

# Universidad Politécnica de Madrid



Escuela Técnica Superior de Ingenieros Informáticos

## Caracterización de Sistemas intensivos en Software desde un punto de vista de innovación. (Characterizing Software-intensive Systems from the innovation point of view).

*Tesis doctoral*

Ing. Agustín Yagüe Panadero

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Universidad Politécnica de Madrid



Departamento de Lenguajes y Sistemas Informáticos e Ingeniería del Software

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Supervised by  
Dr. Juan Garbajosa

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## Abstract

Innovation in Software intensive Systems is becoming relevant for several reasons: software is present embedded in many sectors like automotive, robotics, mobile phones or health care. Firms need to have knowledge about factors affecting the innovation to increase the probability of success in their product development and the assessment of innovation in software products is a powerful mechanism to capture this knowledge.

Therefore, companies need to assess products from an innovation perspective to reduce the gap between their developed products and the market. This is even more relevant in the case of SiSs, where real time, timeliness, complexity, interoperability, reactivity, and resource sharing are critical features of a new system.

Many authors have analysed product innovation assessment and some schemas have been developed but they are not specific to SiSs; in addition, there is no consensus about the factors or the procedures for performing an assessment. Therefore, it has sense to work in the definition of a customized software product innovation evaluation framework.

This thesis identifies the elements needed to build a framework to assess software products from the innovation perspective. Two components have been identified as part of the framework to assess Software intensive Systems from the innovation perspective: a reference-model and an adaptive and customizable tool to perform the assessment and to position product innovation. The reference-model is composed by four main elements characterizing product innovation assessment: concepts, innovation models, assessment questionnaires and product assessment.

The reference model provides the umbrella to define instances of product innovation assessment models that can be assessed and positioned through questionnaires in the proposed tool that also provides automation in the assessment and positioning of innovation.

The reference-model has been rigorously built by applying conceptual modelling and view integration integrated with qualitative research methods.

The tool has been used to assess products like Skype through models instantiated from the reference-model.

**Keywords:** Innovation, Product assessment, Product innovation assessment, Software intensive Systems, Innovation assessment tools.

## Resumen

La innovación en Sistemas Intesivos en Software está alcanzando relevancia por múltiples razones: el software está presente en sectores como automóvil, teléfonos móviles o salud. Las empresas necesitan conocer aquellos factores que afectan a la innovación para incrementar las probabilidades de éxito en el desarrollo de sus productos y, la evaluación de productos software es un mecanismo potente para capturar este conocimiento.

En consecuencia, las empresas necesitan evaluar sus productos desde la perspectiva de innovación para reducir la distancia entre los productos desarrollados y el mercado. Esto es incluso más relevante en el caso de los productos intensivos en software, donde el tiempo real, la oportunidad, complejidad, interoperabilidad, capacidad de respuesta y compartición de recursos son características críticas de los nuevos sistemas.

La evaluación de la innovación de productos ya ha sido estudiada y se han definido algunos esquemas de evaluación pero no son específicos para Sistemas intensivos en Sofwtare; además, no se ha alcanzado consenso en los factores ni el procedimiento de evaluación. Por lo tanto, tiene sentido trabajar en la definición de un marco de evaluación de innovación enfocado a Sistemas intesivos en Software.

Esta tesis identifica los elementos necesarios para construir in marco para la evaluación de de Sistemas intensivos en Software desde el punto de vista de la innovación. Se han identificado dos componentes como partes del marco de evaluación: un modelo de referencia y una herramienta adaptativa y personalizable para la realización de la evaluación y posicionamiento de la innovación. El modelo de referencia está compuesto por cuatro elementos principales que caracterizan la evaluación de innovación de productos: los conceptos, modelos de innovación, cuestionarios de evaluación y la evaluación de productos.

El modelo de referencia aporta las bases para definir instancias de los modelos de evaluación de innovación de productos que pueden se evaluados y posicionados en la herramienta a través de cuestionarios y que de forma

automatizada aporta los resultados de la evaluación y el posicionamiento respecto a la innovación de producto.

El modelo de referencia ha sido rigurosamente construido aplicando modelado conceptual e integración de vistas junto con la aplicación de métodos cualitativos de investigación. La herramienta ha sido utilizada para evaluar productos como Skype a través de la instanciación del modelo de referencia.

**Palabras clave:** Innovación, Evaluación de productos, Evaluación de innovación de productos, Sistemas intensivos en Software , Herramientas de evaluación de innovación.

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To my family.

*“Cuando una puerta se cierra, otra se abre.”*

*“When one door closes, another opens.”*

Miguel de Cervantes Saavedra

Welcome to my future ...

## Acknowledgements

Some years ago I started this long trip. Along this time, many people has helped me to continue working on it, even when I was tired and bored. Thank you Víctor for smiling and kiss me every day and for giving me illusions to finish this thesis. I know that it was also hard for you. Thank you Ana María for being with me in the good times when it is easy, but also in the bad times when it is even harder. You always trusted in me.

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## Part I

# Introduction





# Chapter 1

## Introduction

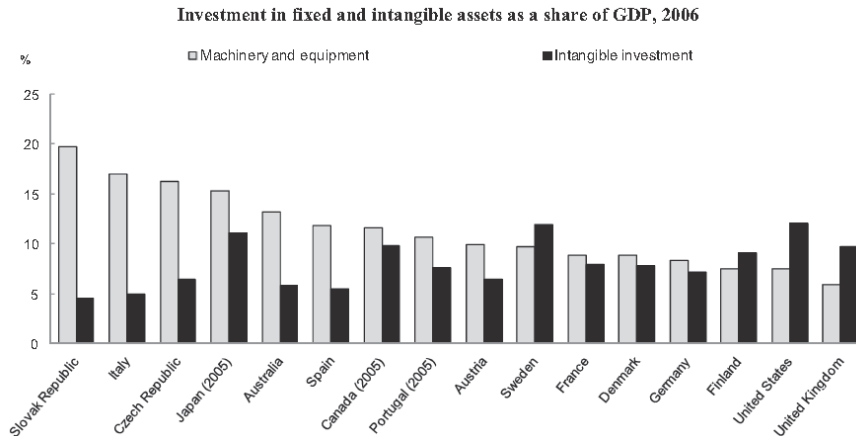
*This chapter discusses about the relevant role of innovation as is perceived by different actors. This chapter is structured in six sections, the first describes the motivation of this research identifying key topics that justify the need of this research. Next section frames the context where this research has been conducted. section 1.3 presents the goals and objectives to be achieved in this research. Then, section 1.4 highlights research contributions obtained at the end of this research. Later, section 1.5 describes the research methodology applied to conduct the research. Finally, section 1.6 overviews the structure of the thesis.*

## 1. INTRODUCTION

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“Software is eating the world” was stated by Marc Andreessen (one of the co-founders of Netscape) in 2011 [5]. The main largest companies in different sectors like booksellers, video services, music, entertainment are software companies. Software is embedded in leading sectors like automotive, robotics or mobile phones [76] conforming what are called “Software intensive Systems” (SiS). IEEE Std 1471-2000 [46] defines SiS as follows: “A software-intensive system is any system where software contributes essential influences to the design, construction, deployment, and evolution of the system as a whole.” But, there is no a unique definition of SiS as it is shown in Annex 7.3 Section 7.3

The Organization for Economic Cooperation and Development (OECD) reported [77] that software innovation is also playing an increasingly important role in growing industries like automotive, healthcare and mobile/smart phones; around 100 million lines of code are embedded in fully-equipped cars or 28 billion € is estimated the R&D expenditure for software in medical equipment by 2015. Innovation concerns with commercial



**Figure 1.1:** Investment in tangible and intangible assets in OECD countries. [75]

and practical application of ideas into real products[102]. The term innovation has been widely overloaded [42, 73, 24, 84, 28, 83]. As it is shown in Annex 7.3 Section 7.3, there is no a unique definition; but knowledge and ideas applied to create new processes, services or methods are underlying all of them. Innovation may not be limited to new ideas or a single view, but different views deal with different angles on innovation[81]. Among other types of innovation, product innovation refers to those products transferred to the market that are new in some sense such as incremental, disruptive or radical; and/or some scope at firm, market or industry level.[28, 36, 82, 24]. But product is a general term affecting to many issues, so this research is focused on Software

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<b>Domain</b>	<b>References</b>
Innovation in Toy Industry	[96]
Evaluating New Product Ideas	[95]
Innovation adoption	[49]
Technology innovation	[8]
Consumer Electronics	[21, 103]
Decision making at management level	[55, 41]
Commercial sector	[9]
Business	[95]
Sports	[95]

**Table 1.1:** Some of the domains found in literature in which Product innovation assessment has been applied

intensive Systems (SiS) and more precisely in the evaluation of products from the innovation perspective.

Innovation in software is becoming relevant not only because software is everywhere [76, 5], but innovation is driving the growth of companies in most of the countries too. Fig 1.1 shows how the investment in intangible assets, where software is included is greater or equal than the investment in other tangible assets in OECD countries [76].

The need to invest in infrastructures for measuring the impact of innovation in software and other fields was also highlighted by OECD [60], and more recently in [31]. These measures will let companies assess the impact of innovation factors to achieve the expected business goals. Balachandra et al. [9] pointed out that it was difficult to predict why some products are successful while most fail. It was later described by Sun et al. [96] in 2005 that companies were investing efforts adopting innovation factors, but, the results were not always successful due to lack of consensus on the impact of each factor. McKinsey [98] reported in 2008 that companies applied assessment mechanisms to diagnose and improve overall innovation performance. The fact of the lack of common approaches for product assessment is not a new topic, Ernst in 2002 [34] highlighted that firms did not apply theoretical approaches or standard procedures when assessing new product development; in consequence, existing studies frequently did not provide reliable coefficients to assess the reliability of new developments. Recently, Soukhokova [95] reported the interest of capturing knowledge through assessment to help companies to realize the expected outcomes of products has been stressed again;

## 1. INTRODUCTION

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assessment also provides valuable information about innovative ideas to align products with market expectations.

Summarizing, firms demand to possess knowledge about factors affecting the innovation to increase the probability of success in their product development. The assessment of innovation in software products is a powerful mechanism to get this knowledge.

Many authors analysed product innovation assessment from different perspectives and application domains [50, 9, 58, 34, 96, 95, 22, 55, 8, 41, 49, 54, 103]. However, in most of the cases, the product innovation assessment was merely based on factors grouped into dimensions, but each author proposes their own interpretation of the innovation factors and assessment, though based on the same concepts. Additionally, no one provides guidelines about how to perform the assessment process. This unveils a lack of consensus on product innovation assessment. None of the authors provided guidelines on how to perform the assessment using factors. Therefore, literature addressed the need of assessment product innovation but no general models are still available.

This thesis aims to identify and present the elements of a framework to assess software products from the innovation perspective. To that end, the concepts needed to represent the assessment of product innovation are combined to build a reference model. The reference model is a composition of the list of factors to model innovation, questionnaires to data gathering and processes to perform the assessment. Additionally, a tool to perform the assessment of software product innovation based on the reference model components has been implemented.

The structure of this chapter is as follows: Section 1.1 introduces the motivation of this thesis. Section 1.2 defines the context of this research. Then, Section 1.3 presents the main goal and specific objectives of this thesis. Section 1.4 presents the main contribution of this thesis and the list of publication authored or co-authored by author of this thesis. Section 1.5 describes the research methodology that has been followed during the thesis development. Finally, Section 1.6 summarizes the structure of the thesis.

### 1.1 Research motivation

It was globally accepted that software is becoming the core of most of the existing systems in automotive, avionics, health care [76]. Software companies like SAP <sup>1</sup>, Skype Inc. <sup>2</sup> previously to be acquired by Microsoft or WhatsApp Inc. <sup>3</sup> are representative examples of how innovative solutions in different application domains drove the growth

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<sup>1</sup><http://www.sap.com/index.html>

<sup>2</sup><http://www.skype.com>

<sup>3</sup><http://www.whatsapp.com/>

of those companies.

Aligned with this growth, software is playing an important role enabling the contribution of ICT to innovation. OECD in 2010 pointed out that innovation in ICT is driving the growth in some sectors like the Internet. The economy is now driven by the growth of ubiquitous software and new software and services, even when the crisis on revenue and employment are affecting to other sectors [75].

Software market has evolved from processes automation to speed things that was already being done in the beginning to strategies for providing products and services not yet offered by firms (what is a synonym of innovation) [37]. This is the case of Honda [94] that is applying simulation to meet changing market needs, avoiding the need of building of prototypes.

The nature of software system development is changing. Software is increasingly built in the context of a software ecosystem where other companies and independent developers add value to products to speed up the time to market[12]. Additionally, software innovation is also perceived as an important issue by software developers [77]. Table 1.2 shows a list of the most relevant factors of software development activities that developers consider to be drivers for software innovation.

Innovation in software is presented by OECD [60] as a process leading to add new

Factor	Importance for innovation
Trained human capital	92
Quality customer rqmnts. quality	81
Cost customer rqmnts.	72
Security customer rqmnts. security	72
Other	71
Protection of intellectual property rights	69
Application of technological Stds.	67
Legal, regulatory and administrative env.	65
Interoperability customer rqmnts.	65
Security issues	62
Customer's financial strength	40
Access to financing	34

**Table 1.2:** Innovative factors of sw. development. [77]

features to existing products/services, to develop new product/services. Product innovation assessment is complex and it is impacted by several factors. One of the goals in

## 1. INTRODUCTION

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measuring innovation is to improve our understanding of success and assess innovation processes to get the highest returns from innovation [4]. Qualitative measures, as it was described by Langdom [62], were intended to get people involved in the innovation process to think more deeply into the factors impacting in product innovation.

Software innovation is often, but not only, driven by user needs during the complete development process. Many are the incentives to drive software innovation and they come from different areas: organization (management, costs, timing), market (existence, competitors, commercial success), technology (patents, research) [9]. The fast evolution of technology is affecting market, e.g. Samsung reached in 2012 in six months the lead position on mobile devices and smart phones after the Galaxy series were launched [45]. As it was reported by Milbergs [67], the nature of innovation makes it difficult to measure it and to assess product innovation a new generation of metrics based on knowledge, tangible and intangibles, networks are needed. Product innovation assessment is seen as a multi-dimensional factors composition [24] where factors on each dimension could impact in the success of a software product. Cooper [21] reported that factors could act as enablers or blockers of innovation. Products should be analysed through features grouped by product drivers or dimensions where feature most strongly affect [97]. Then groups should be arranged in terms of impact on the market and business drivers. Eversheim [36] recommends assigning weights to each mapping between factors and dimensions to let the classification of products through those values [36]. But factors are not always independent, therefore, identify dependencies among factors is critical to have a better understanding of the impact of each factor. Jeyarag et al. [49] defend is that as much independent factors were involved in the innovation process easier is to adopt innovation practices and in addition less impact over products.

Summarizing, firms need to know as soon as possible if their products are aligned or they are ahead with the market to increase their chances to lead the market. That is one of the reasons why innovation assessment is so relevant. Additionally, OECD highlighted the need to invest on infrastructures for measuring the determinants and the impact of innovation in all the fields and specially in software [60], and more recently in [31]. These measures will let companies assess the impact of innovation factors to achieve the expected business goals. Actually, this is not a new problem: Balachandra et al. already reported in 1991 that almost 90% of new products did not achieve their business objectives [9]. As it was pointed out, it was difficult to predict why some products are successful while most fail. It was later described in 2005 that companies were investing efforts adopting innovation factors but, the results were not always successful due to lack of consensus on the impact of each factor, as Sun et al. described [96]. As it

Reference	Type	Type of sources					
		Literature Review	Survey	Empirical	Case Study	Research	Commercial
Åstebro [8]	Study	*		*	*		*
Johne[50]	SLR	*		*		*	
Balachandra et al.[9]	SLR	*		*	*	*	*
Cooper[22]	Experience Report	*	*	*			
Ernst[34]	SLR	*		*	*		
Garbraith[41]	Study	*			*		*
Jeyaraj[49]	SLR			*	*		
Klington[54]	LR	*		*			*
Krishnan[55]	SLR	*		*	*	*	
Lester[58]	Experience Report			*	*		*
Soukhoroukova[95]	Study	*	*	*			
Sun[96]	Study		*	*	*		*
Tsai[103]	Study	*	*	*	*		*

**Table 1.3:** Type of sources considered in the articles included in [117]

was reported by McKinsey [98] companies applied assessment mechanisms to diagnose and improve overall innovation performance.

Therefore, to increase their chances in leading the market, firms need to assess their software products to determine as soon as possible if they are aligned with the market. That is one of the reasons why innovation assessment is so relevant. However, this is not simple. In the literature review performed, we found no information specific to software products. Several approaches for product in general are available, but none are conclusive. In spite of the efforts to innovate, Axel et al. [50] have argued that in many companies, this business objective deviation is due to a gap between their innovation strategies and the developed products. Companies are devoting their effort and resources to building new products, but they do not have any mechanisms for evaluating if the innovative product will be successful or if it will meet its budget

## 1. INTRODUCTION

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and profit expectations. Sun et al. [96] pointed out that companies need to know and understand the factors that cause a product to either succeed or fail. A product fails when it does not achieve its business goals. This would enable a company to invest its money and effort in the adoption of the innovation factors and practices that are relevant to building successful new products.

Consequently, companies need to evaluate products from an innovation perspective to reduce the gap between their developed products and the market. This is even more relevant in the case of SiSs, where real time, timeliness, complexity, interoperability, reactivity, and resource sharing are critical features of a new system [12, 15, 115].

Many authors have analysed product innovation assessment and some schemas to evaluate product innovation have been developed (e.g., [8, 9, 22, 41, 54, 55, 58, 96]), but they are not specific to SiSs; in addition, there is no consensus about the factors or the procedures for performing an evaluation. Moreover, it could be identified that these articles, were based on several industrial application domains such as toy industry, technology or electronics. They could be classified as belonging to the electronic industry and manufacturing rather than to the software industry. This is relevant because the work described within this thesis has been built upon a set of studies that cover very different domains (see Table 1.1), and very different type of studies including literature review, commercial reports, surveys, etc. as shown in Table 1.3. Most of the analysed studies were based on more than one source integrating both empirical research and reviews of the literature.

Ernst [34] detected that the newness of innovation has not been consistently defined in the existing empirical studies and, consequently, the compatibility of findings is somewhat limited. Therefore, further research should be done regarding the definition of general frameworks.

The main mechanism to data gathering while assessing product innovation is the use of questionnaires. [22, 9, 58, 55, 8, 96, 41, 54, 103]. In addition, Tsai [103] identified that there is a lack of reliability of data gathered from questionnaires due to the reduced number of answers collected and the difficulty to have access to the documentation supporting these values. Therefore, literature addressed the need of assessment product innovation, but no general models are still available.

But, to define models for the assessment of product innovation is not a simple task. Product innovation depends on multiple variables organized into dimensions [9, 103]. And, usually by the time an innovation is finally successful, many different stakeholders get involved. One industry that, in the late years, has an outstanding role in the economy is the Software intensive Systems (SiS) industry. According to OECD economy



growth in industrialized countries in the last decade has been led by ICT services [75], confirming that, as the software industry matures, the possibilities for new software functionality aligned with market needs are expanding [60].

## 1.2 Research context

This thesis is framed in the assessment of innovation in software products, more precisely in Software intensive Systems (SiS), from the product perspective. By combining innovation and SiS, as it is explained by Pikkarainen et al. [82], there are three main dependencies between software and innovation: software acting as an instrument for innovation, software acting as an enabler of innovation processes and, software acting as an enabler of business model. To learn about how innovation fostered software development could be very valuable to improve the process development itself and to build better products in the near future. In this scope, this thesis is focused on how innovation has been assessed, up to now, in the development of SiS.

The nature of software system development is changing. Software is increasingly being developed in the context of software ecosystems where companies and external developers work together to add value to the products to speed up the time to market [12]. Therefore, software production is important to both firms and developers. The problem of product innovation assessment to help firms understand the expected outcomes still remains; as it was reported by Soukhokova [95] this assessment provides valuable information to align new products with market expectations.

The amount of time for producing the right product for a particular market is being dramatically reduced, and innovation is increasingly needed to achieve the established goals. For years, companies have been able to evaluate software product quality characteristics by applying the well-known ISO/IEC 9126 [2], which later evolved into the ISO/IEC 25000 series [3], known as SQuaRE. But the fact is that there are no standards, recommendations, or guidelines that are globally accepted for evaluating SiS innovation characteristics. Within this thesis, software product innovation assessment is understood as the evaluation of software products based on a list of factors and from different perspectives to determine the extent a product that is either new or under development satisfies those innovation factors. Innovation factors are indicators for estimating the probability that business expectations will be achieved.

In terms of innovation factors, there is not enough consensus on the relevance of each factor and the number of factors to use. For example: Axel et al. [50] recommended collecting measures to find crosscutting relationships between the innovation strategies

## 1. INTRODUCTION

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and then to develop products in four dimensions that are organization, market, culture, and project management; Cooper [21] proposed between 10 to 15 factors focused on 5 dimensions; Balachandra et al. [9] proposed 72 factors organized into 4 dimensions; and Jerayaj et al. [49] presented 135 factors. Klington et al. [54] proposed the application of artificial intelligence over 23 factors organized into three dimensions. Tsai [103] analysed 5 dimensions through 24 factors covering the main product issues like conceptualization, skills, and organization.

From the beginning of this research, the core was *Product Innovation*. It was a broad field that has evolved to the final topic. The first part of the research was focused on the understanding of the concept of product innovation and which are the basis that are supporting this concept.

The next step in the research was to continue characterizing product innovation through the analysis of the concept of *Smart Product* looking for features and factors affecting this concept. As result of this part of the research e concluded that “Smart Things” are defined in a context and can be represented as a set of characteristics; where characteristics in the case of Smart Products could be instantiated among others as: self-organized, adaptiveness, autonomy, personalization or context-aware.

At this stage, ideas affects to product innovation. Products are characterized by a set of characteristics but is was not still defined how to measure the impact of these characteristics on innovation. So, the next step performed was to study Change Impact Analysis technique as a driver to analyse the impact of innovation. Even though it was a promising result, it was not in the main focus of this thesis about the assessment of product innovation and it was considered as future work to be done.

So that, conducting the research to the definition of a framework to assess product innovation, a deep analysis of the literature was conducted and reported in ***P1***. This publication stated the basis for the next research activities focused on the definition of the model to characterize the assessment of product innovation and the implementation of a tool to assess and positioning product innovation based on the model.

