Ont-EIR Framework to Deliver Sustainable Heritage Projects

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Abstract. Informed retrofitting and maintenance is recognised as a cornerstone of sustainable heritage buildings. Clients and the construction team are concerned with the delivery of projects that are within the timescale, budget, as well as energy efficient and environmentally friendly. Indeed, they are increasingly being challenged to deliver sustainability performance of heritage projects. Employer Information Requirements (EIR) is now seen as essential for in any successful heritage building delivery.

When designing a sustainable BIM project it has to be made sure that a complete and comprehensive EIR is delivered at the beginning of the project, in order to be able to produce a sustainable and energy efficient building, the EIR has to assure delivery of a full package of sustainable requirements for the construction project team, which in turn will allow them to produce a complete and correct BIM Execution Plan (BEP) that will be the basis upon which the whole construction process and definition of roles and responsibilities will be based.

This paper discusses the design and development of an Ontology-based, BIM-enabled framework for EIR, which will support clients of smart-heritage projects to define their requirements in terms of sustainability. It will investigate the innovative approaches and methods used to produce a complete, correct, and comprehensive EIR. This framework will enable the heritage team to capture, analyse, and translate these requirements and convert them into constructional terms understood by all stakeholders, which covers all aspects needed to produce a smart-heritage project. The intention of this study is to save time, effort and cost, and in the same time provide an informed basis for delivering a successful project.

Keywords: Heritage; smart; Sustainable; BIM

1 Introduction

Employer Information Requirements (EIR) is an important document in heritage projects for the information and instructions it holds for the creation, storage and transfer of the digital information when a building is delivered via BIM. (BSI, 2007. BS1192:2007). Designing a successful EIR is an important solution for managing the

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collaboration and integration process that is the main feature of the BIM process in heritage projects. Integration and collaboration are important for reducing the project overrun and cost, removing the non-value-added activities, encouraging collaboration, and increase client satisfaction (Sun and Aouad, 2000).

The need for a comprehensive EIR framework arises from the fact that many issues should be covered completely in the EIR to assure delivery of a full package of requirements for the construction project team, which in turn will allow them to produce a complete and correct BEP, that will be the basis upon which the whole construction process will be based.

The importance of the EIR documents is due to the variety of information that have to be addressed, this information includes management information, technical information, and commercial information, which involve: roles and responsibilities, definitions that will be essential during the construction process, organising the collaboration process between the different project team members, software issues, standards and guidance that will be used during the projects process, defining the construction process of the project in terms of phases, data drops and deliverables, in addition to defining project requirements that should be met during each phase and data drop.

The aim of this framework (OntEIR) which is an ontology based, BIM enabled framework for EIR in construction projects, which also include smart heritage projects, is to enable clients of these projects to answer the main questions of:

- what should be delivered in terms of projects requirements
- how will this information be delivered and managed which will include organizing the collaboration process of the BIM process
- when will this information be delivered in terms of clear data drops and time frames, and who will be involved in the delivery of this information, which includes the project team, in addition to definitions and standards and regulation issues.

OntEIR is a multi-disciplinary project that incorporates the Requirements Engineering (RE) method, which is a branch of systems engineering. The reason for this incorporation is due to the issues it addresses which are vital for OntEIR development, such as the desired properties and constraints of complex systems, organizations and process, through the RE approach in the analysis, refinement, and analysis of requirements.

The significance this research is in the final product which is a complete and comprehensive EIR, that will cover all the issues needed for a successful and sustainable heritage project in an easy and clear way to the clients.

2 Previous studies

Ontology and requirements engineering studies are not evident in construction, and more precisely in EIR, but there are researches on requirements specifications and

requirement engineering in other fields such as systems engineering, for what it offers that field in improving the qualities of requirements, terms of correctness, completeness, and consistency, which will have great effects in saving time and cost (Kossmann et al, 2008, Kossmann and Odeh 2010).

