, tested and modified.

Numerous surveys have been conducted, which conclude that project failures are caused by a lack of proper attention to requirements processes. A survey, which was undertaken by The Standish and Gartner groups, reports that only 26% of software projects are considered successful while 74% are unsuccessful.

When detailing the causes of success or failure, the most frequent area is the subject of user requirements (Eberlein and Leite, 2002). The CHAOS development report published in 1995 and 2000 by The Standish group showed that almost half of the projects failed or were cancelled because of the lack of RE effort. The main reason for project success for a similar percentage of projects was good RE (Eberlein and Leite, 2002).

Another survey by McPhee and Eberlein (2002) showed that senior software developers and project managers believe that the requirements activities should account for 25% of the total development effort. This was the outcome of the survey although the survey focused on the projects that had a critical time for delivery to the end users. As a result, this survey clearly proves that RE is crucial in systems

development. Understanding the users' real requirements is absolutely critical to the development of successful information systems.

To achieve a user-oriented and high-quality system, it is important that the user requirements must be captured and modelled in the right way. If done correctly, the system to be developed will meet the user needs and lead to better user satisfaction and implementation. On the other hand, if the user requirements are not defined correctly, the software is less likely to meet the user requirements, even if the software conforms to the requirements specifications developed.

1.2 Why Requirements Engineering Is Needed for the CIE Development

CIE is an important solution for the integration of the processes through the supply chain. Research has emphasised some of the benefits of integration such as reducing the project lifecycle and cost, removing the non-value-added activities for achieving lean processes and production, encouraging collaboration and increasing client satisfaction (Sun and Aouad, 2000). For example, the construction industry is of a multidisciplinary, traditional and fragmented nature, which results in many different issues and bottlenecks such as lead time, lack of buildability, increased cost, unsatisfied clients and inefficient documentation, to name a few. These challenges can be overcome by implementing CIE systems. However, people in the industry have little awareness of how to use such systems effectively in their work environment because of unfamiliarity with such systems; this results in a gap between the developers of CIEs and industrialists.

One route to developing more user-centred systems is the use of systems development methodologies, which are appropriate to the CIE systems. However, there is currently little debate within the research community as to what the characteristics of a CIE systems development methodology should be.

To date, CIE researchers, especially within the construction industry, have had little focus on RE in systems development, which is actually necessary to develop user-oriented and more practical CIE systems. Despite the increasing interest by both academia and practitioners in CIE, there is little research to identify the best practices in RE. On the other hand, according to the Vision reports published by Aouad *et al.* (1998) and Sarshar *et al.* (2000, 2002), communication, networking, integration and information sharing will be major issues over the next 10 years in the construction industry. The increasing trend towards the implementation of Building Information Modelling (BIM), which enables information sharing, collaboration and interoperability, will

make the uptake of the CIE systems inevitable for the construction industry.

BIM use in some countries such as Denmark is a mandated legal requirement in public property projects. It is believed that these legal requirements will soon be in place in other countries including the United Kingdom for the implementation of CIEs-so called BIM-as a result of moving towards a knowledge economy. Consequently, RE will be vital for the successful development of CIE technologies for virtual enterprising such as BIM-based CIEs for the construction industry. Employing appropriate requirements techniques will provide the following benefits:

- More practical CIE systems
- Increased usability and ease of use
- Configurable systems
- Flexible and scalable systems
- Contribution towards closing the gap between the practitioners and the researchers
- Contribution towards increasing the uptake of CIEs by the industrialists
- Support for the business processes modelling and the product modelling.

Requirements engineering techniques and methods can vary according to the nature, structure and size of the system development project. In other words, while an RE technique works well for one type of software system development, the same method may not work well for another type of system. Therefore, it is necessary to define an RE method that is targeted at software systems for CIEs. The method should provide a standard template of the RE process that is applicable to different CIE systems developments. Therefore, RE will be addressed in this book with a particular focus on the following issues.

- Ascertain the level of awareness about RE in the CIE community and justify the need for the identification of a RE framework.
- Gain a deeper understanding of the RE concept in system development.
- Evaluate the RE approaches explored.
- Elaborate the RE approaches in the case study developments.
- Analyse and evaluate experimented RE approaches in the case study projects.
- Master an RE approach for future CIE system development based on the analysis and evaluations.

- Validate and implicate the mastered RE framework for future studies and CIE developments.

1.3 How the Requirements Engineering Approach Is Formulated

Once contextual knowledge about RE and CIEs is established in the book, it is followed with the identification of the assessment criteria for the RE approaches. In order to extract the key issues of RE, discrete research studies that approach RE from different angles are investigated. In order to set up associations between the key issues and the characteristics of an RE process in a CIE development, the relevance and suitability of these key issues for CIE systems development are also considered and discussed.