Summarizing, the work in this thesis is concerned with the problem of the assessment of software product innovation by identifying the concepts that are needed to perform the assessment and their relationships to build a reference-model as a common model to help researchers to integrate the existing product innovation assessment models increasing the ability to share results.

## 1.3 Thesis objectives

The main goal of this thesis can be formulated as follows:

*“To identify the elements needed to permit the assessment of software products from the innovation point of view.”*

To achieve this main goal concerning the elements of the innovation assessment, three more detailed research questions (RQ) has been formulated to drove the research:

*RQ-1* How product innovation assessment has been performed? This research question has been also divided into three more detailed questions:

**RQ-1.1** What are the goals of a product innovation assessment?

**RQ-1.2** What is the environment of the product innovation assessment?

**RQ-1.3** What are the main challenges of the product assessment schemas?

*RQ-2* What are the components of product innovation assessment model? This research question has been also divided into two more detailed questions:

**RQ-2.1** What are the existing schemas (structure and types) for assessing products from the innovation perspective?

**RQ-2.2** What is the relevance of the innovation factors?

*RQ-3* . What are the components of the innovation assessment framework?

This thesis is organized in three parts and these research questions are addressed to provide answers to each part of this thesis. So, *RQ-1* focuses on the characterizing innovation in the scope of software product assessment. To answer this question, an analysis of the existing literature must be done. *RQ-2* covered the analysis and synthesis of the results obtained in *RQ-1* to build a model to assess software product innovation. And finally, *RQ-3* is focused on the components and their relationships to represent the software product innovation assessment framework.

## 1.4 Research contributions

This section presents the main results and key publications resulting from this thesis. These are also summarized in Table 1.4 and Table 1.5.

# 1. INTRODUCTION

Published					
Type	Published	Title	Revision type	Ranking	Research question
Paper (P1)	Forty-Seventh Hawaii International Conference on System Sciences (HICSS-47). Year 2014	Analyzing Software Product Innovation Assessment by Using a Systematic Literature Review (Nominated to Best Paper Award)	Peer-review	Core A	RQ-1 and RQ-2
Paper (P2)	Forty-Seventh Hawaii International Conference on System Sciences (HICSS-47). Year 2014	A Framework for Positioning and Assessing Innovation Capability from an Organizational perspective	Peer-review	Core A	RQ-1 and RQ-3
Paper (P3)	46th Annual Hawaii International Conference on System Sciences (HICSS-46). Year 2013	Change-Impact Driven Agile Architecting (Nominated to Best Paper Award)	Peer-review	Core A	RQ-1
Paper (P4)	20th Annual IEEE International Conference and Workshops on the Engineering of Computer Based Systems (ECBS). Year 2013	Providing a Consensus Definition for Smart Product	Peer-review	Core B	RQ-1
Paper (P5)	Second Workshop on Managing the Client Value Creation Process in Agile Projects (VALOIR) in conjunction with The 13th International Conference on Product Focused Software Development and Process Improvement. Year 2011	Towards estimating the value of an Idea	Peer-review	Core B	RQ-1

**Table 1.4:** Summary of research questions, results and published publications

In preparation					
Type	Published	Title	Revision type	Ranking	Research question
Journal (P6)	Will be submitted at the end of 2014	Reference model building	Peer-review		RQ-3
Paper (P7)	Will be submitted at the end of 2014	Research methodology combining Design Science and Thematic Synthesis	Peer-review		
Journal (P8)	Will be submitted at the end of 2014	Case study of SiS innovations assessment	Peer-review		RQ-3

Table 1.5: Summary of research questions, results and publications in preparation

## 1. INTRODUCTION

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### 1.4.1 Summary of contributions

The first publication produced was **P5**. **P5** outlined a framework for innovation that will facilitate organizations to identify new ideas and to estimate their potential value. Two main results were achieved: the identification of sources of innovation and a short list of elements that could be needed to estimate the value of ideas. This publication helped to state the problem and their results stated part of the background to answer the research question 1.

The second publication was **P4**. It analysed the concept of *Smart Product* and contributed to this research through the meta-model of the definition of "Smart Thing". Smart Things are defined in a context and can be represented as a set of characteristics. Characteristics that in the case of Smart Products could be instantiated among others as: self-organized, adaptiveness, autonomy, personalization or context-aware. This publication also helped to state the problem and provided background to answer the research question 1.

The third publication **P3** studied Change impact analysis applied to Agile Architecting. Publication **P3** was nominated for the Best Paper Award of the conference. Translating results of **P3** to this thesis, Change Impact Analysis is a powerful tool that could help to determine the effects resulting from the changes on the innovation factors applied in the assessment over a product. Even though it was a promising result, it was not in the main focus of this thesis about the assessment of product innovation and it is considered as future work to be done. This publication helped to state the problem under research and to identify challenges of software product innovation as part of the research question 1.

The fourth contribution was **P2**. Paper **P2** stated the basis of framework for positioning and assessing product innovation from the organizational perspective. The contribution of this paper to the thesis was the overall structure of the framework comprising: a model, a modelling language and a tool to assess and positioning innovation. Publication **P2** was focused only on one of the dimensions impacting on product innovation and it covered both the innovation process and the product. This publication provided was focused on the identification of components of software product innovation assessment to answer both the research question 1 and 3.

Finally, the fifth publication **P1** reported a systematic literature review on the specific topic of this thesis: the assessment of product innovation. It was nominated for the Best Paper Award of the conference. The results of this publication identified that product innovation was impacted by factors organized into dimensions. It was also reported that two main assessment schemas were identified in the literature. This publication

Objective	Result	Publication
Problem statement	Understanding of software product innovation assessment	P1, P2, P3, P4 and P5
RQ-1.1	List of goals of product innovation assessment	P1
RQ-1.2	Environment components of product innovation assessment	P1, P2
RQ-1.3	List of challenges of product innovation assessment	P1, P3 and P5
RQ-2.1	Schemas of product innovation assessment	P1
RQ-2.2	Identifying the impact of innovation factors	P1
RQ-3	Components of product innovation assessment framework	P2, P6, P7 and P8

**Table 1.6:** Summary of research questions, results and publications

stated the basis for the next research activities focused on the definition of the model to characterize the assessment of product innovation and the implementation of a tool to assess and positioning product innovation based on the model. This publication represented the basis to answer the research questions 1 and 2.

The reference model is going to be published as two publications: **P6** to describe the reference model and **P7** to describe the methodology applied in the reference model building. The tool structure and how to build instances of the reference model will be also published **P8**.

### 1.4.2 Contributions

This section presents the main contributions of this thesis and they are contextualized with respect to the objectives of this thesis. Table 1.6 summarizes the relationship between research questions, results and publications. These are the main contributions of this thesis:

1. A Systematic Literature Review of the product innovation assessment. The first step of this research was to conduct a systematic literature review (SLR) to analyse software product innovation. This paper presented the results of an analysis of the existing literature on software product evaluation models. The analysis

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addressed the main existing evaluation schemas and their elements in terms of dimensions, factors, strengths, and challenges. This SLR was published in **(P1) Agustín Yagüe, Juan Garbajosa, Jennifer Pérez, Jessica Díaz: Analyzing Software Product Innovation Assessment by Using a Systematic Literature Review. HICSS 2014: 5049-5058**

2. A reference model for product innovation assessment. This reference model represents all the information around product innovation assessment providing a unified notation to represent the existing product innovation assessment models. It also provides a mechanism to automate questionnaire construction based on the innovation assessment models. Questionnaires are used to perform the assessment of concrete products. To adapt the assessment to specific products or markets, questionnaire customization is possible based on the existing models. The reference model has been built based on current available literature on product innovation assessment. It was built using the research methodology described within this thesis, and taking special care of the quality of the model so that it can be a trustworthy model. An XML-Schema has been defined to represent instances of the reference model that will be used as inputs by the tool to assess and positioning product innovation. This XML-Schema validates instances of the XML files to provide consistence between the reference model and the product innovation assessment tool. This model is expected to be published in 2014 as it is described in **P6** and **P7**.
3. A tool for assessing and positioning product innovation. This tool uses product innovation assessment models instantiated from the reference model and provides questionnaires to perform the assessment and, based on data gathered from the questionnaire, to position product innovation. The innovation assessment tool provides a solution to the problem reported by Lester [58] when the required information is not always available. This fact has been addressed by the definition of three additional measures: *Maximum impact value*, *Minimum impact value* and *Optimal impact value*. These measures provide a clear range of values where the impact is enclosed. An example about how to build and apply an instance of the reference model is expected to be published in 2014 as it is described in **P8**; **P8** contains the results obtained from the assessment of Skype instantiating the reference-model using the assessment model proposed by Balachandra et al. [9]. Skype was analysed from four perspectives: environment, market, organization and technology. Each dimension is represented by a list of factors characterizing



innovation. Data to perform the assessment were gathered through a literature review of the main research databases and search engines. These data were used to fulfil a questionnaire based on qualitative and discrete values to finally obtain a graphical representation of the assessment results. This assessment performed with qualitative data could be considered a limitation, but it presents the great advantage to be easy to get from the people that is fulfilling the assessment.

### 1.5 Research methodology

Research in software engineering covers the creation of new models, methodologies, techniques and tools to help engineers to solve complex problems and to improve effectiveness and efficiency of solutions.

As Shaw [93] reported validity of the research results depends on the process to obtain and validate results. Software engineering research as any other research disciplines needs the existence of guidelines to drive the research process.

Research in this thesis was conducted by a research methodology consistent with the principles of *design science* complemented with *systematic literature review* and *thematic synthesis*. Design science [43] acts as the backbone of the research. It is an iterative research method based on the problem-solving paradigm to create and validate artefacts designed to solve a problem. Artefacts are built following existing natural laws and behavioural theories restricting the problem mixed with the intuition and other capabilities of researchers. Intuition during the design process represents a weak point of the methodology as long as it is directly dependent on researcher's personal skills without any support from a given method. This thesis fits well in the Design Science paradigm in that understanding a problem domain and its solution are achieved by the building of IT artefacts.

Design Science guidelines proposed by Hevner [43] driven this research. The application of these guidelines is deeply described and analysed in Annex 7.3 Section 7.3. They can be summarized as follows:

- research must provide solutions to relevant problems. Section 1.1 stated the relevance and importance of the problem addressed in this thesis.
- research must provide verifiable contributions. Section 1.3 describes the goals of this thesis and criteria to validate each one.
- research must provide a viable artefact resulting from a search problem. Artefacts resulted from this thesis are described in Chapters 4-5

## 1. INTRODUCTION

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- Design artefacts must be rigorously validated. Chapter 4 Section 4.2.5 discusses the validity of the designed artefacts and Chapter 6 provides evidences of the use of these artefacts.
- research must be communicated. Section 1.4 presents the key publications related to the contribution of this thesis.

To achieve the objectives of this thesis, *Design Science* as it was presented by Hevner [43] is not enough to build the expected IT artefacts, so that it was complemented with other techniques and methodologies. So to state the environment of the thesis a *Systematic Literature Review* was conducted and to build the IT artefacts *Thematic Synthesis* was applied.

An SLR is a critical assessment and evaluation of the existing research that address a particular issue. The objective is to determine in advance the selection of the studies to analyze, data collection, and the aggregation strategy. SLR uses a rigorous and auditable methodology for identifying, evaluating, and explaining the available research on specific research questions [53]. According to Budgen et al. [16], SLRs are important for (i) summarizing existing evidence concerning a practice or technology, (ii) identifying the gaps in the current research, (iii) helping position new research activities, and (iv) using empirical evidence to determine whether the given hypothesis is supported or contradicted.

As described by Kitchenham [53], an SLR is composed of three phases: planning, conducting, and reporting. The planning phase involves developing a review protocol, and the conducting phase involves executing the planned protocol. Finally, the reporting phase is comprised of relating the results of the review to the broader community. This process ensures the repeatability of the review and enables understanding of certain decisions have been made.

Thematic Synthesis is research synthesis for identifying, analysing, and reporting patterns from data [25, 99]. As a research synthesis, it integrates findings concerning to a research question extracted from the observation of different sources. Thematic synthesis organizes data over different aspects and these data are enriched with details to facilitate their understanding and the reporting.

Thematic synthesis is built over steps. The first approach presented by Thomas and Harden [99] is based on three steps: coding, theme grouping and analytical themes. Later in 2011, Cruzes and Dyb enriched the approach with guides and recommendations for Software Engineering [25]. The approach proposed, and that was applied in this research, consists of five steps: extract data, code data, translate codes into themes,

create a model of high order themes and assess the trustworthiness of the synthesis. The steps performed to conduct the research were as follows.

Step-1 To State the problem. This step was focused on characterizing the problem of product innovation assessment. The results of this step stated the topics to conduct the systematic literature review.

Step-2 To conduct an SLR to know the state of the art about the topic under study. The results of this step were the bases for the next step and determine the environment to apply Design Science.

Step-3 To build IT artefacts following the guidelines provided by Hevner [43] and the recommendations given by Cruzes and Dybå [25]. First a reference-model was built and based on the reference-model a tool to assess and positioning product innovation was implemented.

Step-4 To instantiate the reference-model built to validate its feasibility. First an instance of the reference-model was created and then a software product was assessed and positioned using the implemented tool.

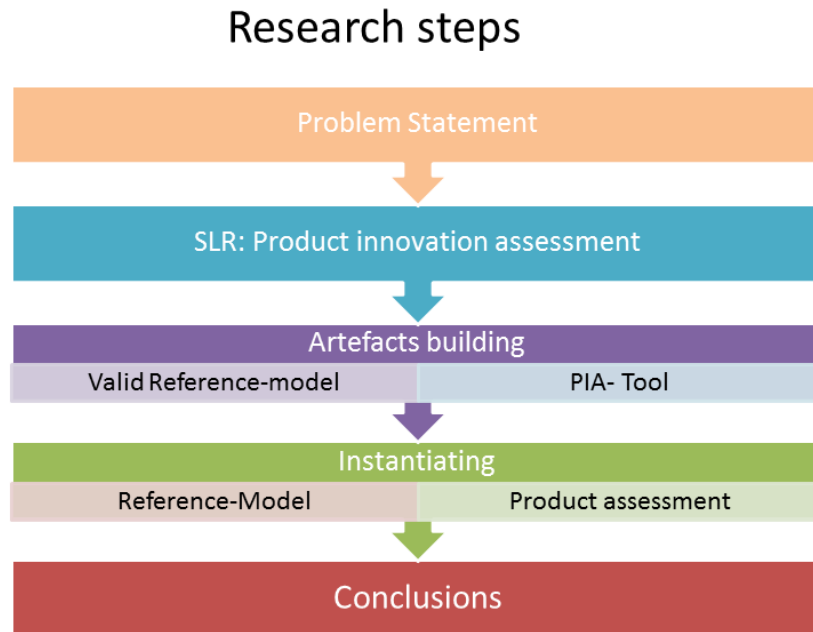
Step-5 Finally, conclusions and future work of this thesis were compiled.

These steps are graphically shown by Figure 1.2.

## 1.6 Thesis overview

The remainder of this thesis is structured as follows:

- Chapter 2: Product innovation assessment models. This chapter presents results and key findings obtained from a systematic literature review conducted in this thesis to state the problem and to understand product innovation assessment concepts and challenges.
- Chapter 3: Software Product innovation assessment framework. This chapter presents an overview of the framework to assess software product innovation. The main components of the framework and their relationships are presented.
- Chapter 4: Software product innovation assessment reference model. This chapter defines and formalizes the main components of the product innovation reference model defined in this thesis.



**Figure 1.2:** Steps performed in the elaboration of the thesis

- Chapter 5: Assessment questionnaire tool. This chapter describes the main features of the tool that has been built to perform the assessment of software products. The assessment process and components are also presented in this chapter.
- Chapter 6: Instantiating the reference model. This chapter applies the proposed framework to assess a software product. It covers instantiating the innovation model, the questionnaire building and the assessment of a product.
- Chapter 7: Conclusions. This chapter summarizes the main conclusions of the thesis and discusses future research.
- Annexes. This chapter presents additional documentation that has been produced in the scope of the thesis in the to build the reference model an instances of a product innovation assessment model.

## Chapter 2

# Product innovation assessment models

*This thesis is framed into the assessment of product innovation applied to Software intensive Systems. A review of the current state of the art about product innovation assessment and how it has been applied to software may provide understanding when assessing software products. The review of the state of the art also helps to identify challenges that have been previously addressed in the literature and new other challenges that could be derived from the findings of the study of the state of the art. In fact, the review provides the problem statement which is resolved in this thesis. It also answers five of the research questions presented in Chapter 1 Section 1.6: RQ-1.1, RQ-1.2, RQ-1.3, RQ-2.1 and RQ-2.2.*

*The remainder of the paper is structured as follows: Section 2.1 describes the method used for the literature review of the state of the art; Section 2.3 summarizes key findings of the literature review; finally, Section 2.4 presents conclusions about the state of the art.*

### 2.1 Systematic Literature Review: the method

A systematic literature review (SLR) was chosen to analyse the software product innovation assessment. An SLR is a critical assessment and evaluation of the existing research that address a particular issue. The objective is to determine in advance the selection of the studies to analyze, data collection, and the aggregation strategy. SLR uses a rigorous and auditable methodology for identifying, evaluating, and explaining the available research on specific research questions [53]. According to Budgen et al. [16], SLRs are important for (i) summarizing existing evidence concerning a practice or technology, (ii) identifying the gaps in the current research, (iii) helping position new research activities, and (vi) using empirical evidence to determine whether the given hypothesis is supported or contradicted.

As described by Kitchenham [53], an SLR is composed of three phases: planning, conducting, and reporting. The planning phase involves developing a review protocol, and the conducting phase involves executing the planned protocol. Finally, the reporting phase is comprised of relating the results of the review to the broader community. This process ensures the repeatability of the review and enables understanding of certain decisions have been made.

#### 2.1.1 First phase: Planning the review

**Objective and Research questions.** The objective of the proposed review is to determine the existing schemas for evaluating software product innovation and also to identify key elements and challenges in product innovation assessments. The systematic literature review performed addressed the following five research questions:

RQ-1.1 What are the goals of a product innovation evaluation?

RQ-1.2 What is the environment of the product innovation evaluation?

RQ-1.3 What are the main challenges of the product evaluation schemas?

RQ-2.1 What are the existing schemas (structure and types) for evaluating products from the innovation perspective?

RQ-2.1 What is the relevance of the innovation factors?

**Search strategy.** A search strategy is a formal method for finding the scientific publications that are relevant to the proposed research questions. A formal search strategy makes it possible for other researchers to replicate the study in the future. To conduct the review, we explored the main electronic databases, including IEEE Xplore,

## 2.1 Systematic Literature Review: the method

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ACM Portal, Science Direct, SciVerse, EI Compendex and Google Scholar. The search retrieved scientific papers, which are considered primary studies; publications based on primary studies, which are considered secondary studies; and tertiary studies.

After defining the search strategy, the next step was to select the search terms. A wide list of search strings including tokens, such as “product”, “innovation”, “software”, “evaluation”, and so on, was set up. The initial list of terms was fine-tuned by an iterative process. Strings like “product innovation”, “software innovation”, or “success product” presented two main challenges: (i) a huge number of results (ii) and most of the results were out of the scope of this research focus because they did not address any factor useful for innovation assessment. Finally, the strings selected included “software product innovation”, “evaluation or assessment or measurement”, and “factors” (which is the term used in the specialized literature related to the evaluation of innovation).

The final terms selected were the following:

- “software product innovation”, as we are interested only in software product innovation
- “evaluation or assessment or measurement”, as we are interested in knowing how innovation has been evaluated.
- “factors”, as we are interested in knowing what factors were considered in the evaluations.

These terms were combined to produce the following search chain: “(software product innovation) and (success factors) and (assessment or evaluation or measurement)”.

**Inclusion and exclusion criteria.** The review protocol also determines the criteria for determining whether each potential publication should be included or excluded in this systematic review. **Inclusion criteria**

- *Type of study:* The study must be scientific material written in English and must include the search terms defined in the previous section. Scientific material includes papers, short papers, experience reports, and summaries of workshops subjected to a scientific peer-review process.
- *Date:* The study must be a scientific paper published before December 2012, which was when we began our analysis.

### **Exclusion criteria**

- *List of factors:* Those publications that did not include innovation evaluation mechanisms or a list of innovation factors were excluded.

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- *Abstract analysis*: Those publications that did not refer to innovation evaluation mechanisms or innovation factors in the title or abstract section were excluded.
- *Innovation process*: Those publications that refer to the innovation process because they addressed factors of the innovation or development processes but did not focus on the products themselves were excluded.
- *Reductio ad absurdum*: The publications that did not fulfil the inclusion criteria were excluded.

**Quality assessment.** Kitchenham’s guidelines [53] suggest performing a quality assessment of each included study, which is complementary to the inclusion/exclusion process. There is no universal definition of the term “quality”, but the Critical Appraisal Skill Programme (CASP) presents a checklist for assessing the quality of qualitative research. These are the criteria, adapted from CASP<sup>1</sup>, that were used in the quality assessment in this systematic review:

- Is there a clear statement of the aims and objectives of the research?
- Is there an adequate description of the context in which the research was carried out?
- Is there an adequate description of the proposed contribution, method, or approach?
- Is the evidence obtained from experimental studies or observational studies?
- Is the study valuable for research or practice?

### 2.1.2 Second phase: Conducting the review

In this phase, the review was conducted by following a sequence of steps: search for studies; select relevant studies’ and perform the quality assessment, data extraction, and data synthesis.

**Search for studies.** By applying the search strategy described above, we retrieved 744 studies. Some results were redundant because they appeared in different databases; therefore, we ended up with 274 different candidate publications for the next step. Table 2.1 presents the results obtained from different research databases, including journals and conference proceedings. The Retrieved Column represents the number of publications obtained from the source. The Included Column represents the number of papers

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<sup>1</sup>[http://www.casp-uk.net/wp-content/uploads/2011/11/CASP\\_Qualitative\\_Appraisal\\_Checklist\\_14oct10.pdf](http://www.casp-uk.net/wp-content/uploads/2011/11/CASP_Qualitative_Appraisal_Checklist_14oct10.pdf)



that were selected for the next step. Finally, Excluded Column represents the number of publications that were excluded because they did not satisfy the inclusion criteria. The Total Row represents the total number of results of each category, including the redundant values.