OntoREM is a semi-automated methodology developed for creating requirements specifications for systems in less time and at reduced costs, while improving the quality of such specifications (Antonini et al, 2014), due to what it offers in the elicitation of the domain knowledge field, and the analysis and validation of the needs, goals and requirements with relevant stakeholders and domain experts. (Kossman and Odeh, 2010)

OntoREM was initially developed to capture and manage reference knowledge and concepts in the domain of RE, which will result in the development of high quality requirements for any specific application domains (Kossmann and Odeh, 2010)

The OntoREM metamodel was developed using OWL DL, and edited by the Protégé tool, according to the approach described by Noy et al (2000), based on this metamodel, more specific instances of OntoREM were created (Kossmann and Odeh, 2010)

OntoREM (Ontology-Driven Requirements Engineering Methodology) is a novel methodology developed in this area. It is the product of a joint project between the University of the West of England and Airbus. OntoREM has been applied in case studies in both aerospace industry and space missions, and was a success in both cases (Kossmann and Odeh, 2010). OntoREM was able to help in developing quality improvements for the generated requirements specification, it assisted in generating about 100% additional project and system requirements (Antonini et al, 2014)

Knowledge-driven methodology is what OntoREM mainly depends on opposed to the more widely used process-driven approach. The argument for that is because knowledge-driven requirements engineering is guided by both the process and knowledge about that process and the problem domain (Kossmann et al, 2008). During the knowledge-driven approach adopted by OntoREM, a set of workflows and associated activities are defined, driven by knowledge and ontologies, which will help in overcoming the problems associated by the process-driven approach of corrective rework, which causes additional costs and delays (Kossmann and Odeh, 2010)

OntoREM has been developed in the area of requirements engineering, which has gained a lot of attention in software engineering for what it has to offer in elicitation, refinement, and analysis of requirements. Requirements Engineering (RE), a branch of software engineering that deals with elicitation, refinement, analysis, etc. of software systems requirements gained a lot of attention in the academia as well as in the industry.

The main advantages of using domain ontologies in the context of OntoREM are that the analysis and re-usability of the specified domain knowledge including requirements is greatly enhanced which, in turn, allows for significant process time savings and increased quality of the data contained in the domain ontology in terms of correctness, completeness and consistency (Kossmann and Odeh, 2010).

This Requirements Engineering Methodology will be adopted in the OntEIR framework for what it has to offer in EIR in terms of Requirement Engineering, and the knowledge driven process, which is considered the best option for the EIR process

3 OntEIR Approach

The development of EIR can initially be a simple process map, on which key decision points that will take place through the construction process are identified, this process map is to ensure that the solution developed satisfies the business needs and defines in very broad terms the information that will be needed to make such decisions. According to the BIM plan of work, identifying the EIR for the project is the main phase, due to its importance in setting out the information required by the employer aligned to key decision points or project stages, and thus enabling suppliers to produce and initial BEP from which their proposed approach, capability and capacity can be evaluated, see figure [1]

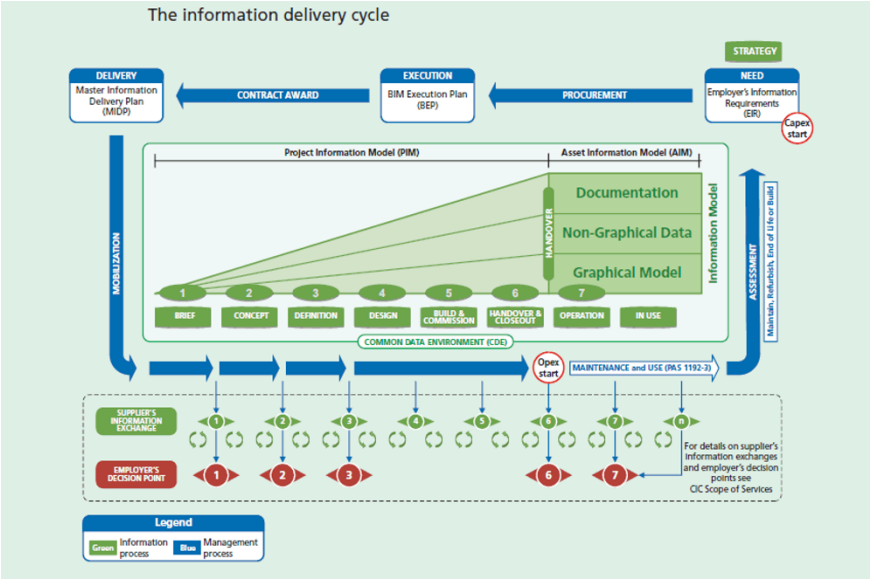

Figure 1: BIM Information Deliver Cycle (Adopted from PAS 1192-2:2013)

The amount of success in which the EIR is measured, is according to the degree in which it meets its purpose, therefore, the identification of this purpose should be done from the beginning of development of EIR. As studies have shown, inadequate, incomplete and ambiguous or inconsistent requirements have a significant impact on the quality of the project delivered (Assaf & Al-Hejji, 2006, Potts, 2008).