In order to measure the success rate of the RE processes under evaluation, the book explains an instrument to evaluate or assess the RE processes. This leads to an analysis of the key issues and criteria through a benchmarking process between the two. Such analysis enables confirmation of the validation of both the key issues and the criteria by establishing categories, sub-groups, relationships and possible dependencies (Hammersley and Atkinson, 1983). Figure 1.1 shows the coherent relationships between the groups.

The criteria specified in the book are designed to measure the success of the RE processes after their implementation in system developments. Therefore, using the criteria for the assessment of RE activities in the case studies is more appropriate than the key issues. However, the key issues will be used as part of the validation process of the proposed RE process at the end.

After the criteria are benchmarked with the key issues, the RE carried out in the case study projects is analysed to explore the strengths and the weaknesses according to these criteria. From the analysis of the case studies, strengths and weaknesses and any problems in the RE approaches adopted in the case study, projects are clearly identified.

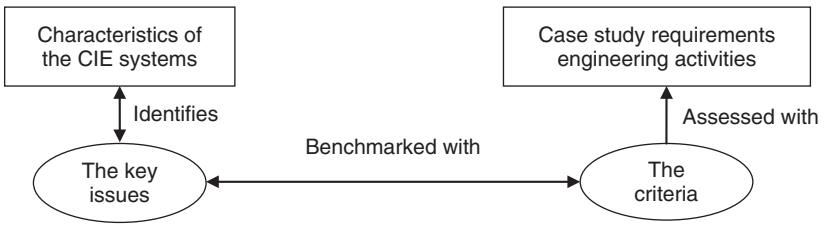

Figure 1.1 Criteria development to assess the requirements engineering experiences.

The process is then enhanced to cure the weaknesses and provide a ready-to-use, simple, adaptable, systemic, domain-specific RE process for the future CIE developments. The enhanced RE framework is validated before proposing it to the CIE community. Because empirical validation is not possible currently, only theoretical validation is conducted comprehensively. For empirical validation, the framework should be implemented in a CIE development project. It is done in two steps – internal (dependent) evaluation and external (independent) evaluation.

Internal evaluation is done against the key issues to be explained later in Chapter 5 of the book. The use of the key issues is more appropriate than the criteria for internal evaluation because the criteria are designed to measure the success of the RE process after the implementation, while the key issues are actually designed to improve the RE process before its implementation. Lastly, making use of the key issues for internal evaluation will allow the setting up of a coherent relationship and a good balance between the stages of the research methodology. This is depicted in Figure 1.2.

Figure 1.2 denotes the evolution of the development of the proposed RE framework. The association between the key issues and the criteria is established through benchmarking analysis. After the critical analysis and elaboration of the RE activities in the case studies, the association between the criteria and the case study RE activities is established in order to evaluate, analyse and measure the success of the RE processes in the case studies. On the basis of this evaluation and analysis, a further association is established between the RE activities in the case studies and the proposed RE framework. A final association is established between the key issues and the proposed RE framework to enable internal validation.

External evaluation is conducted through benchmarks against the external assessment models. Two different models are used for the

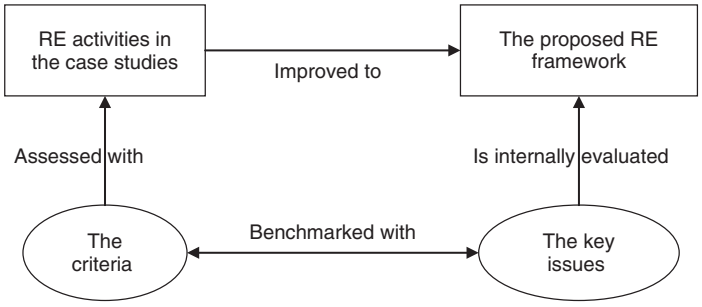

Figure 1.2 Interrelations between different requirements engineering aspects in the development of the ideal RE framework for CIE systems development.

external evaluation the Requirements Engineering Adaptation and Improvement for Safety and Dependability (REAIMS) assessment model (Sommerville and Sawyer, 1997), which is a capability maturity model, and project risk factors determined by Keil *et al.* (1998), Carr (2000) and CHAOS Survey (Standish Group, 1995, 2000).

Lastly, the validated RE process is recommended to be applied to the current or previous CIE development projects and systems to realise what has been underperformed in these developments in regard to RE.

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