Database	Retrieved	Included	Excluded
IEEE Xplorer	46	6 (13%)	40 (87%)
ACM Portal	112	1 (01%)	111 (99%)
Springer	279	10 (04%)	269 (96%)
SciVerse	264	18 (07%)	246 (93%)
EI Compendex	43	8 (19%)	35 (81%)
Total	744	43 (064%)	701 (94%)

Table 2.1: Systematic search results

**Study selection.** After determining which papers met the inclusion criteria, we processed their abstracts and keywords with more detail. Only 18 publications referring to innovation evaluation mechanisms or containing a list of innovation factors were accepted. Therefore, a total of 256 publications were rejected because they did not satisfy the inclusion criteria. Each publication was analysed to extract the following information: publication date, authors, innovation factor list, type of factor evaluation, data gathering method, and strengths and challenges identified in the publication. All these data were organized into a spreadsheet for analysis.

**Study quality assessment.** Each study was assessed on the basis of the quality criteria defined above. Only 13 (72%) publications met the quality criteria. We then synthesized the results. As the number of selected results was too low, an additional quality assessment process was performed. For each selected publication, we performed a reverse search. Those papers citing a selected paper were analysed to determine if any more recent publications could be located, but no new publications related to this research were identified.

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Finally, 13 publications were selected. The selected paper were published between 1998 and 2012 and all dealt with product innovation. All were compilations of studies about product innovation evaluation or innovation factors, but none of the studies were specifically about product software. Therefore, our study is considered to be a tertiary

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study because it is an SLR based on secondary studies. Papers were classified into three groups (Experience, Questionnaires, and Literature Reviews) and sorted according to publication date. Each group name represents the main source used to identify the factors applied in the innovation evaluation. Figure 2.1 shows the distribution of the selected publications.

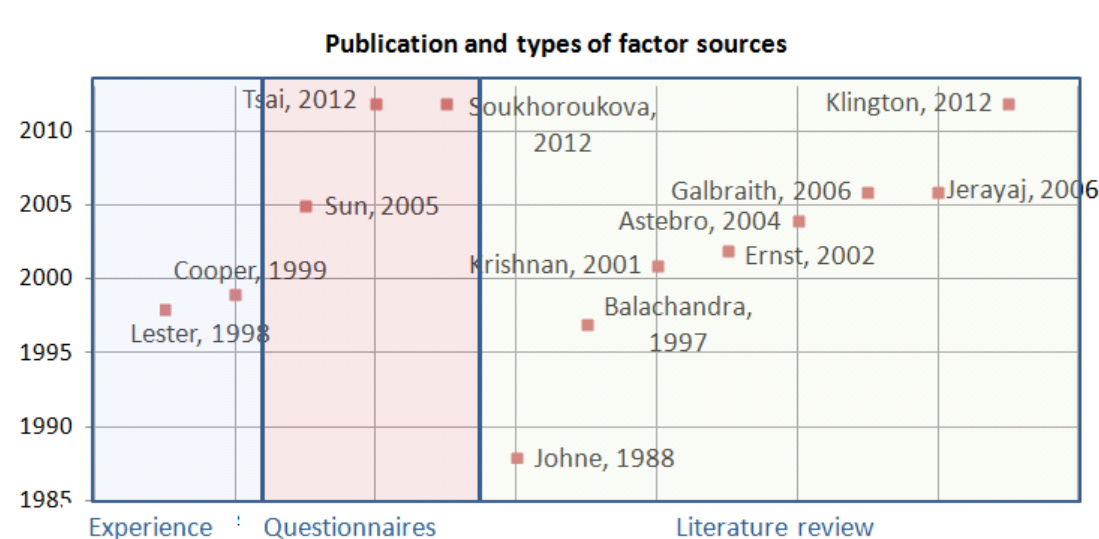


Figure 2.1: analysed publications classified by type

Each paper was then analysed according to the research questions defined in Chapter 1 Section 1.3. The following subsections present the answers to these questions.

### 2.2.1 RQ-1.1. What are the goals of the product innovation evaluation?

Three main goals of product evaluation have been identified in this SLR: to increase the knowledge of success or failed products, to have a better understanding of the impact of innovation factors, and to support decision-making processes.

Product innovation evaluations have been used to increase the current knowledge regarding why products succeed or fail in new product development (NPD), the purpose of which is to create new products and add value to an organization [50]. Success in innovation is a broad field, and researchers have focused on specific issues. According to Johne et al. [50], Lester [58], and Cooper [22], assessment is used to capture the knowledge behind the success or failure of NPD. This knowledge is important to companies because it helps them establish a list of factors for assessing products.

Other authors like Balachandra et al. [9] and Åstebro [8] have proposed that assess-

ment should be used to provide a better understanding of the influence of each factor in the NPD process. The influence of each innovation factor depends on the type of innovation, the market, and the technology applied in the development of the new product. Moreover, Cooper et al. [22] used the list of factors to identify enablers and blockers of NPD. They concluded that a factor acts as an enabler if its presence during the product development process helps the company to achieve product goals. It is a blocker if its presence makes it difficult for the company to reach product goals. Ernst [34] only evaluated the impact of innovation factors on NPD. Sun [96] organized factors in a bi-dimensional model according to development phases and the level of importance/adoption of each factor. He found that innovation factors could impact the entire development process, not only specific activities.

Finally, Krishnan et al. [55] used product innovation assessment to support the decision-making process during product development by implementing a list of innovation factors.

### 2.2.2 RQ-1.2. What is the environment of the product innovation evaluation?

Three main issues determine the environment of product innovation evaluation: the organizational level in the company where the assessment is performed, who is in charge of performing the evaluation, and when the evaluation is performed.

At the organizational level, data on innovation factors are collected internally at the micro-level (project) but have an impact at the macro-level (company). This is relevant because depending on the organizational level (project or firm) where the evaluation is being performed, some innovation factors could remain hidden. At the organizational level, Cooper [22] considered that innovation factors should be assessed at the macro-level (firm level) to understand the impact of the innovation on the whole organization. This is because factors represent internal knowledge that could determine the difference between successful and unsuccessful products. Krishnan [55], however, highlighted that factors are different for different products and types of products. Therefore, the project level is where factors should be analysed. When any new innovation factor is adopted at the project level, it takes time to scale up to company level. Therefore, if the evaluation is performed at the firm level, new factors at the project level are ignored. A possible solution proposed by Crossan et al. [24] is the application of a practice-based view approach with round-trip decisions through all organizational levels from the firm level to the project level and back again.

The second issue of product innovation evaluation is who will be performing the product

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innovation assessment: it is not clear if this should be an internal or external process. Internal and external assessments can potentially be applied at different stages of software product development to improve the feedback received by the company. However, Cooper et al. [22] found that product evaluation is usually performed internally by company personnel. McKinsey [98] agreed with Cooper, stating that companies rely more on internal than external assessments because innovation data come from inside the company. This becomes an issue of trust. It seems that internal evaluation is a good approach because companies have thorough information of the new product under development. But this could also be a challenge because products and their innovation are seen from a subjective perspective.

Other studies, such as Balachandra et al. [9], Lester [58], Sun et al. [96], and Tsai [103], considered that the assessment should be performed by outside companies using questionnaires. In the case of external assessment, internal data are not always available to the evaluators due to privacy policies. Therefore, the results may not be adequate.

Some researchers, such as Lester [58], Åstebro [8], Sun et al. [96], and Galbraith et al. [41], have proposed that product evaluation should be performed as soon as possible; that is, during the requirement definition phase or when the product is only a preliminary version (e.g., alpha or beta releases). This is because at the early stages of product development, it is possible to perform an early analysis of the innovation of the product under development to react to market needs or changes and still change some product features with a limited impact on cost. In spite of this, in most cases, the evaluation is performed when the product is already on the marketplace, when companies can gather data to analyze the impact of the product.

### 2.2.3 RQ-1.3. Which are the main challenges of the product evaluation schemas?

Several challenges were pointed out in the analysed studies. It is important to note that there is no consensus regarding the meaning of each innovation factor and the impact of each one on the success or failure in NPD. This problem has been highlighted by Åstebro [8], Balachandra et al. [9], and Galbraith et al. [41].

Another challenge concerns the nature of each factor whether it is qualitative or quantitative. Again, there is no agreement if factors should be continuous or discrete values, but it seems that qualitative and discrete values are considered more often than other types as an easier way to get data in the assessment.

The type and number of the factors is another challenging issue. Both are very wide, and they depend on the author. John et al. [50] recommended collecting measures to

find cross-cutting relationships between the innovation strategies and to then develop products in four dimensions: organization, market, culture, and project management. Cooper [22] proposed between 10 to 15 factors focused on 5 dimensions, Balachandra et al. proposed 72 factors organized into 4 dimensions [9], and Jeyaraj et al. [49] presented 135 factors. Klinton et al. [54] proposed the application of artificial intelligence over 23 factors organized into three dimensions. Tsai [103] analysed 5 dimensions through 24 factors covering the main product issues like conceptualization, skills, and organization. None of the studies provided guidelines on how to perform the assessment using factors.

The analysis of the various publications revealed that there is no consensus on the name, meaning of each factor and on how to determine whether a factor is successful [8]. Therefore, prior to assessing product innovation, a kind of normalization process to harmonize factor names is needed. This lack of consensus produces three different situations. First, the same factor can be classified in different families. This is not an error because the same factor could impact in a different manner depending on the family; i.e. risk distribution impacts the market and technology dimensions in the Balachandra et al. [9] list of factors. Second, the same factor can be given different names in the same family by different authors; i.e. Krishnan [55] uses the name “Collecting and meeting customer needs” while Balachandra et al. [9] uses “Meets customer needs/wants” in the market dimension. To address this challenge, a systematic process for detecting these situations is recommended. Third, the level of granularity of the dimensions can be different depending on the author; i.e., Montoya et al. [68] presented market competitiveness as a factor, and Balachandra et al. [9] split this factor in three more detailed ones, namely competitive environment, few competitors, and market analysis.

### **2.2.4 RQ-2.1. What are the existing schemas (structure and types) to evaluate products from the innovation perspective?**

Subsections 2.2.1 and 2.2.2 showed that product innovation evaluation is performed based on innovation factors. All the analysed studies considered innovation factors to be complex structures composed by variables. These variables could be represented by continuous or discrete data. All authors agreed on the use of discrete values as input to represent the data. Typical values are very low, low, medium, high, or very high. Discrete values provide sufficient information for evaluating factors at early stages of the product development, even when uncertainty over the product is still high. Krishnan et al. [55] proposed the use of vectors of variables to represent factors. This

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approach allows evaluators to change the factor relevance by assigning weights to factors if it is needed. These vectors represent the innovation of a product. The stored values provide the rationale of the product innovation.

Author	Organization	Market	Environment	Technology	Strategy	Development process	Role & Commitment	Culture	Project Management	Profit	Operations	Risks	Dimension size
Johne et al.[50]	X	X						X	X				4
Balachandra et al.[9]	X	X	X	X									4
Lester[58]	X				X	X	X		X				5
Ernst[34]	X				X	X	X	X					5
Sun[96]	X	X				X			X				4
Soukhoroukova et al.[95]		X											1
Cooper[22]	X	X	X		X	X							5
Krishnan et al.[55]	X	X		X								X	4
Åstebro[8]	X	X	X	X						X	X		6
Galbraith et al.[41]	X			X									2
Jeyarag el al.[49]	X		X										2
Klintong[54]	X	X	X										3
Tsai[103]	X	X	X	X	X								5
<b>Total</b>	<b>12</b>	<b>9</b>	<b>6</b>	<b>5</b>	<b>4</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>50</b>
% citations	92	69	46	38	31	31	23	15	15	8	8	8	Avg size: 4

**Table 2.2:** Innovation factor dimensions

Factors are grouped into dimensions. Dimensions represent abstract concepts sur-

rounding innovation factors. The dimension-based representation allows evaluators to apply different levels of abstraction to model each dimension in terms of the granularity of the information required in the assessment. Twelve main dimensions were identified in the analysed publications (see Table 2.2). The first column contains the first author's name, and the last column shows the number of dimensions considered for each publication. The remaining columns are the dimensions. Each row contains the information for each publication.

When a publication proposes a dimension, it is represented by an "X" in the appropriate column. The two last rows represent the number of citations of each dimension and the percentage of the total number of citations. More than 90% of the studies considered organization and almost 70% considered market as the most relevant dimensions when evaluating product innovation. Two other dimensions (environment and technology) were cited by at least 40% of the publications. These four dimensions covered 64% (32) of all citations and were included in all of the publications. Almost 75% of the studies used four or more dimensions, and only one study (i.e., Soukhokova [95]) analysed one dimension the market. The average number of dimensions considered was four.

Two main approaches were identified for assessing the product innovation factors: apply weights to the innovation factors and not applying weights. A weighted evaluation schema consists of a mechanism to assess product innovation through a list of factors and has the possibility of giving different weights to each factor. Therefore, each factor could have a different impact on the evaluation. Åstebro [8] used a subset of the factors provided by Balachandra et al. [9]. The subset was composed of the factors with the highest significance levels, and weights were calculated by statistical methods.

Other studies have applied different strategies to represent the influence of each factor. Galbraith et al. [41] combined the application of Delphi processes [91] and statistical analysis to assign weights to factors. Tsai [103] also applied weighted factors, but he used artificial intelligence (fuzzy logic) to calculate the weights. Similarly, Klintong [54] proposed the application of other artificial intelligence techniques, such as an artificial neural network or genetic algorithms, to assign weights to factors.

Un-weighted evaluation schemas consist of a mechanism to assess product innovation through a list of factors and give the same impact to each one. Therefore, each factor has the same weight in the evaluation. Table 2.3 includes detailed information of the studies according to each approach.

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Factor family	Un-weighted References	Weighted References	Number of un-weighted References	Number of weighted References	Total references
Organization	[50, 9, 58, 34, 96]	[22, 55, 8, 41, 49, 54, 103]	5	7	12
Market	[50, 9, 96, 95]	[22, 55, 8, 54, 103]	4	5	9
Environment	[9]	[22, 8, 49, 54, 103]	1	5	6
Technology	[9]	[55, 8, 41, 103]	1	4	5
Strategy	[58, 34]	[22, 103]	2	2	4
Development process	[58, 34, 96]	[22]	3	1	4
Role & Commitment	[50, 58, 34]		3	0	3
Culture	[50, 34]		2	0	2
Project Management	[58, 96]		2	0	2
Profit		[8]	0	1	1
Operations		[55]	0	1	1
Risks		[8]	0	1	1

**Table 2.3:** Citation by type of evaluation schema

In these studies, the main mechanism for data gathering was questionnaires. In the most of the analysed studies (e.g., [8], [9], [22], [41], [54], [55], [58], [96], and [103]), product evaluation was performed by the people involved in the evaluation using questionnaires. According to Tsai [103], it is very important that questionnaires are based on qualitative instead of quantitative values to reduce the uncertainty of answers.

### 2.2.5 RQ-2.2. What is the relevance of the innovation factors?

Another issue highlighted in the studies is that all of the factors on each dimension do not have the same impact. For example, Balachandra et al. [9] presented a list of 72



## 2.2 Reporting the review

factors organized into four dimensions: organization (35 factors), market (21 factors), technology (13 factors), and environment (7 factors).

Id	Factor description	Citation Frequency	Rate	Aggregate rate
1	Available Resources or Raw material	4	0.36	0.36
2	Political/Social factors	2	0.18	0.55
3	Government Regulations	1	0.09	0.64
4	Industry restructure opportunity	1	0.09	0.73
5	Public interest on product	1	0.09	0.82
6	Risk Distribution	1	0.09	0.91
7	Product liability	1	0.09	1.00

**Table 2.4:** Environment dimension factors[9]

Table 2.4 shows the list of factors for the environment dimension and their frequency. The Frequency Column represents the number of times that each innovation factor was seen as relevant in the study performed by Balachandra et al. [9]. The Rate Column represents the rate of each factor, which is calculated as the number of the factor's citation divided by the total number of factor citations. The Aggr. Rate Column represents the cumulative sum of the rates. By analysing the evolution of the aggregate rate, it can be seen that all dimensions have asymptotic behaviour without a dependency of the number of factors of the dimension. Figure 2.2 depicts the asymptotic evolution of the aggregate rate (y-axis) and the number of factors aggregated (x-axis). When there is a large number of factors, such as for organization or market, the common solution is to define an accuracy limit, which can determine the number of factors that should be used in the evaluation to achieve a determined level of confidence. This method ensures that those factors with the highest frequency have been considered in the evaluation. Therefore, not all the factors are used in the assessment process.

Dimension	Num. Factors	70% coverage	Percentage
Organization	36	16	44%
Market	21	11	52%
Environment	7	4	57%
Technology	13	6	46%

**Table 2.5:** Factors reach an accuracy limit of 70%.

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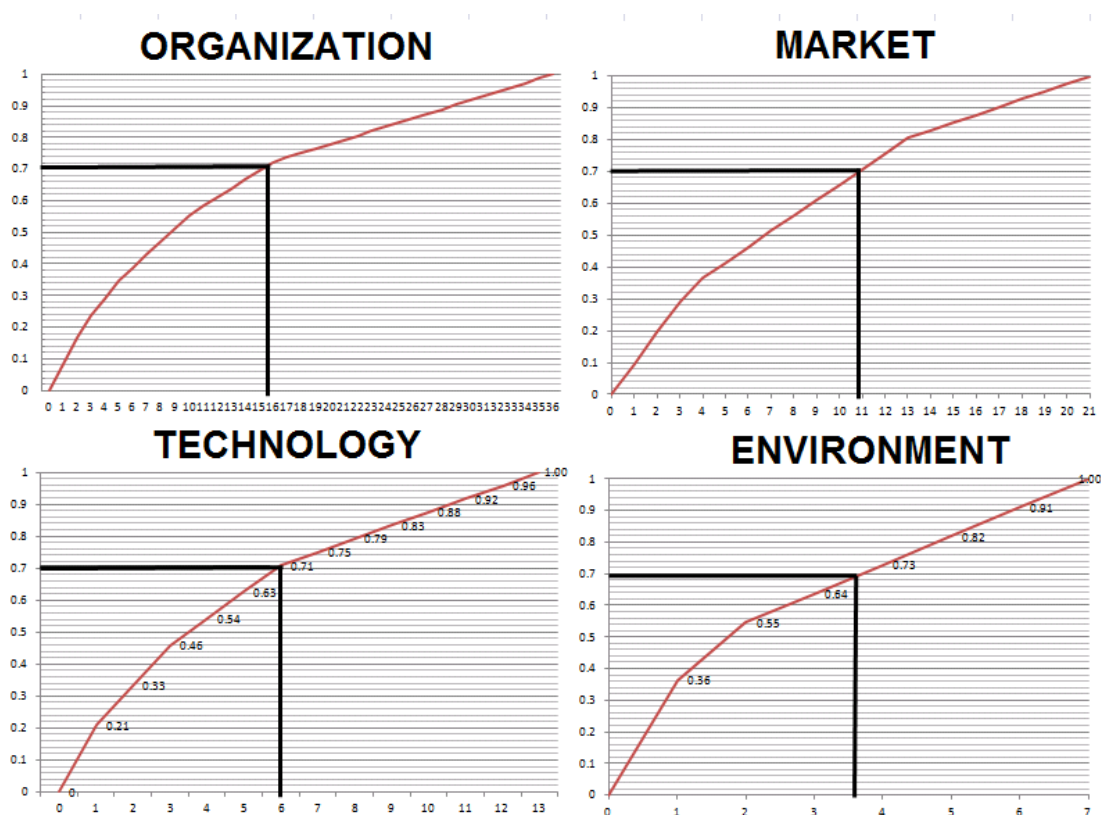


Figure 2.2: Innovation factors aggregate rate evolution

This solution also has weaknesses. As the accuracy limit is based on factor frequencies, it represents a barrier for new factors that are identified and that need time to be relevant enough to be included in the assessment. This is one of the reasons why the impact should be evaluated periodically. Table 2.5 shows the number of factors needed to achieve an accuracy limit of 70% for each dimension. The first column contains the dimensions name, the second column represents the total number of factors on each dimension, the third column represents the number of factors needed to achieve the accuracy limit of 70%, and the last column represents the percentage of factors needed to achieve that limit. The average is 50% of the factors. This means that only 50% of the factors with the highest frequencies is needed to achieve an accuracy limit of 70% for each dimension.

### 2.3 Key Findings on Product Innovation Assessment

The findings from this SLR can be divided into three main categories: (i) general findings about product innovation assessment, (ii) findings regarding product innovation assessment preparation, (iii) and findings related to the assessment process.

#### 2.3.1 General findings

Concerning general findings, the analysed literature reports the following:

**Finding 1.** There is no evaluation schema focused on software product innovation, although there are general evaluation schemas that are applicable to any type of product. However, innovation in software has a different nature than other types of products. As Pikkarainen et al. [82] pointed out, software is malleable and intangible, and it has a low threshold for entering into the market. Software is also exposed to fast market changes and has a reduced time to market. Finally, OECE reported that software plays an important role in enabling ICT to contribute to innovation [77]. Therefore, it has sense to work in the definition of a customized software product innovation evaluation framework.

**Finding 2.** A product innovation evaluation has been applied in different domains. In all of the reviewed studies, the assessment was based on a list of factors that were used in different domains. Some examples include Galbraith et al. [41], who used the factors to build models to predict future technologies; Jeyaraj et al. [49], who performed an assessment of the adoption of innovation; and Soukhoroukova et al. [95], who used innovation factors to support the classification, filtering, and selection of candidates in an idea market. However, these studies did not evaluate software products.

**Finding 3.** Product innovation evaluation has been used to increase knowledge of successful and unsuccessful products, to have a better understanding of the impact of innovation factors, and to support decision-making processes. This finding was discussed in Section 2.2, subsection 2.2.1.

**Finding 4.** Three main mechanisms have been used to select the factors for determining product innovation: (i) literature reviews (e.g., [8], [9], [34], [41], [49], [50], [54], and [55]), (ii) questionnaires (e.g., [95], [96], and [103]); and (iii) professional experience (e.g., [22] and [58]). Figure 2.1 presents the evolution of these studies over the time. It shows that literature reviews have been the most popular method for compiling a list of factors.

**Finding 5.** There is no agreement about the nature of innovation factors, Should they be qualitative or quantitative? Should they be continuous or discrete values? It was

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described in Section 2.2, subsections 2.2.4 and 2.2.3.

**Finding 6.** There is no consensus regarding the meaning of each factor or how to determine when a factor can be considered successful. Consequently, factor information is sometimes available under a different name. This was explained in subsections Section 2.2, subsections 2.2.4 and 2.2.3.

These findings show that a systematic process for supporting the rationale for a software product innovation evaluation is needed. There is enough literature to establish the fundamentals for a software product innovation assessment.