The OntEIR approach was designed to guide construction clients in defining and specifying Employers' Information Requirements (EIR) for construction projects. The Requirements Engineering (RE) Methodology was adopted in the development of OntEIR. EIR researchers have had little or no focus on RE system development, which is actually important if we are looking to develop a more client-oriented and more practical EIR, and despite the increasing interest in EIR, there is no research to identify the best practices in RE. Kossmann (2013) argues that 'requirements are detailed expressions of specific aspects of less detailed stakeholder needs'. They formalize relationships between the stakeholders or customers of a system, and the developers or suppliers of the system. 'A system here is defined as an integrating set of interacting elements; such as products, services, people, processes, hardware, software, firmware, and information that serves a defined purpose'.

OntEIR is an important solution for the integration and collaboration of processes and project team members. A comprehensive and clear EIR will have substantial benefits on the integration process in BIM projects. As suggested by this research, RE is necessary to develop user-oriented and a more practical EIR. Aouad and Arayici (2010) suggest that employing the appropriate requirements techniques will provide the following benefits:

- More practical systems
- Increased usability and ease of use
- Configurable systems
- Flexible and scalable systems
- Contribution towards closing the gap between the practitioners and the researchers

Due to the importance of defining accurate requirements, Employer Information Requirements should go through a series of an iterative process of requirements engineering that includes eliciting requirements, modelling and analysing requirements (Nuseibeh & Easterbrook, 2000). As described by Lamsweerde (2000), and Nuseibeh & Easterbrook (2000) RE includes the covering of the following activities:

• *Domain analysis*: the environment for the system-to-be is studied. The relevant stakeholders are identified and interviewed. Problems with the current system are discovered and opportunities for improvement are investigated. Objectives for the target system are identified.

• *Elicitation*: alternative models for the target system are analysed to meet the identified objectives. Requirements and assumptions on components of such models are identified. Scenarios could be involved to help in the elicitation process.

• *Negotiation and agreement*: alternative requirements and assumptions are evaluated; risks are analysed by the stakeholders; the best alternatives are selected.

• *Specification*: requirements and assumptions are formulated precisely.

• *Specification analysis*: the specifications are checked for problems such as incompleteness, inconsistency, etc. and for feasibility.

• *Documentation*: various decisions made during the requirements engineering process are documented together with the underlying rationale and assumptions.
• *Evolution*: requirements are modified to accommodate corrections, environmental changes, or new objectives.

The OntEIR framework will have the aim to facilitate the identification, clarification, and representation of employer requirements for heritage projects. The initial framework developing process will go through a series of stages that attempt to define functions, classify functions, and develop function relations based on the literature review and interviews conducted.

1- Generating high-level goals:

Using mind mapping, the problem domain will be elicited and analysed, the data visualized in the mind map is actually a representation of elicitation and analysis of requirements done with relevant stakeholders and domain experts via interviews. High level needs are formulated as result.

The visualization of the initial EIR framework will be done through mind mapping that consists of all aspects of the EIR which are broken down to reach high level goals, this will help us in determining and generating requirements more clear and precise, and help the employer body in determining their more specific requirements and concerns regarding the project.

The analysis of the EIR mainly divides the domain into two parts: static information and dynamic information

- Dynamic requirements (which include the commercial information):

This set of requirements looks at the process as different stages; each stage having its own set of requirements and information to be delivered, it includes details on the Client's strategic purpose, the defined deliverables and a competence assessment for those looking to tender the heritage project and demonstrate their ability to deliver the requirements of the EIR

These requirements are more specific to the construction phases, what is required by the project team to be delivering at each phase, who will be involved, and how will that be done, they will answer the major part of the plain language questions. These requirements include:

- Main outcome of the data drop
- Project requirements for each data drop
- Level of detail, and level of information (as defined in the management information) for each data drop
- Actors
- Standards and guidance needed
- Software formats to be used
- Security

- The employer should specify the different stages he would prefer the process to go through (data drops).
- The employer should define the different levels of development, and levels of information, which will be delivered at the different data drops.
- Software platforms that will be used during the BIM process including version numbers that will be used by the supply chain to deliver the project, including any particular constraints set by the employer on the size of model files.
- Standards, Protocols, and regulations to be used during the process.
- Coordination and clash detection
- Defining roles and responsibilities of the BIM team

Static information are more of a definitive nature. In a more specific sense, and as discussed previously, static requirements include the management information and the technical information; Management will detail high-level roles and responsibilities, standards, data security, the key decision points and the information to be available at each one. Technical will cover things like information format and file types, the minimum Levels of Definition at each stage and the software platforms to be used for exchanging information. For Clients in the public sector, that doesn't mean you have to endorse a particular vendor. It could be stating your preference for email or explaining the common data environment you will be using.

In general goals should cover these issues:

- The employer should specify the different stages he would prefer the process to go through, data drops, and define the deliverables for each drop.
- The employer should define the different levels of development (LOD), and levels of information (LOI), which will be delivered at the different data drops.
- Software platforms that will be used during the HBIM process including version numbers that will be used by the supply chain to deliver the project, including any particular constraints set by the employer on the size of model files.
- Standards, Protocols, and regulations to be used during the process.
- Coordination and clash detection

Management requirements will detail high-level roles and responsibilities, standards, data security, the key decision points and the information to be available at each one. Technical requirements will cover issues like information format and file types, the minimum Levels of Definition at each stage and the software platforms to be used for exchanging information. Figure 2 shows a mind map of the analysed EIR information

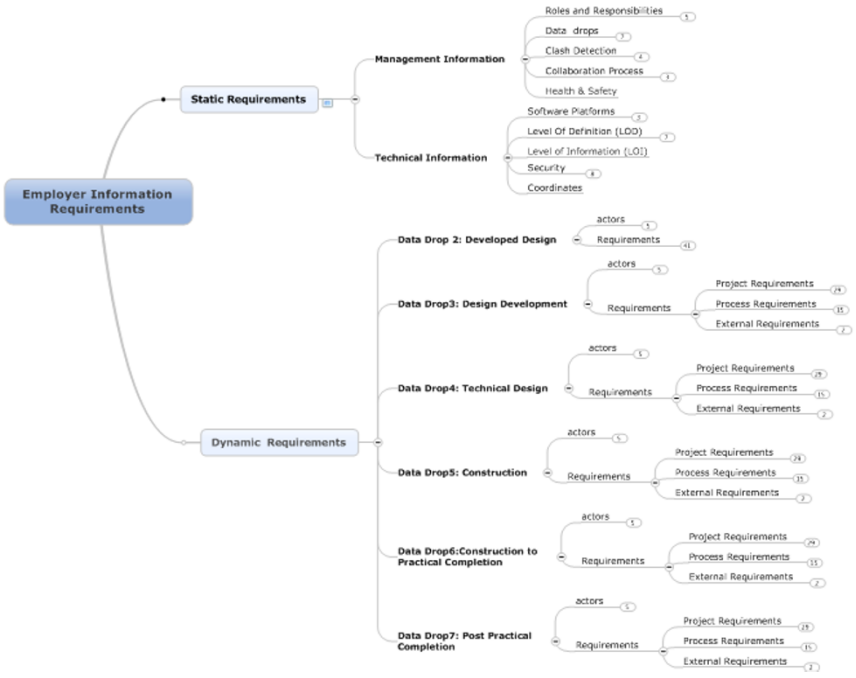

Figure 2: EIR information

2- Requirement specification

After reached root goals in the goal hierarchy generated by the mind map, requirements are used where relevant. In case the requirements do not cover a root goal, then new requirements will have to be generated.

3- Requirements validation

Goals generated from mind map will be validated with relevant stakeholders and domain experts in the construction industry.

After reaching the mind map that holds the necessary information: EIR domain knowledge, problem domain knowledge, solution domain knowledge, and stakeholder information, ontology will be applied to develop OntEIR, to create an ontology-based system for EIRs, which will create quality employer information requirements in terms of consistency, completeness, correctness, traceability, and the ability to be instantiated to any construction project.

The approach for accomplishing should have the ability to classify and prioritize the requirements, determine the relations between them and deliver them in terms understandable for the construction team

3.1 *Re-using Ontologies*

The re-use of ontologies enables us to save time and effort, because of the use of ontologies that have already been validated in the field of research through practical use in applications. The OntoREM is an ontology-driven requirements engineering methodology that will be re-used in this research.