### 2.3.2 Product innovation assessment preparation

Regarding the preparation of the product innovation assessment, the following are the main findings identified from the evaluated literature:

**Finding 1.** The assessment process has been performed at different organizational levels: project, department, and firm. Depending on the organizational level, the assessment generated results with different targets from team groups to the whole company. This finding was analysed in Section 2.2, subsection 2.2.2.

**Finding 2.** Questionnaires are the main artefact used to perform the product innovation assessment evaluation. This was shown in Section 2.2, subsection 2.2.4.

**Finding 3.** The assessment process has been performed at different stages of product development: at the beginning of the project to allow the company to react to a changing market or at the end of the project when the product is already on the market to increase the knowledge about the impact of the innovation on the company. This finding was analysed in Section 2.2, subsection 2.2.2.

**Finding 4.** Large questionnaires require too much of the respondents' time, and the relevance of some answers is low. In most cases, analysing around 50% of the available innovation factors is enough to cover almost 70% of the possible factors. This information is relevant to build adapted questionnaires to perform the product innovation assessment and was analysed in Section 2.2, subsections 2.2.4 and 2.2.5.

These findings show that it is helpful to use a questionnaire that contains a sufficient number of factors for performing a product innovation assessment. The number of factors should balance the time required to fill out the questionnaire and the relatively high accuracy of the available factors.

### 2.3.3 Assessment process

Finally, the following findings summarize the conclusions drawn regarding the assessment process:

**Finding 1.** Two types of general evaluation schemas are available: un-weighted and weighted. This was analysed in Section 2.2, subsection 2.2.4.

**Finding 2.** Organization, market, environment, and technology are the most considered dimensions when evaluating product innovation from a general perspective. It was analysed in Section 2.2, subsections 2.2.4 and 2.2.5.

**Finding 3.** When the number of factors is high, this is harmful to the evaluation process for several reasons: (i) The time needed to perform the assessment could be very high, (ii) the respondents are asked to provide data with very low relevance for the evaluation process, and (iii) too much time is spent gathering the data. An additional problem identified by Lester [58] is that the required information is not always available. This finding was analysed in Section 2.2, subsection 2.2.3

These findings show that four main dimensions have been clearly selected in the literature. Balachandra et al. [9] has presented a complete list of factors in all these dimensions with adequate information for measuring the impact of factors.

### 2.3.4 Final considerations

Some final considerations should be considered. The Balachandra et al. [9] study referred the same most cited dimensions that have been identified in this SLR. They also provide a complete list of factors that could be considered as the base for the evaluation process.

Finally, to keep this systematic literature review up to date, we made an effort during the review to include the latest papers published. As a result of the literature review, new research topics in close relation to product innovation assessment, such as variables or innovation metrics, have been identified. It is still not clear how to handle lists of factors to keep them up to date.

## 2.4 SLR Conclusions

The main contribution of this systematic literature review is the identification of the main goals of product innovation evaluation answering the **RQ-1.1**. In addition, the advantages of different organizational levels have been identified. This review has been structured around 13 findings and has answered 5 research questions that address mul-

## 2. PRODUCT INNOVATION ASSESSMENT MODELS

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multiple aspects of product innovation assessment. The methodology used has been SLR, and articles determined to be applicable have basically been previous SLRs. Therefore, this paper can be considered to be a tertiary study of the existing evaluation schemas of product innovation.

Existing evaluation schemas have been applied to different industry domains, but none has been focused specifically on software product innovation. Product innovation evaluation has been used mainly to increase the knowledge and understanding of innovation factors in product development. Evaluation schemas have three main sources: questionnaires, professional experiences, and the existing literature. However, there is no agreement regarding the meaning and nature of the innovation factors. Questionnaires are the main artefact used to perform product innovation assessment. Questionnaires could be applied at different organizational levels (project or company) and at different stages of product development.

Two main evaluation schemas have been identified: un-weighted and weighted. Both evaluation schemas are based on what has been called innovation factors. These factors are grouped into factor families. Organization, market, environment, and technology are the most referenced factor families. The results of this study contain limitations due to the reduced number of studies analysed in the SLR.

Obtained results also have limitations derived from the reduced number of existing studies. These studies usually include different industrial sectors. Therefore it becomes necessary to extrapolate conclusions to the SiS industry, and conclusions need not always be true. Some limitations may also be derived from the search string used in the SLR. However this limitation has been minimized performing reversed search from the obtained results from SLR.

Based on these results, the next step is to define a framework specifically adapted to evaluating software product innovation. This framework will help companies reduce the existing gap between developed software products and market needs. Our understanding is that the Balachandra et al. study [9] is a promising starting point. This framework will include an assessment process, a software product innovation assessment model, and a process for updating the innovation factors and the assessment rationale with innovation knowledge. Another issue that will be addressed is to increase the level of automation to support working with the framework. More research is also needed about how to measure the identified factors.

## Part II

# Software Product Innovation Reference Model Building





## Chapter 3

# Software Product innovation assessment framework

This thesis pointed out a framework to assess software product innovation. This chapter presents an overview of the framework elements to assess and position software product innovation. The framework comprises: a reference model to represent all the concepts concerning to represent product innovation assessment models and a tool based on instances of the reference model to support data gathering to perform the assessment and to positioning the innovation for an assessed product.

### 3. SOFTWARE PRODUCT INNOVATION ASSESSMENT FRAMEWORK

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#### 3.1 Introduction

This Chapter presents an overview of the framework to perform software product innovation assessment. This framework comprises: a reference model containing the concepts identified to represent software product innovation assessment and a tool based on instances of the reference model to support data gathering to perform the assessment and to positioning the innovation for an assessed product which is termed as Product Innovation Positioning System.

Models support the formal specification of systems and their exploitation and automation through software tools [10]. The capture of innovation information, their storage and mining help researchers in the application of reasoning mechanisms over the space of product innovation. This is reason why the software product innovation assessment framework presented in this thesis is based on conceptual models.

The definition of a framework based on the reference model provides the following advantages: (i) the automation of questionnaires generation; (ii) the automation of product assessment; (iii) the formalized representation of the assessment; (iv) the availability of a repository of the assessment of products; (v) and, the building of a knowledge base about product innovation to help the reasoning over the space of product innovation. To automate the assessment, this framework will be supported by a tool that has partially developed in the scope of this thesis. It is called Product Innovation Assessment Tool (PIA-Tool). This tool will cover the whole process, but in the scope of this thesis only includes the implementation of the assessment questionnaires representation to provide a support for data gathering, and then the application of these collected data to assess and positioning products from the innovation perspective.

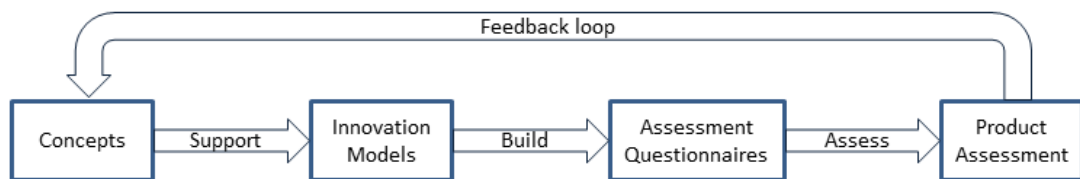
One of the goals of product innovation assessment in general and reported in Chapter 2 was to provide support in the understanding of the impact of each innovation factor. Aligned with this goal, the ability to store the evolution of product assessment through questionnaires may help companies to perform a retrospective evaluation of the evolution of the impact of innovation factors across the time. This information could be useful for managers to drive the development of innovative products in the future and to try to align product to market needs. The assessment framework could be applicable at the beginning product development as it is proposed by Lester [58], Åstebro [8], Sun et al. [96], and Galbraith et al. [41] to align the product with the market. In this sense, the assessment acts as a way to predict the innovation of a product. When the assessment is performed at the end of the development, when products are in the market, the assessment is used to understand the impact of each innovation factor in

the exploitation of the product.

The rest of the chapter describes at high level the elements of the framework that will be deeply analysed in the following chapters: the reference model and its main concepts and positioning tool.

### 3.2 Software Product innovation assessment reference model

The reference model building will be deeply described in Chapter 4, this section only presents a high level overview of the main components comprising the reference model. The software product innovation assessment reference model has been built following the research methodology described in Chapter 1 Section 1.5. The building process was driven by *Design Science* combined with *Thematic Synthesis* and *Conceptual Modelling*. From a high level perspective, four main elements formalize a software product innovation assessment: concepts, innovation models, assessment questionnaires and product assessment. Figure 3.1 depicts the main elements and their relationships.



**Figure 3.1:** High level elements comprising the reference model

*Concepts* represents the abstraction of the components that are needed to represent innovation in terms of innovation factors, dimensions, factor impact and weight. It is continuously growing with contributions from different fields: research, business, users, assessors. Concepts play a fundamental role to support the rest of the elements because they are the basis to define more complex relationships needed to model the innovation assessment framework.

*Innovation models* are combination of factors, dimensions, impacts and weights to capture specific knowledge about innovation. Some examples are available in the literature [9, 8, 21, 103]. They are based on the concepts previously defined. These models are defined by Researchers, business analysts or companies to get a better understanding of the market, product or any other relevant issues they need. These models could be as complex and complete as needed to represent the fact to analyse.

*Assessment questionnaires* represent those artefacts that have been defined to capture

### 3. SOFTWARE PRODUCT INNOVATION ASSESSMENT FRAMEWORK

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data for the assessment of product innovation. Business analysts or researchers build questionnaires based on product innovation assessment models to collect data. The same product innovation assessment model could be represented by as much questionnaires as needed depending on the nature of factors, available data and the goals of the research. Assessment questionnaires could cover all the factors existing in the model or only a subset of them depending on the goals of the study or the targeted assessors. Finally, *Product Assessment* represents data provided by survey respondent through questionnaires. These data are used to perform the assessment and to positioning the product by the impact of the assessed factors. Products are analysed through the values assigned to innovation factors in questionnaires and the corresponding impact of the factor in the innovation models. For each factor available in questionnaires, assessors should decide if it is applicable or not the assessed product. In the case of being applicable, the next step is to provide a value for the impact or in the case of missing information or the information is still not available, to assess the factor as *Unknown*. These results could be used to achieve different goals: (i) as it is proposed by Axel et al. [50], Lester [58], and Cooper [22] they are used to capture the knowledge behind the success or failure of NPD; (ii) other authors like Balachandra et al. [9] and Stebro [8] proposed that results of the assessment could be used to provide a better understanding of the influence of each factor in the NPD process; (iii) finally, Krishnan et al. [20] indicated that product innovation assessment results could be used to support the decision-making processes during product development. The feedback loop from *Product Assessment* to *Concepts* represents that based on the results of the evaluation of software products, new factors could be discovered or some factors could change their impact or, even new innovation models could be inferred.

A reference model by itself is not enough, therefore, it needs to be instantiated to enable the assessment of product innovation. To make feasible the instantiating process, a language has been defined. The language involves the creation of a set of primitives and associations derived from all the elements defined in the reference model. The instance of the product innovation assessment model will be used as input to configure the assessment and positioning tool. The language has been defined by using XML-*Schema*<sup>1</sup> and models are represented by XML<sup>2</sup> documents. One of the advantages of having a language to represent the assessment framework is the ability to automate the questionnaire building process and the validation of models.

XML-Schemas and XML has been widely used to define languages and to support

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<sup>1</sup><http://www.w3.org/XML/Schema>

<sup>2</sup><http://www.w3.org/XML/>

model transformation [79, 33, 106, 11]. XML is flexible and extensible and all the existing programming languages provides facilities to manage this type of documents. Textual representation of languages has been mainly applied for documentation and specification [79] that is the target of the language in the scope of this thesis.

In addition, many recommendations to transform UML models to XML-Schemas are available in the literature. It is not a unified process and authors proposed their own mechanism to perform this transformations [30, 39, 92, 104, 116]. One of the challenges identified in the literature to transform UML models to XML-Schemas is that general transformations rarely produce the expected results [33]. Another challenge is related to traceability and bi-directional update between models [30]; however this is not a problem affecting to our transformation because it will be an unidirectional transformation from the reference model to its corresponding XML-Schema representation.

Chapter 4 Section 4.4 will describe how the transformation has been performed and the resulted XML-Schema to validate XML instances of the reference model.

### 3.3 The assessment and positioning system

The last, but not the least element of the software product innovation assessment framework is the Assessment and Positioning System. This tool called Product Innovation Assessment Tool (PIA-Tool) is still under development that is, PIA-Tool will cover the whole process, but in the scope of this thesis it includes the implementation of the assessment questionnaires representation to provide a support for data gathering, and then the application of these collected data to positioning the product from the innovation perspective.

Even considering that there is no agreement whether factors should be qualitative or quantitative, in this thesis and based on the findings obtained in the SLR performed [117], we decided to use qualitative values to represent innovation factors because data collection with these type of data is simpler for survey respondents than quantitative data. Following the recommendations of Tsai [103], factors are represented by discrete values and the criterion scale proposed is *VP: Very Poor*, *P: Poor*, *F: Fair*, *G: Good* and *VG: Very Good*. Scoring values for each rating are 1, 2, 3, 4, and 5, respectively.

The assessment and positioning tool will provide the following facilities:

1. To import instances of the reference model. It is important to customize the assessment and positioning system to achieve the goals driven the assessment.
2. To present the innovation models available perform the assessment. It is relevant

### 3. SOFTWARE PRODUCT INNOVATION ASSESSMENT FRAMEWORK

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to let assessors to perform the assessment of products through different innovation assessment models.

3. To present the list of questionnaires defined to each specific innovation assessment model, providing the ability to select the questionnaire to be used in the assessment.
4. To build questionnaires based on software product innovation assessment models. These questionnaires will be composed by factors grouped into dimensions.
5. To build a knowledge base to support the assessment of each dimension by providing the facility to upload files or to link to URLs to support the answers given to the assessment of a particular factor.
6. To provide the assessment of each dimension justifying the obtained values.
7. To position the product innovation through dimensions that are comprising the questionnaire
8. An innovation model could be represented by different questionnaires with a different number of factors
9. PIA-Tool could be easily to update and extend.

Prior to perform the assessment by using PIA-Tool, an organization must to adhere the following steps:

1. To build the instance of the product innovation model identifying those dimensions, factors and questionnaires that will be used in the assessment.
2. To load the instance in PIA-Tool to be able to present the innovation model and the defined questionnaires
3. To fulfil the appropriate questionnaire
4. To get results of the assessment and positioning of the assessed product.

## Chapter 4

# Software Product Innovation Assessment Reference Model

This chapter defines and formalizes the main components of the software product innovation reference model defined in this thesis. The definition of the reference model has been done based on the combination of two research methodologies: Design Science and Thematic Synthesis. Design Science is the methodology applied to drive the complete research and Thematic Synthesis is the methodology used to build the reference model.

This chapter also describes the elements that comprising the reference model. The reference model has been represented using UML classes diagrams containing the concepts and relationships between concepts formalizing the software product innovation assessment.

This chapter is structured as follows: Section 4.1 states the research methodology selected and provides an overview of the alternatives that were analysed previously to perform the reference model building. Section 4.2 presents the research methodology that has been applied to drive the building process. Next, Section 4.3 describes the reference model and how it has been built. Finally, Section 4.4 describes a language created to instantiate models from the reference model.

## 4. SOFTWARE PRODUCT INNOVATION ASSESSMENT REFERENCE MODEL

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### 4.1 Research methodologies overview

This section is present a well-stated research methodology for building a reference model to represent the existing software product innovation assessment for SiS and other methodologies that were analysed and discarded.

One of the challenges to build the reference model is to follow a rigorous process to assure, on one side that the model is as complete as possible and on the other side, the validity of results. Research methodologies, and more precisely qualitative methods, provide the right umbrella for the building process.

This research has been performed based on a qualitative approach. It is the appropriate approach because as Creswell [23] reported, qualitative research methods are concerned with discovery and build theories. The primary purpose of qualitative methods is to generalize qualitative findings based on few individuals. In addition, the relevance of applying qualitative research methods is that researchers could develop artefacts in a limited scope and in a systematic way. These artefacts could be used later to support and analyze quantitative data. Among other qualitative methods available in the literature (thematic synthesis, grounded theory, ethnographic research) design science was selected to build the reference model.

Design science [43, 44] is an iterative research method that enable researchers to capture business needs and to include them as artefacts in the acquired knowledge base. Design Science is a research methodology that has been previously applied alone and in combination with other approaches to build artefacts in several domains revealing that it is an appropriate methodology to build a reference model in the scope of innovation assessment. So Weber et al. [108] applied design research to build a grid-based, service-oriented architecture. Nabukenya [72] integrated design science and action research; where design science drove the research and Action research was applied to validate the parts defined in the theory and case study research to study new phenomena and build theories. Design science has also been used successfully as a problem solving method in different application domains like: maturity models[56] or portfolio measurement management[109].

In our approach, Design science has been selected to drive the artefact building process, extending its capabilities in the design cycle with Thematic Synthesis [25] and Conceptual Modelling [110] increasing the robustness of the building process.

Other research methodologies were also analysed but finally discarded by different reasons. So *Ethnographic research* [71] was discarded because it is mainly focused on analyze the topic under study from social and organizational perspectives. But we are



## 4.2 Research methodology design and implementation

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not interested in the social impact of product innovation assessment but in the definition of the model itself.

*Grounded Theory* [19] was also analysed too. It consists of systematic guidelines for collecting and analysing qualitative data to construct theories grounded on data. Although it provides iterative processes to build artefacts and it is based on qualitative data, in the case of the incorporation of new data to the knowledge base, theories that have been defined should be discarded and the process to construct the theory should be performed again.

*Thematic Synthesis* [99, 13, 26] without combination with other research methodologies was also studied. Thematic Synthesis is often applied to analyze data to bring together and integrate findings of other qualitative studies [100]. It describes an incremental process to build new concepts based on the observation and interpretation of raw data. Thematic Synthesis organizes data over different aspects related to a research question. These data are enriched with details to facilitate their understanding and the finding reporting. It is built over steps [100, 26] moving from data coding to assess the trustworthiness of the results. It is a powerful methodology to synthesize results and to build artefacts, but, it is not enough to systematically update results of the synthesis when new data is available. Actually Thematic Synthesis was used to support the reference model construction.

Next subsection describes how the research methodology was designed implemented in the scope of this thesis.

## 4.2 Research methodology design and implementation

### 4.2.1 Overall strategy

This research was started by performing an exploration of innovation assessment literature following the methodological guidance described by Creswell in [23]. The main objective of this exploratory job was to identify if a model for software intensive systems innovation assessment had been developed, or, otherwise, if software intensive systems innovation characteristics had been assessed using a general purpose model. What was found as a result of the SLR performed and already reported in [117], is that no specific assessment model was available for Software intensive Systems. At this stage of the research the decision made was to carry on the job of analysing existing innovation assessment models, available in literature, usually non-specific to a concrete industry, to identify model elements, or even the better building a reference model that could be the basis to assess software intensive systems.

#### 4. SOFTWARE PRODUCT INNOVATION ASSESSMENT REFERENCE MODEL

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Therefore, and aligned with Creswell [23, pags 215-216], a qualitative process with two phases was devised: the first phase consisted in an exploratory process performed to identify all relevant elements involved in product innovation assessment models, followed by a second phase for building a reference model for product innovation assessment, considering this second process, in terminology of qualitative methods, an instrument development. As it will be discussed below in Section 4.2.4, it was possible to design a reference model, correct from a modelling point of view, and respecting existing models already in use.

To implement the first phase a Systematic Literature Review(SLR) was conducted and it has been described in Chapter 2. As Creswell highlighted [23] SLR is a method used when the research strategy follows an exploratory schema. SLR is useful to compile results that summarize the existing studies about, in our case, of product innovation assessment and in addition, providing the list of relevant papers addressing the topic under research. The findings of the first phase were summarized in section 2.3.

The second phase was focused on the reference model construction. The following issues were taken into account for the construction: (i) the reference model would be an Information Technology (IT) artefact; (ii) the reference model would include all relevant factors and groups of factors in software product assessment innovation, and; (iii) the knowledge source would be the SLR previously performed, presented in Chapter 2 and reported in [117]. At this stage the next issue to face was related to decide which qualitative research methods would have to be applied.

While different qualitative research methodologies where under consideration such as Design Science, Thematic Synthesis, Grounded theory and Ethnography, Design science, as it was proposed by Hevner [43] and later by Wieringa [111], was chosen. It is a qualitative research method that can be used to construct artefacts. In the case of IT artefacts, Hevner [43] proposed to represent these artefacts as: constructs(vocabulary and symbols), models, methods and instantiations.

Design Science provides a research process based on three cycles: relevance, design and rigor. More detailed explanation of design science is available in Annex II.1. Design Science provides a well defined and documented constructivist research methodology supported by processes and expected results. Design Science applies incremental activities to rigorously construct artefacts in a defined environment and supported by a knowledge base.

Design Science has been used as the method to build the product evaluation assessment framework model; however, Design Science does not provide a systematic method to deal with the output from the Systematic literature Review, or a method to build con-

ceptual models, i.e. an IT model, as it was the case of the product assessment reference model. Therefore, it is necessary to complement Design science with two other qualitative methods: Thematic synthesis and Conceptual modelling. As it will be explained in section 4.2.3 Thematic Synthesis is a rigorous method that provides a constructionist approach for identifying, analysing, and reporting patterns within data, and as it was pointed out by Creswell [23], it is the most useful methodology in capturing the complexities from textual data, that is based on evidences. Thematic synthesis, supported by the tool Atlas-ti®, takes texts selected by the SLR as inputs and provides network of concepts as results.

As is explained in section 4.2.4, conceptual modelling method can use of these network of concepts to produce the product innovation assessment reference model. In the following subsections, Design Science, Thematic Synthesis, and Conceptual Modelling are explained in detail, and how they were applied in the context of this research.

### 4.2.2 Design Science for building IT models

Design science provides the following features:

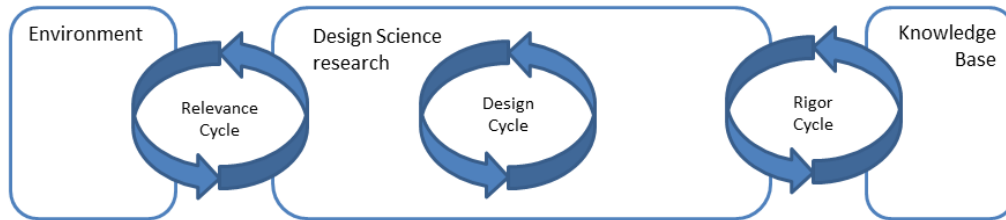
- It is systematic, Hevner [43] and Wieringa [111] justified why it is a method that can be specifically applied to build IT models; this IT model is one of the final objectives of this research.
- Artefacts are constructed through cycles facilitating that artefacts could be adapted when the environment changes [43].
- As it is proposed by Wieringa [112] artefacts are constructed and validated against requirements and a knowledge base. Design Science defines feedback loops at different levels so that these artefacts are validated.

Therefore, when applying Design Science in the construction process of the product innovation assessment reference model the following goals were achieved:

- i the model construction is strongly supported by a knowledge base. The knowledge base provides the raw data from and through the research is accomplished [43]. This knowledge base, in our case, is obtained from the documents representing the body of knowledge about product innovation assessment and that have been previously validated by the community.
- ii the rigor is achieved by appropriately applying existing foundation and methodologies. Therefore, the model is validated by the knowledge base and artefacts are constructed to meet the defined requirements.

## 4. SOFTWARE PRODUCT INNOVATION ASSESSMENT REFERENCE MODEL

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**Figure 4.1:** Design Science framework. Based on [43].

iii the model is constructed using conceptual modelling applying the existing knowledge as it was described by Wieringa [110]: concepts are identified and are used to make a reference model.

Summarizing, Design Science is a powerful research methodology providing a complete framework to design the artefacts needed to represent the software product innovation assessment reference model.

The following evidence described in Section 2.3 and reported in the SLR [117] indicated that applying design science was a good decision:

- i sources are heterogeneous like journals, conference papers, books or white-papers providing product innovation assessment mechanisms.
- ii the list of innovation concepts have been identified in terms of dimensions and factors.
- iii dimensions and factors are used to define evaluation schemas in the product innovation assessment.
- iv some of the findings were that gaps like the lack of consensus about factors and their nature and commonalities like all were based on were identified.

Design Science is structured into three main components: environment, design science research and knowledge base. These components are involved into three cycles: relevance, design and rigor. Figure 4.1 depicts the Design Science components.

The *Environment* represents the space problem where the topic under study is stated [43], in the case of our research the software product innovation assessment. Wieringa claims in [111] that problem domain knowledge can be accumulated in different ways by understanding interaction between domain concepts. The *Environment* establishes the requirements to construct artefacts [43, 112] and, in addition to validate results; summarizing, the Environment identifies two main issues: the class of problem

## 4.2 Research methodology design and implementation

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and the problem domain [57]. Domains are complex combinations of people, organizations, technologies and they are represented by goals, tasks, problems and opportunities affecting the environment.

Considering that the Environment frames the problem representing its requirements, it imposes goal criteria and constraints upon the artefacts to be constructed [43]. The relevance cycle starts with these requirements and moves the research through next cycles to end with the validation of the obtained results.

In terms of the Environment, Wieringa [110] distinguishes between *relevance* and *applicability* of artefacts. Relevance is related with goals to be achieved by artefacts while applicability is focused on where these artefacts are going to be used. As result of the relevance cycle the research requirements and also the acceptance criteria for the results are obtained.

The *knowledge base*, according to Hevner [44], contains all the application-domain available resources representing: (i) foundations for the topic under study; (ii) experiences and expertise defining the state of the art of the problem; (iii) and existing artefacts and processes for the application domain. Yagüe et al. reported that [117] the existing knowledge on product innovation assessment had been considered from three perspectives: literature reviews (secondary studies) [50, 9, 55, 34, 41, 49, 54], questionnaires [96, 103, 95], and professional experiences [58, 22].

Rigor (cycle) addresses how the research is conducted: Hevner [43] highlights that rigor is derived from the effective use of the knowledge base. The rigor cycle materializes the rigor of constructing IT artefacts [44] through their evaluation. In the case of this research work, rigor is achieved through the different methods applied: SLR to select the appropriate sources, thematic synthesis and conceptual modelling to construct the artefacts. Hevner [43, 44] states that rigor cycle provides the past knowledge about a topic based on the state of the art, the existing artefacts and processes in the research domain. Application of the rigor cycle should ensure that contributions from the design cycle are not merely interpretations of the existing knowledge but innovations.

The heart of Design Science methodology is the *Design Science Research* and the *Design Cycle*. They represent the artefact construction activities. Artefacts are constructed in an iterative way, with three activities: construction, evaluation and feedback. Artefacts resulting from every iteration are evaluated against the defined requirements and should satisfy the acceptance criteria defined by the relevance cycle. This cycle depends considerably on the other two cycles, i.e. relevance and rigor, since requirements are obtained in the relevance cycle, and knowledge specified in the rigor cycle. Artefacts implement the concepts and practices of the application domain. Artefacts should be

## 4. SOFTWARE PRODUCT INNOVATION ASSESSMENT REFERENCE MODEL

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strongly grounded, and validated using the outcomes from the previous cycles. Experimental situations are the best scenario to validate artefacts [44]. It must be highlighted that most of the elements obtained in the first phase resulted from real operations, not from work in laboratory, and through the analysis performed in literature reviews. For each generated artefact, rigor should be assessed with respect to its applicability and generalizability in the environment. Artefact *instantiation* is used to evaluate the feasibility of the process. Chapter 6 presents an example of instantiation of the reference model using the innovation assessment model based on Balachandra et al. [9] extended with a questionnaire to collect data and applied to assess a Software intensive Systems like Skype®. The knowledge base is a live body that is extended with the artefacts constructed and validated.

### 4.2.3 Concept networks synthesis

Design Science does not explain how to deal with the knowledge and data obtained from, in this case, the SLR in a systematic way. This elaborated knowledge and data should be in a form that it could be effectively deployed to construct the artefact, that, in this thesis, is the reference model. Thematic Synthesis [25] provides a constructionist method for identifying, analysing, and reporting patterns within data. Thematic Synthesis uses rigorous and explicit methods to provide answers to particular questions [99]. As it was pointed out by Creswell [23], thematic synthesis is the most useful methodology in capturing the complexities from textual data, that is based on evidences. Therefore to construct artefacts during the design cycle, Thematic Synthesis was applied. A more detailed explanation of Thematic Synthesis is available in Annex II.3.

The first phase of thematic synthesis consist of extracting data and coding documents. The free line-by-line coding was applied to those paragraphs containing references to product innovation assessment concepts, these annotated text are called “*quotations*” in the terminology of Atlas.Ti®. Each quotation could have one or more codes depending on the number of concepts referred by the text. Fig 4.2 shows an example of the coding phase using Atlas Ti®.

After coding each document obtained from the SLR, the next step for each document was to build a network of concepts to find themes and relationships between themes. It is aligned with the definition of vocabulary and symbols to build artefacts proposed by Hevner [43]. The network of concepts was built using the Atlas Ti® facilities by adding codes, quotations and displaying their neighbours and co-occurrences. It helped to identify relationships between codes to build more abstract concepts. Fig 4.3 shows a

## 4.2 Research methodology design and implementation

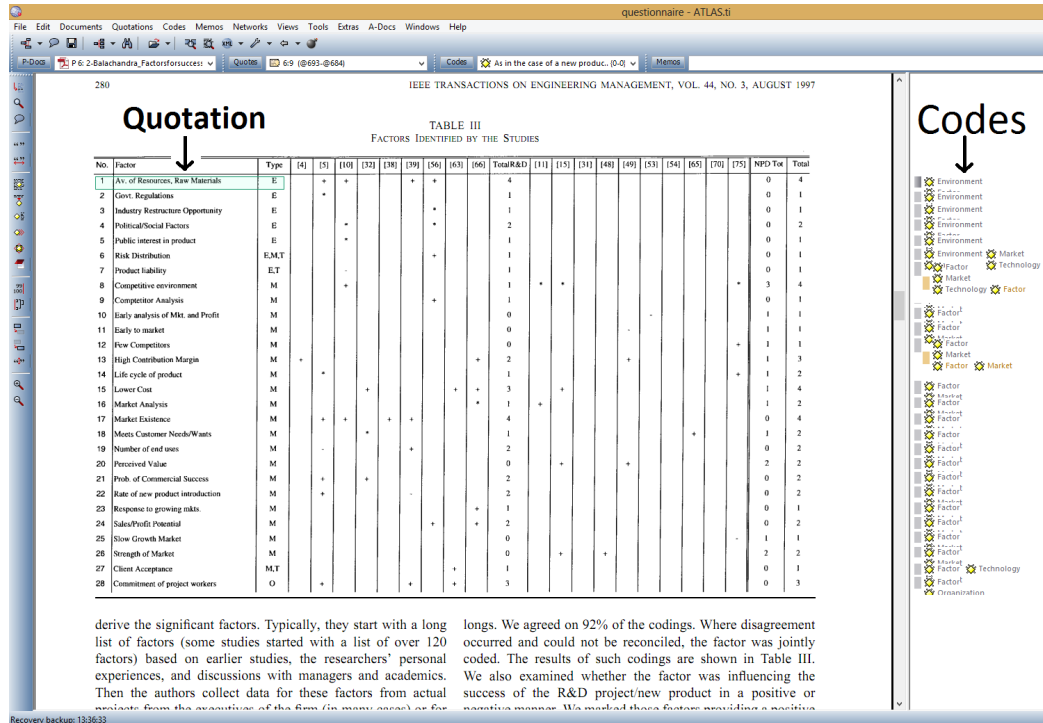
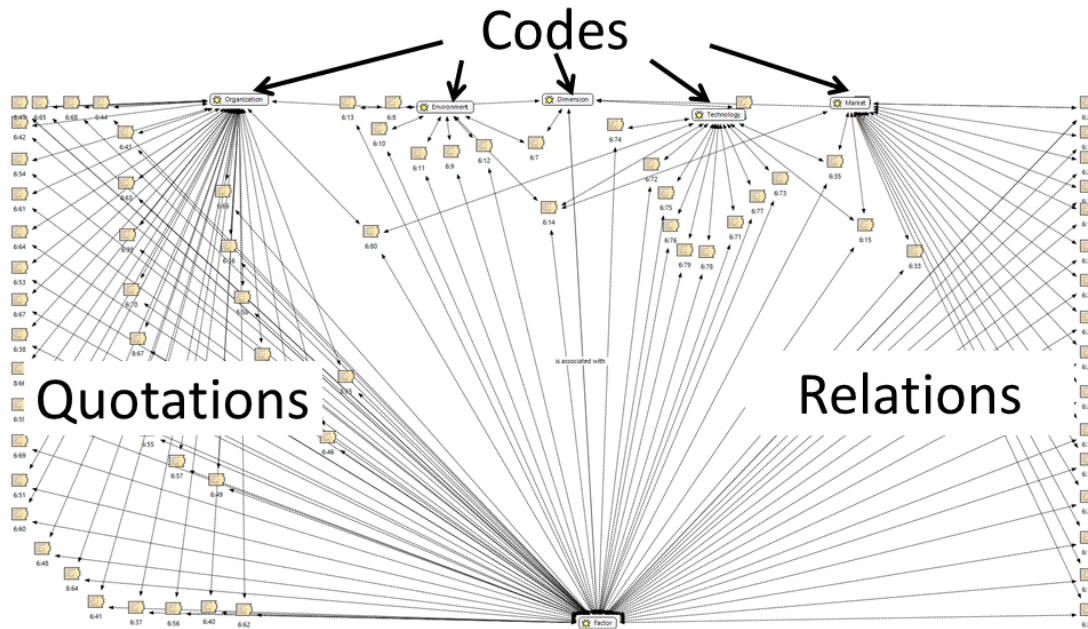


Figure 4.2: Synthesis process: codes to quotations assignment for Balachandra et al. paper [9].

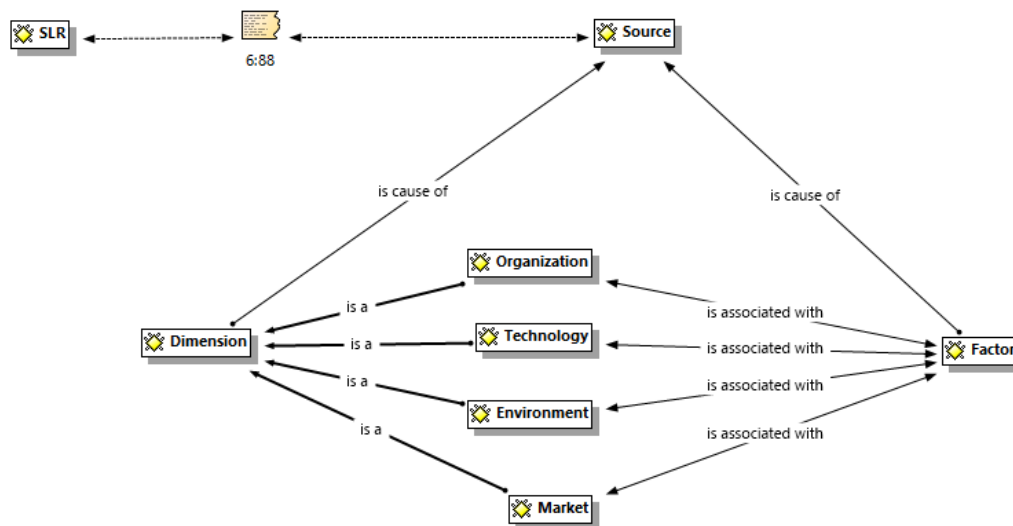
part of the network obtained from the Balachandra et al. journal paper [9] representing the product innovation factors and dimensions. Three main elements are displayed in Figure 4.3: Codes, quotations and the relationships between concepts. Codes are represented by rounded squares, quotations are represented by small boxes and relationships are lines between elements.

Aligned with Cruzes et al. [25], the next step is to build a model based on high-order themes, according to the thematic synthesis terminology [25], to represent the problem domain based on the identified concepts and themes. Relation between codes were analysed to identify more complex relationships and abstractions. Considering relationships shown in Figure 4.3 they were synthesized to build the model represented with high-order themes depicted in Figure 4.4. In that figure and to increase the understandability, all the core quotations were removed and only the main relationships remain. As authors propose different factors and sources, in the model was required to include codes to model source types (represented as “Source” in Figure 4.4) and specific sources like Systematic Literature Reviews (represented as “SLR” in Figure 4.4).

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**Figure 4.3:** Code-quotations links used for analysis of Balachandra et al. paper [9] as part of the synthesis process. Atlas-ti@network view snapshot.



**Figure 4.4:** Code to code links used for synthesizing the reference model from Balachandra et al. paper [9] analysis outcome. Atlas-ti@network view snapshot.



### 4.2.4 Schema design and integration

Finally, constructing the reference model from the obtained high-order themes is the next step. To accomplish this objective conceptual modelling has been used. Wieringa explains in [113] how conceptual can be used in conjunction with design Science to build IT models. The reference model was assimilated to a schema and the view integration approach [32, 74, p.p. 315] was applied. The design cycle is an iterative process and on each iteration, while each network of concepts is analysed, new parts of the model are built (considered as an schema or view) and integrated with the rest of the model. Each new high order model was considered as a view; views merging and restructuring was performed such that the following qualitative criteria was respected: completeness and correctness, minimality and understandability [10]. This is a powerful approach because each individual view can be later reconstructed as external schemas after view integration and each view actually designs its own conceptual schema from its requirements.

The second approach applied is view integration. Instead of building an upfront design of the reference model what is not clearly aligned with the iterative behaviour of the design cycle and thematic synthesis, an iterative building process has been applied. As it was described above, on each iteration new schemas are built to capture concepts in the codes and themes that were analysed and synthesised. In the view integration approach, models emerge from requirements to compose a global conceptual model for the problem under study.

Whenever a product is developed to reach the required quality level is essential so that the product preforms as it was initially expected. This is the case of the product assessment model, that can be classified as a conceptual model. For this reason quality was a concern from the beginning of this research and it has been a concern during all its process. An introduction to the assessment of quality of conceptual models is provided in [69].

A narrative synthesis approach was followed to uncover the concepts used in the analysed publications and the relationships between those concepts. The trustworthiness of a synthesis will depend on both the quality and the quantity of the evidence base it is built on.

View integration and schema integration was performed following the guidelines and recommendations proposed by Batini [10]. Quality was assured in model building process. Batini introduced in [10] the foundations for view and schema integration, and defined three criteria that should be respected, criteria later confirmed by Lindland et al. [59]: completeness and correctness, minimality and understandability. The Lindland

## 4. SOFTWARE PRODUCT INNOVATION ASSESSMENT REFERENCE MODEL

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et. al [59] framework also suggests that a systematic evaluation of quality considers a model's syntax (how well does the model adhere to the rules of the modelling language), semantics (how well the model reflect the reality modelled) and pragmatic (how well is the model understood and used). It is generally agreed that IS stakeholders rely on their perception of reality in order to evaluate semantic quality.

These criteria were applied as follows: every concept that existed as a high order theme was included in the reference model. It covers the *Completeness and Correctness* because the reference model contains all concepts present in any component schema correctly. The integrated reference model must be a representation of the union of the application domains associated with the schemas. *Minimality* refers that if the same concept is represented in more than one component schema, it must be included only once in the integrated schema, but maintaining its relationships. In our research, whenever the same concept had a different name it was represented only once providing *Minimality*. The last criteria, *Understandability* is related to assure that the integrated schema should be easy to understand for the designer and the end user. This implies that among the several possible representations of results of integration allowed by a data model, the one that is (qualitatively) the most understandable should be chosen. In our research, model schemas were specified using the Extended Entity Relationship model [74] and represented by the Unified Modelling Language (UML) class diagrams [78]. Class diagrams are commonly used to represent the Extended Entity Relationship model schemas because actually classes are similar to entity types in many ways providing *Understandability*. This integrated schema, that describes the reference model, is displayed in Figure 4.13.

### 4.2.5 Threats to Validity

To study the validity of the artefacts designed in our research is an important issue. Wieringa [110] reported that design validation is a knowledge task performed to check whether the designed artefacts have been implemented correctly. The challenge of validity is to reduce the uncertainty about artefacts when there is no practical evidences yet [111]. Three main relevant questions must be addressed in design validation: internal validity through the causal and value questions and external validity about the application of designed artefacts to other contexts.

Internal validity is focused on demonstrate that artefacts designed and implemented represents a solution to the problem in the context of the problem. A part of the Internal validity concerns to a causal claim, that is, in the scope of the problem to analyse the effects that the solution proposed have in the environment where the implemented

### **4.3 Building the software product innovation assessment reference model**

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artefacts interact. In our research, the ability to assess product innovation through questionnaires built and based on the reference model provides the expected effect of increase the knowledge about the innovation and the impact of factors that it one of the goals of product innovation assessment as it was described in Chapter 2 Section 2.2.1.

The second part of the internal validity is related to value claim, that is to check if the obtained effect is aligned with criteria derived from the environment. In the case of our research one of our objectives was to be able to assess software products from the innovation perspective. Artefacts implemented provides this functionality and let researchers to assess products from the innovation perspectives, covering another goal of product innovation assessment.

Additionally, as Wieringa [110] proposed external validity of a solution is analysing whether the design argument remains valid if the domain and/or environment changes. In the case of our research, the environment is defined by many application domains. Documents resulting from the SLR described in Chapter 2 Section 2.1 refers to different application domains like the ones presented by Table 1.1 in Chapter 1. Artefacts built can be applied without any change to these domains, therefore it is expected that artefacts could be used in some other application domains without any domain.

Summarizing the artefacts built in this thesis has probed demonstrated their internal and external validity.

### **4.3 Building the software product innovation assessment reference model**

This section is framed in the application of *Design Cycle* of the Design Science research methodology to build a reference model for product innovation assessment following the methodology described in the previous section. The Design cycle was composed by three phases: construction, evaluation and feedback. As it was mentioned in the previous section the construction phase was driven by applying *Thematic Synthesis*. To construct the reference model based in the literature resulting from the SLR, an iterative an incremental approach has been applied after coding, building network of concepts and finding their relationships. On each iteration a subset of codes and concepts concerning to innovation have been considered to facilitate the application of conceptual modelling by small increments. On first iterations, the most used codes were analysed, and in next iterations more abstract concepts derived from the synthesis performed were included. The construction process was finished when all codes and concepts were processed and

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No.	Factor	Type	[4]	[5]	[10]	[32]	[38]	[39]	[56]
1	Av. of Resources, Raw Materials	E		+	+			+	+

FACTOR
DIMENSION
IMPACT

**Figure 4.5:** Example of the coding of a quotation from which core concepts were derived. Text is from Balachandra et al. paper [9]. Atlas-ti@snapshot.

no changes were required to the constructed reference model. To present examples of the process the publication of Balachandra et al. [9] was selected because as it was reported in [117] they referred the most cited dimensions when evaluating product innovation and they also provide a complete list of factors that could be considered as the base for the evaluation process.

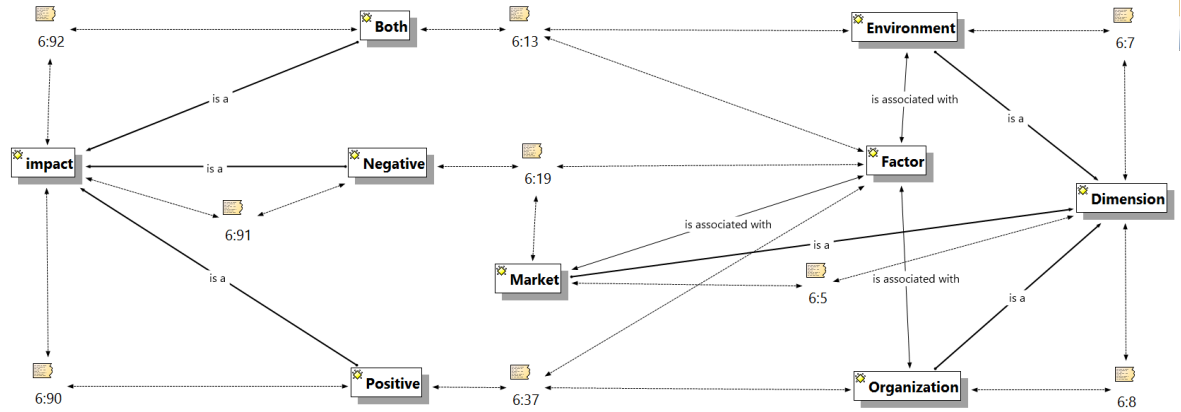
### 4.3.1 Core concepts subschema

The goal of the first iteration was to identify core concepts needed to represent product innovation assessment. Those codes with the highest number of *quotations* were included in the analysis. *Quotations* are raw data that are part of the text in publications representing relevant information for the research. Each quotation has assigned a code or a list of codes.