The reason for the re-use of this particular requirements engineering methodology is due for what it has to offer in the area of requirements engineering in the field of EIR. It will facilitate the process of analysis and requirements elicitation, and due to the fact that knowledge-driven requirements engineering which is the approach of OntoREM, is the most suitable requirements engineering approaches for the elicitation and specification of employer information requirements, that is because in order to be able to plan a successful construction project you should acquire knowledge of both the domain and the process of that domain, which is what OntEIR will be doing.

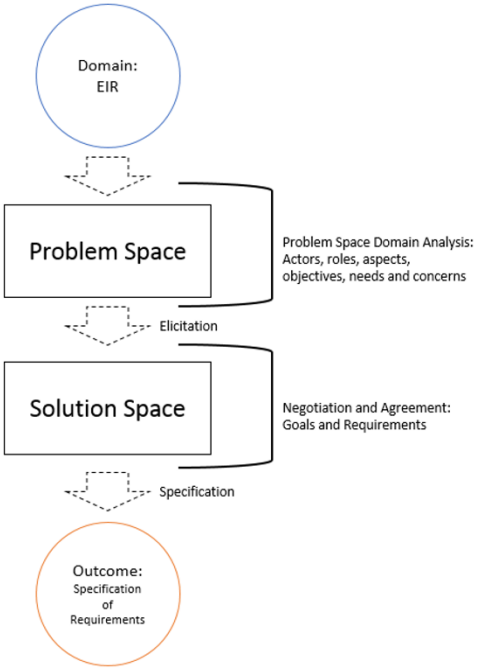

Figure 3: Requirements Engineering Methodology aproach

The Requirements Engineering methodology mainly divides the domain into two aspects: the input and the output, what is meant by the ‘input’ is the ‘problem space’, while the ‘solution space’ being ‘output’. The problem space is all the relevant knowledge of the domain, including its main actors and their roles, aspects,

objectives, needs and concerns, on the other hand, the solution space is the outcome of the analysis of the problem space, and holds the most important outcome of the methodology, which is the requirements specifications, as illustrated in fig [3] [Kossmann and Odeh, 2010].

4 OntEIR

As mentioned before the Ontology-driven Requirements Engineering Methodology is adopted in creating OntEIR. Due to the nature of this methodology to be a knowledge-driven methodology, information and knowledge, regarding the domain (EIR) had to be gathered, which will be crucial for the forming of the requirements for the projects. This information includes the roles and responsibilities, life cycle phases, workflows, concerns and definitions will be the basis platform in creating the OntEIR. When applying the Ontology Requirements Engineering Methodology, a pattern can be seen in using this information, which will help in eliciting additional information, which will all assist in the specification of EIR requirements which is the end results and the purpose of this framework.

The domain is mainly divided into two aspects: the input and the output, what is meant by the input is the problem space, and the solution space is the output. The problem space is all the relevant knowledge of the domain, including its needs and concerns, the solution space is what holds the most important outcome of the methodology, which is the requirements specifications [Kossmann and Odeh, 2010].

In order for requirements to be specified, EIR will have to go through a series of phases, which starts with the elicitation, which will result in generating high level goals, those goals will be the basis for specifying the requirements, which at the end will be validated. Figure (4) below illustrates the process in which requirements go through before being reached according to the OntEIR approach.

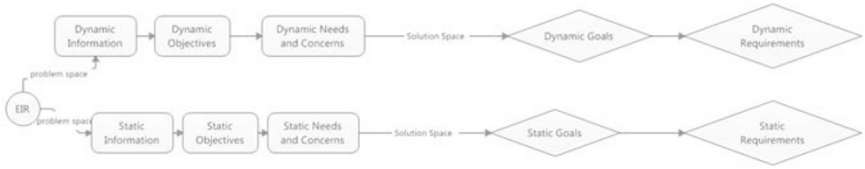

Figure 4: requirements elicitation in OntEIR

The process of identifying the requirements goes through a series of iterative phases, the process involves the identification of different concepts, and the relationships between them, feeding them in the OntEIR, in both the problem space and the solution spaces, in order to end up with clearly specified Employer Information Requirements.