Figure 4.5 shows an example of quotation and coding applied to the Balachandra et al. [9] publication. In that publication, authors provided a table listing innovation factors, dimensions and references to other publications where each factor was referenced. In the table shown in Figure 4.5, column labelled with “*Factor*” represented the name of the identified innovation factors; column labelled with “*Type*” represents the dimensions proposed by Balachandra et al. Four different values were assigned to this column: E (Environment), T (Technology), M (Market) and O (Organization); and finally columns with numbers between brackets represent references to publication where each factor was defined or described. Each reference is either left blank or checked with one of three values “+” (positive), “-” (negative), “\*” (both) representing the proposed impact of that factor in the reference. So, Figure 4.5 highlighted in a box the text with relevant data for the research, the factor “*Av. of Resources, Raw Material*” was coded as factor, “*E*” was coded as “*Environment*” and finally “+” was coded as “*positive*”.

Figure 4.6 presents a subset of the generated network. Codes are represented as 3D-rectangles labelled with the code name, quotations are represented as small boxes and dependencies are represented by bidirectional arrows. Figure 4.6 shows that quotation “6:7” in the top-right of the figure is connecting the code “*Environment*” with code

### 4.3 Building the software product innovation assessment reference model



**Figure 4.6:** Code network describing core concepts synthesis. Atlas-ti® network view snapshot

“*Dimension*” representing that Environment has been identified as a dimension by this author. The same happened with quotations “6:5” and “6:8”.

Analysing quotations about factors, “6:13”, “6:19” and “6:37” shown that there are relationships between factors and dimension and that they are characterized by an impact type (positive, negative or both) that depends on the relationship. Based on the dependencies obtained from the network of concepts, two main concepts were identified: factors and dimensions. So Cooper [22] proposed between 10 to 15 factors focused on 5 dimensions, Balachandra et al. proposed 72 factors organized into 4 dimensions [9], Jeraya, et al. [49] presented 135 factors, Klington et al. [54] proposed the application of artificial intelligence over 23 factors organized into three dimensions or Tsai [103] analyzed 5 dimensions through 24 factors covering the main product issues like conceptualization, skills, and organization. It is relevant the lack of consensus in the literature about the number of factors and dimensions.

An additional issue while coding was that authors gave different names in the same dimension for the same factor; i.e. Krishnan [55] used the name “Collecting and meeting customer needs” while Balachandra et al. [9] uses “Meets customer needs/wants” in the market dimension. Sometimes factors presented different levels of granularity depending on the author; i.e., Montoya et al. [68] presented market competitiveness as a factor, and Balachandra et al. [9] split this factor in three more detailed ones, namely competitive environment, few competitors, and market analysis. This fact highlights that there is a relationship between factors. It was modelled as a UML reflexive association labelled as *related to* in Figure 4.7.

Applying conceptual modelling in the building process, the first concept identified was

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Organization	Market	Technology	Environment
Commitment of project workers	Competitive environment	Demand Push vs Technology push	Available Resources or Raw material
Communication	Competitor analysis	Risk Distribution	Government Regulations
Correct distribution channel	Risk Distribution	High performance/cost proportion	Industry restructure opportunity
Create, Make market interface	Early to market	Incremental product	Public interest on product
Demand for quick result	Few competitors	Innovative product	Risk Distribution
...	...	...	...

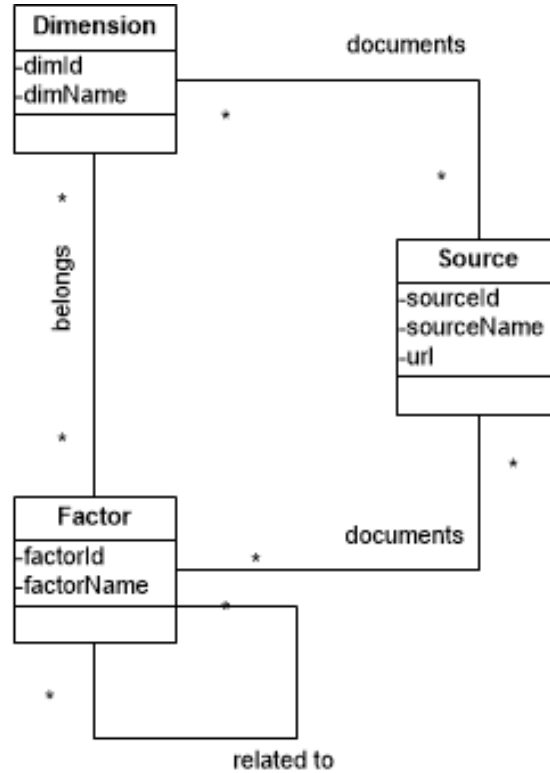
**Table 4.1:** Table showing evidence of how a factor can be assigned to several dimensions. Based on [9].

Factors. Factors are concepts that characterize and impact product innovation. It was modelled as a UML class. Class *Factor* represents innovation factors. Each factor is identified by a *factorId* and is described by its *factorName* besides some other less relevant fields.

Factors were grouped into Dimensions. Where dimensions represent abstract concepts surrounding innovation factors. Dimensions were also modelled as a UML class. Class *Dimension* represents innovation dimensions. Each dimension is identified by a *dimId* and is described by its *dimName*. The literature enhanced that each factor could affect to one or more dimensions. An example of this issue is shown in Table 4.1 extracted from Balachandra et al. [9] representing a subset of factors and dimensions where e.g. the factor *Risk distribution* highlighted in dark grey is assigned to three dimensions: Market, Technology and Environment.

As it was mentioned above, the dimension-based representation let researchers apply different levels of abstraction to model each dimension depending on the granularity of the information required in the assessment. This relationship between factors and dimension was modelled as a UML association. Finally to have traceability about where each factor and dimension was defined and used, the class *Source* and its relationships were modelled. Fig 4.7 depicts the UML class diagram representing these concepts.

### 4.3 Building the software product innovation assessment reference model



**Figure 4.7:** Core concepts sub-schema for product innovation assessment. Core concepts include factors, dimensions and source.

The generated model is guaranteed by construction, and following Wieringa [110] the design end is reached when it is achieved one of the stakeholder goals. All the analysed papers referred to this two core concepts: factors and dimensions. Concerning the validity of this part of the model the twofold validity proposed by Wieringa [110] has been considered: internal and external. Related to internal validity, the proposed part of model satisfies the answer to the causal questions about if factors and dimensions have effect in product innovation assessment models. It is clear that yes because all the analysed model contains both concepts. External validity has also been achieved because the analysed papers belongs to different contexts.

#### 4.3.2 Innovation assessment models subschema

As it was described above and presented in Table 4.1, factors could be considered as part of one or more than one dimension. Each factor has an impact and a weight that have been modelled as attributes. Balachandra et al. [9] pointed out that the impact of

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a factor could be *positive*, *negative* or *both* depending on the assessment model. A *positive* impact means that the factor acts as an enabler of innovation and *negative* impact means that it acts as an innovation blocker being aligned with the Cooper proposals of factors acting as enablers or blockers [21]. Factors could have different impact types on each dimension [9, 8].

Weight represents the relevance of a factor over a dimension in relationship with other exiting factors in the dimension. As it is described in [117] factors impact could have assigned a weight because not all factors have the same relevance rate [9, 8, 41, 103, 54]. To model specific information to identify each specific combination of factors, dimension, impacts and weight a class *Model* was defined. Each model is identified by a *modelId* and is described by its *modelName*. Other relevant attributes are: *modelVersion*, *modelYear* and *modelDescription*. A product innovation assessment model is a composition of *ModelItems*. Finally, class *Source* represents those documents that have been used to: on one side to document the model and on the other side, to justify the relationship between factors and dimensions. This factor-dimension relationship could be modelled as it is depicted in 4.8.

So it is possible to represent un-weighted innovation models with type of impact (positive, negative or both) as it was presented by Balachandra et al. [9] and also weighted models like the one presented by Merrifield [66] or by Åstebro [8]. All these models referred this two core concepts (factors and dimensions) with different impacts and weights. As in the previous iteration, the external validity has been achieved because the analysed papers belongs to different contexts

All these classes represent concepts needed to formalize product innovation assessment models. They could be as complex and complete as needed to represent the fact under evaluation.

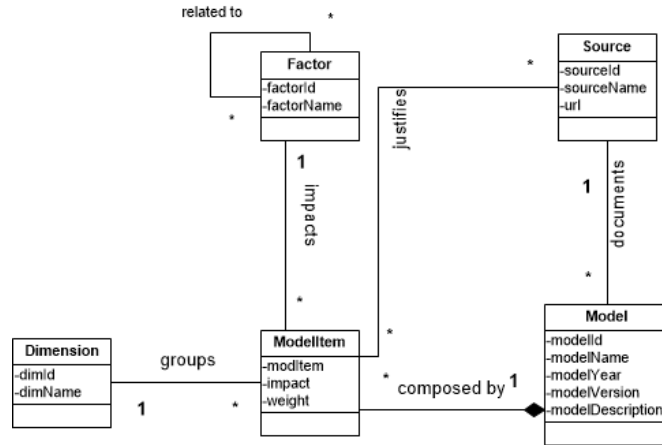
Finally, As it is possible to identify in Fig.4.6 in product innovation assessment there is a clear relationship between factors, dimensions and impact, the goal of this iteration is to build a conceptual model to represent that relationship, considering that different authors [21, 9, 8, 41, 103, 54] proposed similar solutions. Analysing core concepts resulted from the first iteration, it was needed to introduce a more abstract structure to model the relationship between factors and dimensions: *ModelItem* class.

### 4.3.3 Questionnaires subschema

The next iteration is focused on modelling the relationship between product innovation models obtained in the second iteration and questionnaires. This relation is relevant



### 4.3 Building the software product innovation assessment reference model



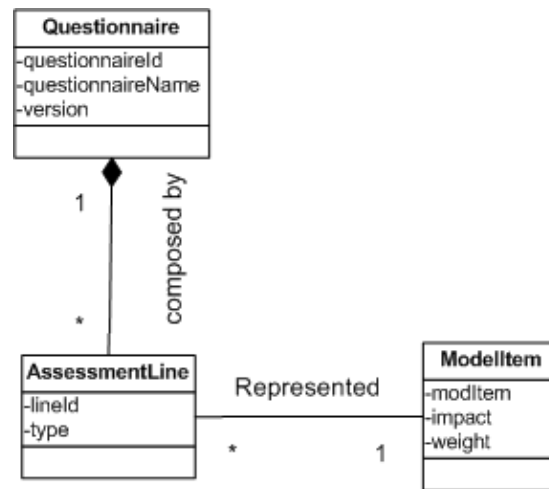
**Figure 4.8:** Innovation assessment models sub-schema. This schema extends the Core concepts sub-schema 4.3.1 with the classes to support the innovation assessment models

because as it is highlighted in the literature, questionnaires are the main artefact used to perform product assessment [22, 9, 58, 55, 8, 96, 41, 54, 103]. Questionnaires are composed by a set of questions that survey respondents must fulfil to get the assessment of a product. Each question represents an innovation factor and the set of values to assess it. But there is no agreement in the literature about the best nature to represent factor values in questionnaires.

According to Tsai [31], it is very important that questionnaires were based on qualitative instead of quantitative values to reduce the uncertainty of answers provided by questionnaire respondents. Analysed authors [55, 8, 54, 103] were agreed on the use of discrete values like (*Very Low, Low, Medium, High* or *Very High*) as data input to represent questions because they provide, even at early stages of the product development, sufficient information to evaluate factors. Lately, questions are processed to provide the assessment result. An additional problem identified by Lester [58] is that the required information about factors is not always available. To manage this fact, an additional value labelled *Unknown* it would be desirable. When a factor is evaluated as *Unknown* means that there is still no information available for survey respondents, and, therefore it is not clear how the factor is impacting in the product. Finally, it happens that a factor, by several reasons, is not applicable to a product. In that case, a new discrete value labelled *Not Applicable* has been added to each question. In the case of *Not Applicable*, the factor is omitted in the evaluation. Summarizing the discrete values proposed to each factor are: *Not Applicable, Unknown, Very low, Low, Medium, High* or *Very high*. Figure 4.10 depicts an example of the representation of these values.

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**Figure 4.9:** Product innovation assessment questionnaire sub-schema.

To model the relationship between factors and their representation in questionnaires the *AssessmentLine* class has been defined. An *AssessmentLine* represents a question of a questionnaire defined to measure a product innovation factor. Each *AssessmentLine* is derived from one and only one *ModelItem*, but a *ModelItem* could be represented by more than one *AssessmentLine* depending on the mechanism to measure the factor. An *AssessmentLine* has a *LineId* and a *type*. The attribute *type* determines the set of values available for the question to measure the factor in the questionnaire.

The same product innovation model could be represented through different questionnaires. As it was reported by Astebro [8] and Balachandra et al. [9] when the number of factors is large, the common solution is to select a subset of factors including only those with the highest weights. Therefore, and to support this need, more than one questionnaire could be required. In consequence, business analysts or researchers build questionnaires based on product innovation assessment models to collect data.

To model questionnaires the UML class *Questionnaire* has been defined. Class *Questionnaire* models those attributes needed to identify an specific questionnaire like: *questionnaireId*, *questionnaireName* and *questionnaireVersion*. A *Questionnaire* is composed by a set of *AssessmentLine*. Figure 4.9 depicts those classes and their relationships to model product innovation assessment questionnaire knowledge.

Fig 4.10 shows an example of questionnaire based on the Balachandra et al. innovation model. In Figure 4.10 dimensions are represented by containers with factors. Fig 4.10 displayed the *Environment* dimension. Each factor is represented as a rounded square labelled with the factor name containing discrete values available to measure

### 4.3 Building the software product innovation assessment reference model

The screenshot displays the PINnoA tool interface. At the top, there are four tabs: 'Organization', 'Market', 'Environment', and 'Technology'. The 'Environment' tab is selected. Below the tabs, there are four main sections, each representing a factor. The first section is 'Available Resources or Raw material', which has a dropdown menu set to 'Unknown' and a set of radio buttons for discrete values: 'Unknown', 'Not Applicable', 'Very few', 'Few', 'Medium', 'High', and 'Very High'. To the right of these buttons is a 'Hide Add Files' button. Below this section is a 'Sources' area with an 'Add url' button and a text input field, and an 'Add file' button with a file selection interface showing 'Seleccionar archivo' and 'Ningún archivo seleccionado'. The other three sections are 'Government Regulations', 'Industry restructure opportunity', and 'Political/Social factors', each with a similar set of discrete value radio buttons and an 'Add Files' button.

**Figure 4.10:** PINnoA tool snapshot displaying an example of evaluation questionnaire for Skype. The underlying schema is compliant with 4.3.3.

the impact of the factor.

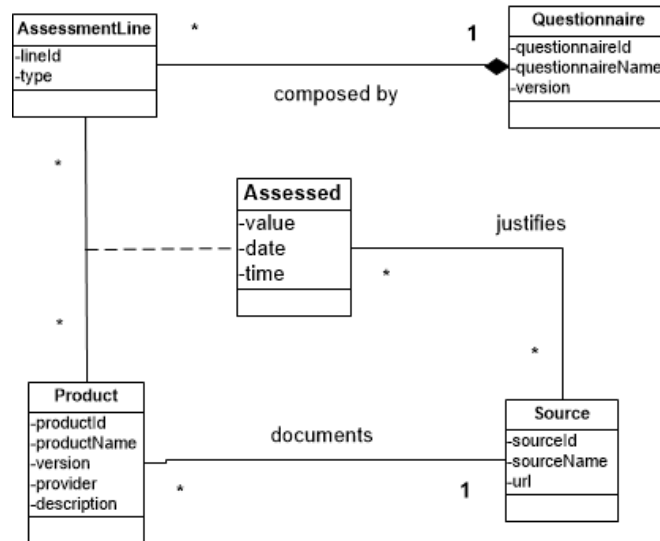
Concerning the internal validity this part of the model provides the ability to construct different questionnaires depending on the needs and support let assessors to create questionnaires to evaluate products selecting a subset of the most relevant factors of an specific innovation model as it is proposed by Åstebro [8]. The model built is not dependent of the domain, so that questionnaires could be applicable in different application domains providing the external validity for the reference model.

#### 4.3.4 Performed Assessments subschema

In previous iterations there are no elements to model data collected from questionnaires to each product. Therefore, the goal of the fourth iteration is to complete the reference model with mechanisms to capture data gathered while assessing a product from the innovation point of view. Product innovation assessment consists of assigning values to each innovation factor for the product under assessment. Data gathered are often supported by documentation that is important to maintain to increase the level of knowledge about a product from the innovation perspective. The provided data are mainly composed by two types of information: (i) product description, formed by documents where products are described; and (ii) assessment support containing the sources where the assessment values for each factor are based. Fig 4.10 depicts the part of the proposed questionnaire to provide the sources for each factor. Where Sources

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**Figure 4.11:** Performed Assessments subschema. This sub-schema extends the subschema *questionnaire subschema* 4.3.3 so that a given product assessment can be supported.

could be URL or files to upload to the server supporting the value selected if they are available.

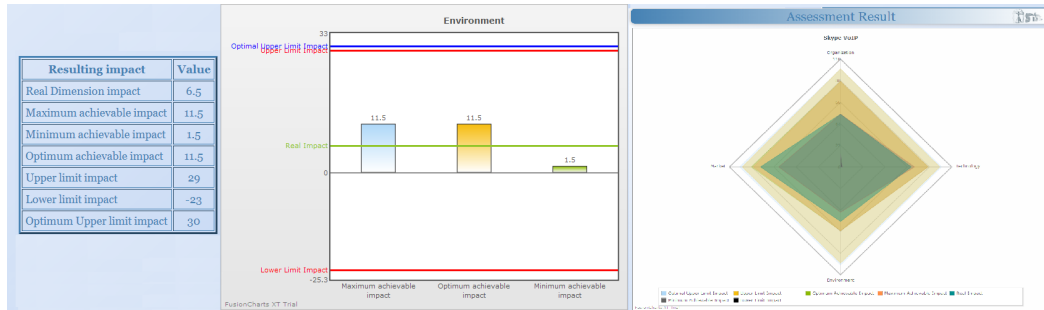
Fig 4.11 depicts those classes that model the concepts needed to represent data gathered. So the class *Source* has been defined to capture the information related to mentioned items (i) and (ii). Moreover, the class *Product* contains the specific product description and its relationship with source refers to those documents where Products are described. Finally, the class *Assessed* and its relationships with classes *AssessmentLine*, *Product* and *Source* represents the needed support to capture the product innovation assessment data. *Assessed* stores the assessment *value*, *date* and *time* when the assessment was performed. Time and date are relevant to provide traceability over time about the assessment of products.

### 4.3.5 Product Innovation Assessment Reference Model

Fig 4.13 depicts a representation of the reference model integrating all the subschemas described in the previous iterations.

Fig 4.12 shows a the result of an evaluation based on the Balachandra et al. product innovation assessment model. The left part contains values assigned to each innovation factor, the type of impact that the factor (positive, negative or both), weight and the sources of this factor. For each dimension the following values are displayed: (i) total

### 4.3 Building the software product innovation assessment reference model



**Figure 4.12:** An example of product innovation assessment filled questionnaire display of PInnoA tool fro SKype. The underlying schema is compliant with the Product Innovation Assessment Reference Model schema 4.3.5 compliant. This figure displays the values obtained and how the impact on the different dimensions

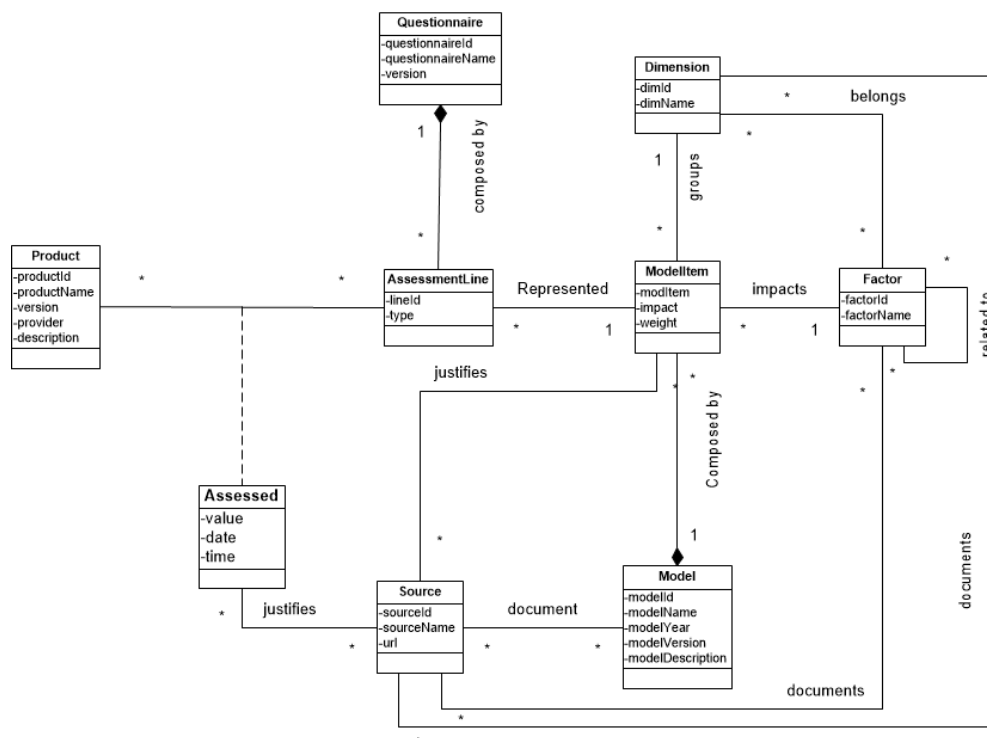
impact of the dimension obtained as result of the values provided in the questionnaire; (ii) maximum impact that could be obtained in the dimension; (iii) most favourable impact in the dimension. This value is calculated assigning the maximum impact to those factors that are still unknown when the evaluation was performed; (iv) less favourable impact in the dimension. This value is calculated assigning the less impact to those factors that are still unknown when the evaluation was performed. With these values it is possible to how relevant a dimension could be for a product.

The right part of the picture shows a chart representing the dimensions of the model and for each dimension results obtained in the fourth values described above. This values are presented by shapes describing areas of impact. This figure has been obtained with a tool developed by authors in the scope of this thesis to build questionnaires based on product innovation assessment models.

The internal validity of this part of the model, following the Wieringa approach [110] provides answers to the causal and value question. Concerning to the causal question about if the proposed reference model have effect in product innovation assessment models. The answer is yes, because it provides support for those requirements related to the ability to evaluate products. The proposed solution also represents an answer to the value question that is: Does the reference model satisfy stakeholder criteria of being able to assess product innovation? The answer is also yes, because this reference model has been built based on the identified literature about factor to assess product innovation and it has been constructed validating each iteration of the design process. Finally, results applied to different application domains and to different products and questionnaires provide the external validity to the reference model.

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**Figure 4.13:** Product innovation assessment reference model. This Figure represents the result of integrating of the formerly obtained sub-schemas.

## 4.4 The instantiating language

The software product innovation assessment reference model needs a mechanism to represent instances. To make feasible to instantiate the reference model, a domain specific language has been defined. Chapter 3.1, Section 3.2 stated briefly that XML-Schemas was selected to define the language and XML was selected to represent instances of the reference model. This section describes the primitives of the domain specific language to define instances of the reference model.

The process to transform the UML reference model was based on methods and algorithms proposed by Wojnar et al.[116], Elmarsi et al [33] and Domínguez et al. [30]. Due to this language is being used as an input to build questionnaires and through the questionnaires data to perform the assessment of product innovation will be collected, only those primitives needed to model questionnaires will be defined. That is, primitives to represent concepts, innovation models and assessment questionnaires.

The process to describe the language is driven by the following rules:

1. Innovation assessment model will be the root of the instance.
2. The process is driven from root to leaves.
3. XML labels will be implemented as an XML-Schema *element*.
4. Each element with the highest level of abstraction identified in the framework overview will be the root of a hierarchy and will be implemented as an XML-Schema *element*.
5. Each element with the highest level of abstraction identified in the framework overview will be implemented as an XML-Schema *complexType*.
6. Each class will be implemented as an XML-Schema *complexType*.
7. Each class attribute will be implemented as an *attribute* in the terminology of XML-Schemas.
8. Each class representing a collection will be implemented as an XML-Schema *complexType*.

To start the language definition a type to model the root of the document. As it was presented in Chapter 3.1, Section 4.4 the elements with the highest level of abstraction that will be modelled are: `concepts`, `innovation_models` and `assessment_questionnaires`. Applying rules 1, 2 and 4 the type to define the root of the document is as follows.

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**Listing 4.1:** “Product innovation assessment language root”

---

```
<xs:element name="innovation_assessment_model"
  type="Tinnovation_assessment_model" />
<xs:complexType name="Tinnovation_assessment_model">
  <xs:sequence>
    <xs:element name="concepts" type="Tconcepts" maxOccurs="1" />
    <xs:element name="innovation_model" type="Tinnovation_model"
      maxOccurs="1" />
    <xs:element name="assessment_questionnaires"
      type="Tassessment_questionnaire" maxOccurs="1" />
  </xs:sequence>
</xs:complexType>
```

---

Following the rule 2, the next step is to proceed with the definition of *complexType*s for each XML-Schema element defined in Listing 4.1: *concepts*, *innovation\_model* and *assessment\_questionnaire*. Applying rules 3, 5, 6, 7 and 8 to the first element named *concepts* provides the following primitives: *<concepts>*, *<dimensions>*, *<dimension ...>*, *<factors>* and *<factor ...>*. The XML-Schema to model these primitives and an example of the use of this primitives are listed by Listing 4.2.

**Listing 4.2:** “Concepts hierarchy primitives and types”

---

```
<!-- Start Definition of types needed to formalize concepts -->
<xs:complexType name="Tdimension">
  <xs:attribute name="dimid1" type="xs:string" />
  <xs:attribute name="dimName" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tdimensions">
  <xs:sequence>
    <xs:element name="dimension" type="Tdimension"
      maxOccurs="unbounded" />
  </xs:sequence>
</xs:complexType>
<xs:complexType name="Tfactor">
  <xs:attribute name="factorId" type="xs:string" />
  <xs:attribute name="name" type="xs:string" />
  <xs:attribute name="definition" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tfactors">
  <xs:sequence>
```



```

        <xs:element name="factor" type="Tfactor"
            maxOccurs="unbounded" />
    </xs:sequence>
</xs:complexType>
<xs:complexType name="Tconcepts">
    <xs:sequence>
        <xs:element name="dimensions" type="Tdimensions"
            maxOccurs="1" />
        <xs:element name="factors" type="Tfactors" maxOccurs="1" />
    </xs:sequence>
</xs:complexType>
<!-- End Definition of types needed to formalize concepts -->

```

The next shows an example of instantiating these primitives:

```

<concepts>
    <dimensions>
        <dimension dimid1 = "dim01" dimName = "Organization" />
    </dimensions>
    <factors>
        <factor factorId = "factor01" name = "Commitment of project
            workers" definition = "It is the perception among the
            project team than the project is going to be completed
            successfully. Some factors contributing to commitment
            include loyalty to project leader, ego satisfaction, and
            a sense of liking for the project and the resulting new
            product." />
    </factors>
</concepts>

```

---

Applying now rules 3, 5, 6, 7 and 8 to the second element named *innovation\_model* provides the following primitives: *<innovation\_model>*, *<model>*, *<model\_items>* and *<model\_item ...>*. The XML-Schema to model these primitives and an example of the use of this primitives are listed by Listing 4.3.

**Listing 4.3:** “Innovation model hierarchy primitives and types”

---

```

<!-- Start Definition of types needed to formalize innovation
    models -->
<xs:complexType name="Tmodel">
    <xs:attribute name="modelId" type="xs:string" />

```

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```
<xs:attribute name="modelName" type="xs:string" />
<xs:attribute name="modelYear" type="xs:int" />
  <xs:attribute name="modelVersion" type="xs:string" />
  <xs:attribute name="modelDescription" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tmodel_item">
  <xs:attribute name="modItemIid" type="xs:string" />
  <xs:attribute name="modelId" type="xs:string" />
  <xs:attribute name="dimid1" type="xs:string" />
  <xs:attribute name="factorId" type="xs:string" />
  <xs:attribute name="impact" type="xs:string" />
  <xs:attribute name="weight" type="xs:float" />
  <xs:attribute name="interpretation" type="xs:string" />
  <xs:attribute name="help" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tmodel_items">
  <xs:sequence>
    <xs:element name="model_item" type="Tmodel_item"
      maxOccurs="unbounded" />
  </xs:sequence>
</xs:complexType>
<xs:complexType name="Tinnovation_model">
  <xs:sequence>
    <xs:element name="model" type="Tmodel" maxOccurs="1" />
    <xs:element name="model_items" type="Tmodel_items"
      maxOccurs="1" />
  </xs:sequence>
</xs:complexType>
<!-- End Definition of types needed to formalize innovation
models -->
```

The next shows an example of instantiating these primitives:

```
<innovation_model>
  <model modelId="modelBa1997u" modelName="Balachandra"
    modelYear="1997" modelVersion="1.0"
    modelDescription="Balachandra product innovation model
    unweighted" />
  <model_items>
    <model_item modItemIid = "mid201" modelId="modelBa1997u"
      dimid1="dim01" factorId="factor01" impact="positive"
```

```

weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = " It should be rated
with <i>Very high</i> when the team has the
perception about the success of the project and with
<i>Very low</i> it is not clear if the
project is going to be finished." />
</model_items>
</innovation_model>

```

---

Finally, Applying rules 3, 5, 6, 7 and 8 to the third element named *assessment\_questionnaire* provides the following primitives: *<assessment\_questionnaires>*, *<questionnaire>*, *<assessment\_lines>* and *<assessment\_line ...>*. The XML-Schema to model these primitives and an example of the use of this primitives are listed by Listing 4.4.

**Listing 4.4:** “Assessment questionnaire hierarchy primitives and types”

---

```

<!-- Start Definition of types needed to formalize assessment -->
<xs:complexType name="Tassessment_line">
  <xs:attribute name="lineId" type="xs:string" />
  <xs:attribute name="questionnaireId" type="xs:string" />
  <xs:attribute name="modItemId" type="xs:string" />
  <xs:attribute name="type" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tassessment_lines">
  <xs:sequence>
    <xs:element name="assessment_line" type="Tassessment_line"
      maxOccurs="unbounded" />
  </xs:sequence>
</xs:complexType>
<xs:complexType name="Tquestionnaire">
  <xs:sequence>
    <xs:element name="assessment_lines" type="Tassessment_lines"
      maxOccurs="1" />
  </xs:sequence>
  <xs:attribute name="questionnaireId"
    type="xs:string"></xs:attribute>
  <xs:attribute name="modelId" type="xs:string"></xs:attribute>
  <xs:attribute name="name" type="xs:string"></xs:attribute>
  <xs:attribute name="version" type="xs:string"></xs:attribute>
</xs:complexType>
<xs:complexType name="Tassessment_questionnaire">

```

#### 4. SOFTWARE PRODUCT INNOVATION ASSESSMENT REFERENCE MODEL

---

```
<xs:sequence>
  <xs:element name="questionnaire" type="Tquestionnaire"
    maxOccurs="unbounded" />
</xs:sequence>
</xs:complexType>
<!-- End Definition of types needed to formalize assessment -->
```

The next shows an example of instantiating these primitives:

```
<assessment_questionnaires>
  <questionnaire questionnaireId = "quest_u_1" modelId =
    "modelBa1997u" name="complete" version="1.0">
    <assessment_lines>
      <assessment_line lineId = "line_u_1_01" questionnaireId =
        "quest_u_1" modItemIid = "mid201" type="Radio1"/>
    </assessment_lines>
  </questionnaire>
</assessment_questionnaires>
```

---

A complete listing of the XML-Schema is available in Annex 7.3 Section 7.3 and a complete example of an instance representing the Balachandra et al. [9] innovation assessment model is available in Section 7.3.

## Chapter 5

# Software Product Innovation Assessment Tool

Software Product Innovation Assessment Tool (*PIA-Tool*) is a web application developed to automate the assessment of software product innovation. *PIA-Tool* is a highly adaptable and scalable tool that includes functionalities to support the process to assess product innovation and to positioning innovation.

This chapter is structured as follows: Section 5.1 presents an overview of the *PIA-Tool* features. Section 5.2 describes how innovation types of impact are supported and added in the *PIA-Tool* application. Section 5.3 explains how the innovation assessment and innovation positioning has been included in *PIA-Tool*. Finally, Section 5.4 presents an overview of the application architecture and the stakeholders involved in product innovation assessment.

## 5. SOFTWARE PRODUCT INNOVATION ASSESSMENT TOOL

### 5.1 PIA-Tool overview

PIA-Tool is a web application implemented on the basis of a layered architecture. *PIA-Tool* has been developed to provide support for software product innovation assessment, but it could also be used to perform the assessment of any other kind of products from the innovation perspective if it is customized with the appropriate dimensions and factors. *PIA-Tool* has been developed to cover some of the needs identified in the Systematic Literature Review reported in Chapter 2 Section 2.3 like: to support weighted and un-weighted assessment schemas, it is based on qualitative and discrete values or it provides repositories to build a product innovation knowledge base.

It is reported by existing literature (e.g., [8], [9], [22], [41], [54], [55], [58], [96], and

The screenshot shows a web browser window with the URL `oeixatil-13.eui.upm.es/questionnaire/buildquestionnaire.php`. The page title is "Product innovation assessment questionnaire". The interface is organized into several sections:

- ASSESSMENT DATE:** Includes a tab for "Evaluation Date" and a form with fields for "Model: Balachandra", "Questionnaire: complete", "Date: 04/06/2014", and "Time: 11:08".
- PRODUCT DESCRIPTION:** Includes a tab for "Product details" and a form with fields for "Name", "Version", "Provider", and "Description".
- Dimensions:** A section with four tabs: "Organization", "Market", "Environment", and "Technology". Under the "Environment" tab, there are seven factors, each with a "Factor" label and a "Values" label. The factors are: "Available Resources or Raw material", "Government Regulations", "Industry restructure opportunity", "Political/Social factors", "Public interest on product", "Product liability", and "Risk Distribution". Each factor has radio buttons for "Unknown", "Not Applicable", "Very Few", "Few", "Medium", "High", and "Very High". There are also "Add Files" buttons for each factor.

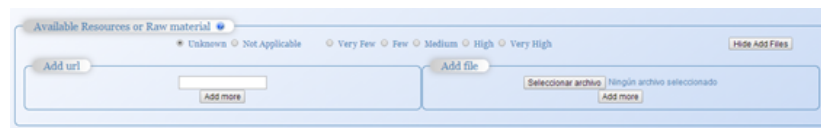
Figure 5.1: PIA-Tool questionnaire general structure

[103]) that questionnaires are the main mechanism to data gathering. The core of *PIA-Tool* are questionnaires representing software product innovation assessment models. These questionnaires are structured in three main sections: *assessment date*, *product information* and *innovation factors*. Fig 5.1 depicts the general structure of a ques-

tionnaire. At the top of the questionnaire shown by Fig 5.1 is located the *assessment date* section. This section captures date and time when the assessment is going to be performed and also shows information of the innovation model and the questionnaire to be fulfilled. This information is highly valuable to build trending charts of products positioning.

The next section below to the *assessment date* is placed the *product information* section. This first version of *PIA-Tool* just collects basic product information: version and product name, company that developed the product and a brief product description. These data were only collected to identify the product and not to provide a complete description of it.

The next section at the bottom part of the questionnaire is the *innovation factors*. This is the core of the questionnaire. It is structured in folders representing each folder a *Dimension*. Fig 5.1 presents a questionnaire with four dimensions labelled as: *Organization*, *Market*, *Technology* and *Environment*. Only one dimension is visible at time. Innovation factors are represented on each folder. Following Tsai [103] recommendations, each factor is represented by discrete values and the criterion scale proposed is *VP: Very Few*, *P:Few*, *F: Fair*, *G: High* and *VG: Very High*. Due to the type of assessment: weighted or un-weighted is a characteristic of the specific product innovation assessment model used to build the questionnaire, this information is omitted because it does not provide any relevant to the questionnaire respondent. Each factor value could be justified with document files or URLs to access to resources that will be added to the product innovation assessment knowledge base. Fig 5.2 shows the part of the questionnaire to add documents to the knowledge base.



**Figure 5.2:** PIA-Tool Options to populate the knowledge base uploading files and annotating URLs

## 5.2 Types of innovation impact

One of the findings of the SLR [117] described in Chapter 2 was that innovation factors could impact positively, negatively or both. Cooper et al. [22] concluded that any factor presents a positive impact acting as an enabler if its presence during the product development process helps the company to achieve product goals in the scope of innovation.

## 5. SOFTWARE PRODUCT INNOVATION ASSESSMENT TOOL

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Label Value	Positive (+)	Negative (-)	Both (*)
Very low	1	-1	-5
Low	2	-2	-2.5
Medium	3	-3	0
High	4	-4	2.5
Very high	5	-5	5

**Table 5.1:** Numeric values assigned to each discrete value of a type of innovation impact.

Negative impact is considered as a blocker, that is its presence makes it difficult for the company to achieve product goals.

It was stated in Chapter 4 that product innovation assessment models consist of associations between factors and dimensions with their corresponding impacts and weights. Depending on the assessment goals, each type of impact could be represented in different ways: discrete values, continuous values, ranges or any other representation. Following the recommendations given by Tsai [103] and other authors, in this thesis, impact is represented by discrete values. Discrete values [55, 8, 54, 103] provide sufficient information for evaluating factors even at early stages of the product development when uncertainty over the product is still high.

*PIA-Tool* supports these three types of impact and their corresponding representation as discrete values that will be assigned to the Assessment lines elements while building a questionnaire. *PIA-Tool* has been implemented to be scalable and adaptable with respect to innovation impacts and new representation of impacts could be provided.

In the case of factors with positive impact the proposed values are: *Very low*, *Low*, *Medium*, *High*, or *Very high*. Where *Very low* represents that the factor has a minimum impact in the development of the product and *Very high* represent that the factor was highly relevant in the development of the product.

To represent negative impact, the same discrete values were proposed but with different interpretation. In the case of negative impact *Very high* represents that the factor has a maximum negative impact in the development of the product and *Very low* represent that the factor impacted negatively very few in the development of the product.

Finally, to represent impact that could be either positive or negative depending on the environment, the same discrete values were proposed; but the interpretation of this factors is different than in the other two impacts. It has two meanings, values *Very low* and *low* represents negative impacts of the factor a *High* and *Very high* represents positive impacts of the factor. Value *Medium* represents that the impact is neither



positive nor negative.

Each line of a questionnaire has assigned a representation for the type of impact of the factor that is representing. The same factor could be represented by different types. Table 5.1 presents the numeric values proposed to each discrete value on these three types of impact following the Tsai [103] recommendations. The first column represents discrete values and the rest of columns represents the innovation impacts considered in *PIA-Tool*. These values are used during the assessment to obtain the impact of innovation.

### 5.3 Assessment and Positioning process

*PIA-Tool* provides two levels of innovation assessment. The first one represents the assessment of each dimension that exists in the innovation assessment model and that will be referred in this section as dimension innovation assessment; therefore it is applied only to dimensions. The second level of innovation assessment provides an integrated view of the assessment of each dimension; it will be referred in this section as innovation positioning.

The dimension innovation assessment process for a particular product is performed by assigning values to each factor defined in the dimension. The process to assess a dimension consists of to iterate through all the factors of the dimension and collect the discrete value assigned to each factor to summarize the total impact. Each value is translated to the appropriate numeric value determined by the type of representation assigned to Assessment line associated to the factor in the questionnaire. Table 5.1 shows the values considered in this thesis. In the case of weighted models, the factor impact value is obtained as the product of the numeric value by the factor weight. In the case of un-weighted models the impact value is the same than the numeric value. The result of iterating through factors of a dimension is a numeric value representing the total impact of the dimension.

There are two special situations while processing factors: the first is when a factor is not applicable and the second is when there is not enough information to assess a factor. Under specific situations some factors could be considered as not applicable, that is, questionnaire respondent determines that some factors do not impact in the product innovation and there are evidences of this fact, i.e. factor *Patents* in the technology dimension is not applicable in the case of an open source project under a free software foundation licence or factor *R&D process well planned* in projects without any research activity.

## 5. SOFTWARE PRODUCT INNOVATION ASSESSMENT TOOL

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The second situation was pointed out by Lester [58] and it happens when at the moment of performing a product innovation assessment, there are no evidences about the impact of the factor: it could impact in some degree or even it could not be applicable under certain circumstances. The existence of *Unknown* factors is relevant during the product innovation assessment process because they could derive in three different situations: (i) the factor is not applicable, so that is should not be considered during the assessment; (ii) the factor is applicable with the most positive impact; and (iii) the factor is applicable with the most negative impact.

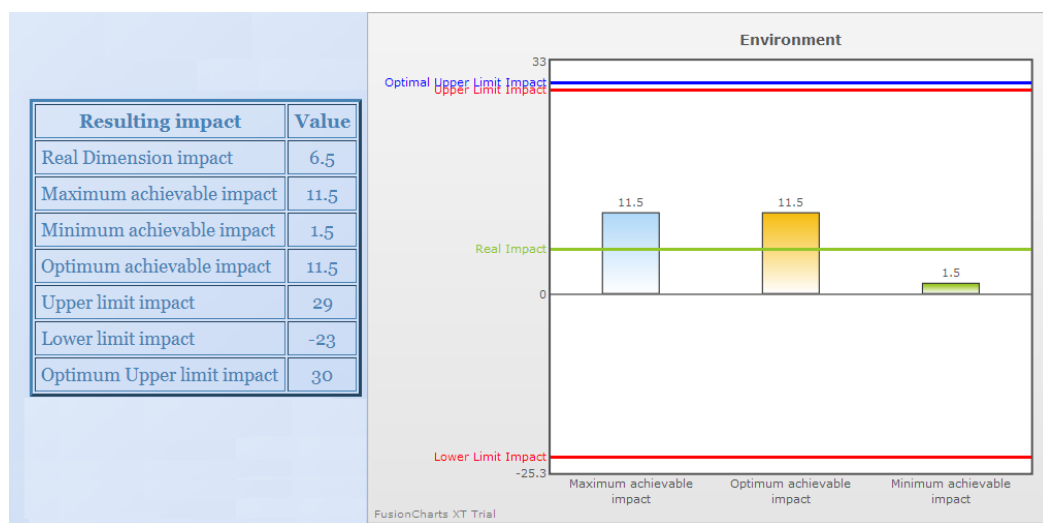
The assessment process is affected by the existence of *Not Applicable* and *Unknown* factors. In the case of *Not Applicable* factors they are omitted in the assessment to not affect neither positive or negative in the total impact of the affected dimension. In the case of the existence of *Unknown* factors the impact of the affected dimension could be different. To analyse the impact the following measures are obtained:

- *Real impact value*, it represents the impact considering that *Unknown* factors have not impact yet.
- *Maximum impact value*, it represents the maximum impact achievable considering that all the *Unknown* factors are applicable; that is in the case of factors with positive or both impacts, they are considered with the most positive value. In the case of factors with negative impact the are considered with the less impact as possible.
- *Minimum impact value*, it represents the minimum impact achievable considering that all the *Unknown* factors are applicable; that is in the case of factors with positive they are considered with the less positive value. In the case of factors with negative impact or both impacts the are considered with the most negative impact as possible.
- *Optimal impact value*, it represents the highest impact achievable considering the most favourable scenario for each factor. The most favourable scenario is achieved when: (i) all the *Unknown* factors with positive or both impacts are impacting positively with the highest value and (ii) those factors with negative impact are considered as *Not Applicable* to the product.

For those dimensions having factors with only positive of both impacts, the Maximum and Optimal impact values are the same. In the case of dimensions with negative impact, the optimal impact value could be greater than the Maximum impact value. Finally a chart representing these four values is built to show in a graphical way how

### 5.3 Assessment and Positioning process

much the impact could be. Finally, to be able to compare the obtained impact on each dimension with the maximum and minimum achievable impact in the case of application of all factors in the most and less favourable and optimal scenarios. The most favourable impact means that all the factors are applicable with the maximum impact; and the less favourable impact means that all the factors are applicable with the lower impact. Both values represents the upper and lower limits of the impact over a dimension. Figure 5.3 shows an example of a dimension assessments.



**Figure 5.3:** Dimension assessment impact results and chart.

The algorithm to calculate the innovation impact of a dimension is listed below at Listing 5.1.

**Listing 5.1:** “Algorithm to obtain the impact of a dimension”

```

Initialize variables
for each factor
  Get value assigned to the factor
  Obtain the numeric value
  Update ideal values (minimum, maximum and optimal)
  switch value
    case ``Not Applicable`` : Do nothing
      break;
    case ``Unknown`` : update dimension impact
      actual += 0
      maximpact += maxvalue
      minimpact += minvalue

```

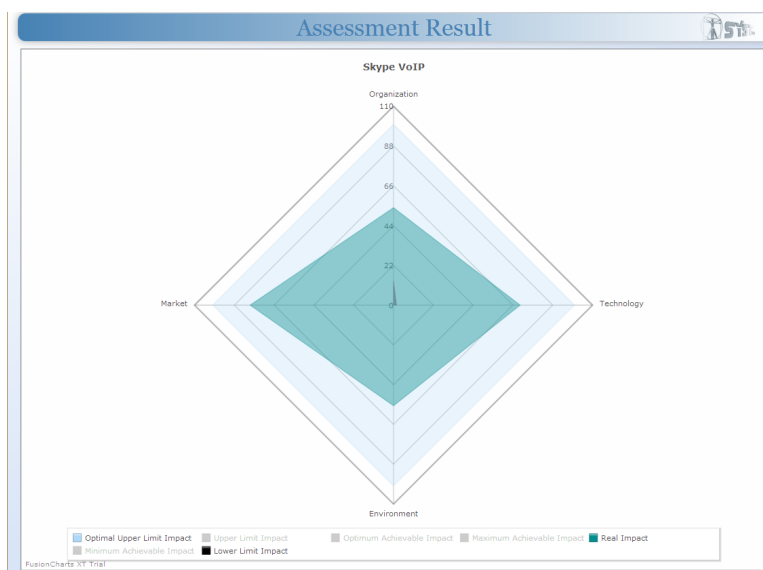
## 5. SOFTWARE PRODUCT INNOVATION ASSESSMENT TOOL

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```
        optimalimpact += optimalvalue
    default : update real impact
        actual += real
        maximpact += real
        minimpact += real
        optimalimpact += real
    end switch
end for each
```

---

Finally, after all dimensions have been assessed and all measures have been obtained product innovation could be positioned. The positioning system is based on the same structure and ideas proposed in [90] customized to product innovation assessment. The positioning system is represented by a spider chart where each analysed dimension is an axe of the chart. To present data of different axes with the same scale, results of each dimensions have been normalized. The maximum value is 100% and the minimum is 0. So that, dimensions can be analysed to have a better understanding of which dimension has impacted more from the innovation perspective that is aligned with the ideas of Balachandra et al. [9] and Åstebro [8]. Figure 5.4 shows an example of the innovation positioning of Skype.