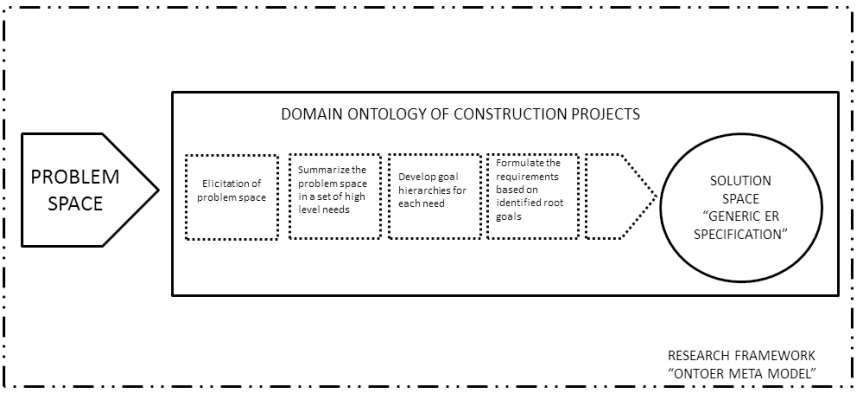

Figure 5: OntEIR Meta Model

5 Concluding remarks

This on-going and novel study of creating an ontology-based, BIM-enabled framework for defining EIRs will have potential in delivering a better defined, comprehensive and consistent EIR, on which the BEP will build on. Above all, a clearer EIR will lead to a more successful construction project, which includes heritage and smart heritage projects.

The success of OntEIR is due to following characteristics:

- Stakeholder and expert contribution to the study assists in understanding the need in construction projects, including smart heitage, which leads to defining better requirements in OntEIR to bridge the gap between clients and execution in construction projects;
- OntEIR is able to cover all aspects of a well and complete defined EIR as specified in PAS 1192:2, in a clear and understandable form for both the employer and the project team.
- Hierarchy and tractability offered by ontology will make it possible for OntEIR to be instantiated for different types of projects;
- OntEIR is able to clearly answer the plain language questions and requirements that are to be met before moving from one stage to the other;
- OntEIR will assist employers defining clear and adequate requirements, and at the same time will be easy to be interpreted by the design team and translated into building terms, and thus create better BEP;
- OntEIR saves time in specifying requirements for projects and gives excellent results in terms of quality and consistency.

References

BS 1192:2007, Collaborative production of architectural, engineering and construction information, The British Standards Institute, 2007.

Sun, M. and Aouad, G. (2000), “Integration Technologies to Support Organisational Change in the Construction Industry”, Proceedings of the Seventh International Conference on Concurrent Engineering, Lyon, France, 17-20 July 2000, 596-604.

Kossmann, M., Odeh, M., Gillies, A. and Wong, R., From Process-driven to Knowledge-driven Requirements Engineering Using Domain Ontology, IS’08, INCOSE, 2008.

Kossmann, M. and Odeh, M., Ontology-driven Requirements Engineering: A case study of OntoREM in the aerospace context, IS’10, INCOSE, 2010.

Antonini. K., Lange C., Kossmann, M., Odeh, M., Applying OntoREM to a Space Mission: Developing Requirements for the MASCOT Lander, INCOSE 2014

Noy, F. and McGuinness, D., 2000, Ontology Development 101: A Guide to Creating Your First Ontology. Stanford University.

M. Kossmann, R. Wong, M. Odeh and A. Gillies, "Ontology-driven Requirements Engineering: Building the OntoREM Meta Model", 3rd International Conference, Information and Communication Technologies: From Theory to Applications (ICTTA), 2008.

Assaf, S. A., & Al-Hejji, S. (2006). Causes of delay in large construction projects. International Journal of Project Management, 24(4), 349-357.

Potts, K. (2008) Construction Management, Learning from Case Studies. 2nd ed. New-york: Taylor & Francis.

Aouad, G and Arayici, Y 2010, *Requirements engineering for computer integrated environments in construction* , Wiley-Blackwell, Oxford, United Kingdom

B. Nuseibeh, S. Easterbrook. Requirements Engineering: A Roadmap. Proc. Conference
on the Future of Software Engineering, Limerick, Ireland, June 2000.

A. van Lamsweerde. Requirements Engineering in the Year 00: A Research Perspective. 22nd International Conference on Software Engineering (ICSE’2000), Limerick, Ireland, June 2000.