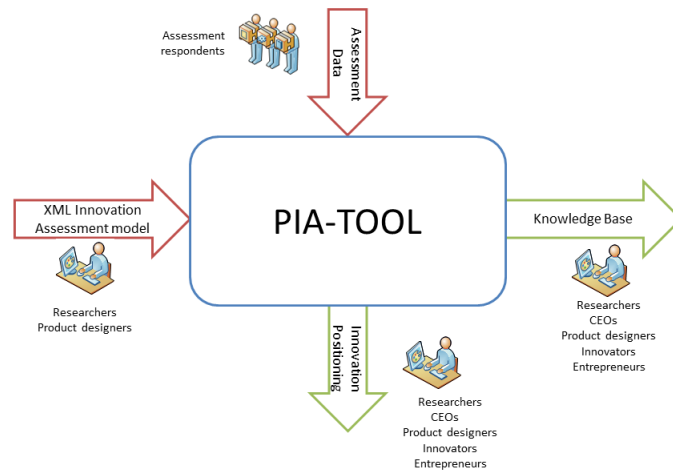


**Figure 5.4:** Product innovation positioning chart of Skype. Real impact.

## 5.4 High level Architecture

To end this chapter a high level architecture is presented to show the main architectural components, inputs and outputs of the complete system. Figure 5.5 depicts the main inputs, outputs and stakeholders involved in PIA-Tool. PIA-Tool needs two types of inputs: Product innovation assessment instance and data from the assessment and two types of outputs are obtained after the assessment is performed: an extended knowledge base and the Innovation positioning.

Product innovation assessment instance is prepared by researchers and/or product



**Figure 5.5:** PIA-Tool inputs and outcomes and main stakeholders

designers. They are in charge of identifying specific dimensions and factors to assess product from the innovation perspective. The instance must be built using the specific language defined to represent product innovation assessment models described in Chapter 4 Section 4.4. This instance of the model must be loaded previously to start the assessment of products.

Assessment respondents provide data for the assessment of products through the questionnaire. This information is needed to perform the assessment. Not all the information must be collected at the beginning of the assessment process, but a questionnaire could be completed later when additional information was available. For those data without evidences, the *Unknown* value must be selected.

Concerning outputs, all the information (values, documents and URLs) provided by respondents is included in the knowledge base. This information is useful to justify values

## 5. SOFTWARE PRODUCT INNOVATION ASSESSMENT TOOL

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given to each factor. The innovation positioning summarizes the relevance of factors of each dimension. It helps to have a better understanding of product innovation that is one of the objectives that is aligned with the ideas highlighted by Balachandra et al. [9] and Åstebro [8].

These types of output could be very useful to:

- Researchers to increase the level of understanding of innovation factors and to know how factors are impacting in product innovation.
- CEOs and Product designers to help them to take decisions at different levels like: company, team, market or project as it was reported by Krishnan et al. [55].
- Innovators and Entrepreneurs to help them to understand which innovation factors were relevant in the success of previous products. It also helps them to create new products and add value to an organization as it was reported by Axel [50].

*PIA-Tool* mainly comprises three main blocks: *Questionnaire weaving module*, *Assessment module* and *Knowledge management module*. Figure 5.6 depicts these modules and their dependencies.

*Questionnaire weaving module* is the one responsible of building questionnaires using product innovation assessment model instances based on the product innovation reference model. The input of this module is the model instance and outputs are the questionnaires described in the instance. These questionnaires are available to perform the product innovation assessment when it is needed.

*Assessment module* is the one responsible of performing the assessment by obtaining the measures needed to get results for each dimension and to position the product innovation. Two sub-modules comprises the assessment module: *Dimension assessment* and *Innovation positioning*. The *Dimension assessment* sub-module iterates for each factor impacting the dimension obtaining their assessment value, dimension measures of: *Maximum impact value*, *Minimum impact value*, *Optimal impact value*, *Upper limit*, *Lower limit* and *Optimal upper limit* and building the Dimension chart. The innovation positioning combines dimension measures to obtain the positioning chart.

Finally, *Knowledge base* module is responsible to update the knowledge base with relevant data obtained from questionnaires: values for each factor and documents and URLs justifying those values in the case that they were provided. Values and URL are stored in a product innovation database and documents are added to a product innovation repository. Both, database and repository will be very helpful for researchers, CEOs, innovators and entrepreneurs to have a better understanding of innovation factors and how impacted in the innovation assessment of products.

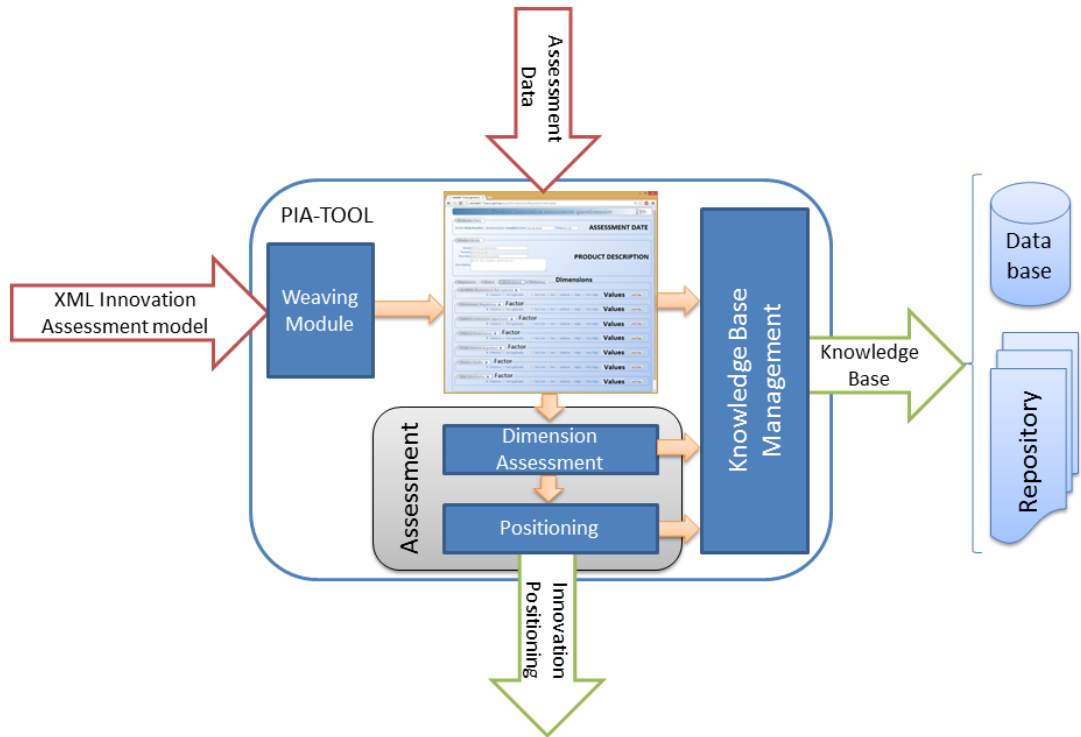


Figure 5.6: PIA-Tool high level architecture

## **5. SOFTWARE PRODUCT INNOVATION ASSESSMENT TOOL**

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## Part III

# Instantiating the Reference Model



## Chapter 6

# Instantiating the Reference Model

The goal of this chapter is to instantiate the reference model to perform the assessment of innovation for a software product. Following the recommendation of Wieringa [110], to build an instance to assess software product innovation based on a list of factors and questionnaires is a way to demonstrate the internal validity of the proposed reference model. In addition, building an instance enables to check that guidelines provided by Hevner [43] have been applied in an appropriate way to build IT artefacts. This chapter is structured in three main sections. Section 6.1 describes the innovation model instance that has been applied to build assessment questionnaires. Section 6.2 describes how the assessment has been performed to assess a successful product such as Skype from the perspective of product innovation. Section 6.3 how the assessment has been performed to assess a failed product such as Google Wave from the perspective of product innovation.

## 6. INSTANTIATING THE REFERENCE MODEL

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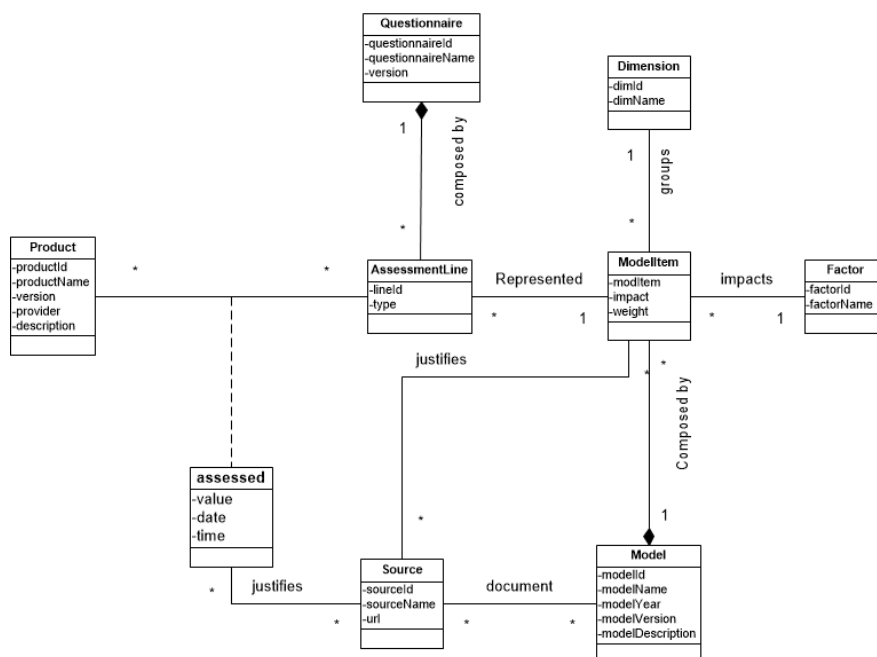


Figure 6.1: Product innovation assessment reference model.

### 6.1 Software product innovation assessment model selection

This section describes the process followed to select the model to assess product innovation. Model selection is based on the reference model depicted in Figure 6.1 and described in Chapter 4 Section 4.3. The product innovation assessment model is composed by three main elements: the innovation model, questionnaires and the assessment of products. The following sections present how each element is being instantiated to assess products.

#### 6.1.1 Innovation model

A software product assessment innovation model is a combination of factors and dimensions used to assess product innovation. Each factor assigned to a dimension has a type of impact (positive, negative or both) and a weight. In a innovation model, a factor could impact into one or more than one dimensions. The innovation model built in this chapter as a proof of concept to assess software products is organized in four dimensions: *Environment*, *Market*, *Organization* and *Technology*. As it was obtained as a result of the SLR[117] reported in Chapter 2 Section 2.3, these four dimensions

## 6.1 Software product innovation assessment model selection

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were the most cited in the literature when assessing product innovation.

To drive the impact of factors over dimensions, an un-weighted approach was selected, that is all factors have the same impact when assessing product innovation. Even when a weighted approach based on frequencies of citations for each factor, the un-weighted approach was selected because there is not an agreement on how to assign weights to factors; so Galbraith et al.[41] combined the application of Delphi processes[91] and statistical analysis to assign weights to factors. Also Tsai[103] applied weighted factors, but using AI (fuzzy logic) to calculate the weights. In the same direction, Klintong[54] also proposed the application of other AI techniques such us Artificial Neural Network or Genetic Algorithms to assign weights to factors.

The list of factors proposed is based on the one proposed by Balachandra et al. [9]. This list of factors is quite exhaustive and most of them have been also proposed by other authors in the literature. Two dimensions: market and organization are composed by a large number of factors; the common solution reported by Åstebro [8] is to select a subset of factors to define a coverage limit of the to achieve a determined level of confidence in the analysed factors. It was reported in the SLR [117] that, in average, with 50% of the factors is enough to achieve a confidence rate of 70%. This means that assessing only 50% of the factors with the highest frequencies the confidence achieved is 70% for each dimension.

Annex III.1 presents the complete list of factors classified by dimension, their impact type and the list of factors needed to achieve a confidence of 70%.

### 6.1.1.1 Environment dimension

Environment represents a number of different aspects related with political and social factors impacting at different levels in the innovation of a software product. Some factors are due to interaction with external providers like *Raw material* or *Risk Distribution* but some others reflect un-tangible factors like *Political/Social factors* or *Public interest on product*. Sometimes innovation can not be success in some products if the environment is not ready to support it, though in most of the cases this is not so important, it can become critical in times of hostilities and market-induced shortages.

Annex III.1, Table 1 identifies 7 factors proposed by Balachandra et al.[9] impacting in the environment. Only two of them were clearly considered as relevant factors by the literature analysed by Balachandra et al. [9]. The rest of the factors were identified by only one publication. The total number of citations is 11. Most of the factors have both impact (negative or positive) depending on if they have been considered or not during the product development. If companies do not consider the environment while

## 6. INSTANTIATING THE REFERENCE MODEL

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developing their products, the probability to build a success product is very small. In the case of the Environment dimension five factors are needed to achieve the confidence rate greater than 70% (73%).

### 6.1.1.2 Market dimension

There is universal agreement that market is an important dimension. Market is an overloaded term and in the scope of this thesis is defined in terms of product as “*the market for a particular item is made up of existing and potential customers who need it and have the ability and willingness to pay for it.*” [17]

Many factors around the market dimension have been identified in the literature. Annex III.1, Table 2 presents the list of factors collected by Balachandra et al. [9] from 19 studies that were considered that have impacted in product innovation. The market dimension addresses several issues like market maturity, market needs, market competitors and how to access to the market.

Annex III.1, Table 2 identifies 21 factors. The total number citation of factors is 41. Most of the factors have positive impact in the market dimension, that is that they act as enablers to produce successful products. But some others like *Early to market* or *Slow growth market* present a negative impact implying that if a market is not mature enough to accept the product or the market growth is still slow then new products are giving chances to secondary offerings to build more successful products based on the missing features of the earlier products. Finally, some other factors could have positive or negative impact depending on if other considerations. So, *Life cycle of product*, *Market analysis* or *Meet customer needs/wants* present this behaviour. So, if a market analysis has performed in advance, the chances to build a innovative product adapted to the market needs are greater than in the case of absence of this analysis.

Summarizing, market dimension is highly dependent of the context and it could have different impact under different situations. In the case of the Market dimension 11 factors are needed to achieve the confidence rate greater than 70% (80%); but it is recommended to consider 13 factors due to this is the border of factors having a frequency greater than 1, and there are no clear arguments to dismiss two of the proposed factors with greater than 1.

### 6.1.1.3 Organization dimension

Organization dimension refers to those factors directly related with companies and their ability to get the new product into the market. These factors measure organizational

## 6.1 Software product innovation assessment model selection

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aspects of a company related to team organization like or “*Commitment of project workers*”, company strategy like “*Emphasize Marketing*” or “*Technology tied to business strategy*” and project management like “*High Level Management support*”. This is the most studied dimension in the literature and the list of factors is wider than in other dimensions.

Annex III.1, Table 3 comprises 36 factors. The total number citation of factors is 74. Most of the factors (90%) have positive impact in the organization dimension, that is that they act as enablers to organize how to produce successful products. Only three: *Understanding market*, *Newness to firm* and *Use outside communication* could have positive or negative impact depending on if they were considered or not. *Understanding to market* presents both impacts because if companies do not understand the market, they could build a wrong product or to offer a product to the market in the wrong way; what represents a negative impact for the company. But in the opposite, if companies understand the market, they could build and present the product in accordance to the needs of the market, representing an positive impact in the product. The analysis of *Newness to firm* is similar; if the product under development is completely new to firm, the time needed to put the product in the market could be greater than expected giving opportunities to other firms to take advantage in the market. This represents a negative impact in the product. No specific negative factors related to this dimension have been identified in the literature.

In the case of the Organization dimension 17 factors (less than 50%) are needed to achieve the confidence rate greater than 70% (74%). It is the same situation than in the market dimension, the border of selected factors is determined by a frequency greater than 1.

### 6.1.1.4 Technology dimension

Technology dimension represents those factors related with those platforms, techniques and devices that are needed to build the new product. Products using new technologies have a greater chance of success in the market. This dimension is closer to software products than *Market* and *Organization* because the nature of software: high dependence of technology, intangible, malleable and low threshold to enter in the market[82]. The degree of innovativeness from the technology is an important consideration [9]. Mansfield [63] identified that, concerning technology factors, in general companies that invested money on finding markets for new technologies (technology-push) had less success probabilities than those companies driven by market (demand-pull) due to the probability of technical completion is expected to be high in a well market specified

## 6. INSTANTIATING THE REFERENCE MODEL

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problem. As it was concluded by Balachandra et al. [9], the influence of technology factors is highly dependent on other contextual factors related to the innovativeness of the technology.

Annex III.1, Table 4 comprises 13 factors. The total number citation of factors is 24. Most of the factors (85%) have positive impact in the technology dimension, that is that Technology acts as an enabler to produce successful products. Only two factors *Product liability* and *Utility* present a non positive impact. So, *Product liability* has negative impact because it measures the responsibility of the company to ensure that innovative products are safe and they do not cause injury to users [70, 85]; that in the case of software is derived from bugs or missing requirements. These injuries could affect to the firm reputation.

In the case of *Utility*, it could have both (negative and positive) [51] depending on user perception. So, when the product is considered as useful to a wide range of customers it will have a positive impact but when it is not clear how useful is to customers, or it is only useful to a small group of customers it will produce a negative impact. In the case of the Technology dimension six factors are needed to achieve the confidence rate greater than 70%. This dimension presents the same behaviour that Market and Organization dimensions and the border of selected factors is determined by a frequency greater than 1.

### 6.1.2 Questionnaire

The next element of the product innovation assessment model is questionnaires. A questionnaire represents the template to data gathering for product innovation assessment models. The reference model depicted in Figure 6.1 shows that each item of innovation models could be represented by several ways. This representation is done through associating one or more than one Assessment lines in questionnaires depending on the type of inputs that will be requested to respondents. In the case of the product innovation assessment model that is being instantiated, and derived from the types of impacts associated to each pair factor-dimension, three types of Assessment lines have been defined.

The first type of Assessment line was defined to represent factors with positive impact. Following the recommendations given by Tsai [103] and other authors, we built questionnaires based on qualitative questions representing factors rated by discrete values to reduce the uncertainty of answers. The proposed values are: *Very low*, *Low*, *Medium*, *High*, or *Very high*. Where *Very low* represents that the factor has a minimum impact in the development of the product and *Very high* represents that the factor played a



## 6.1 Software product innovation assessment model selection

Label Value	Positive (+)	Negative (-)	Both (*)
Very low	1	-1	-5
Low	2	-2	-2.5
Medium	3	-3	0
High	4	-4	2.5
Very high	5	-5	5

**Table 6.1:** Numeric values assigned to each discrete value of an assessment line in terms of the impact.

relevant role in the development of the product. Each discrete value has assigned a numeric value that it is shown in Table 6.1 to measure its innovation impact.

The screenshot shows a web browser window with the URL 'oeixtati-13.eui.upm.es/questionnaire/buildquestionnaire.php'. The page title is 'Product innovation assessment questionnaire'. It features several sections:

- Evaluation Date:** Model: Balachandra - Questionnaire: complete Date: 04/06/2014 Time: 11:08
- Product Description:** Fields for Name, Version, Provider, and Description.
- Dimensions:** A list of factors with radio button options:
  - Available Resources or Raw material
  - Government Regulations
  - Industry restructure opportunity
  - Political/Social factors
  - Public interest on product
  - Product liability
  - Risk Distribution

**Figure 6.2:** Questionnaire built assess software products.

For those factors with negative impact, the same discrete values were proposed. In the case of negative impact the interpretation of values is the following: *Very high* represents that the factor has a maximum negative impact in the development of the product and *Very low* represent that the factor impacted negatively very few in the

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development of the product. Each discrete value has assigned a numeric value that it is shown in Table 6.1 to measure its innovation impact.

Finally, for those factors with both impacts, the same discrete values were proposed. The interpretation of this factors is different than the other two. It has two meanings, values *Very low* and *low* represents negative impacts of the factor a *High* and *Very high* represents positive impacts of the factor. Value *Medium* represents that the impact is neither positive nor negative. Numeric values to to measure its innovation impact are shown in Table 6.1.

Two additional facts could happen when assessing innovation factors: the first is that a factor is not applicable to an specific product, i.e. factors related to research in a non research product. The second is that there are no evidences about the impact of the factor with the existing information available of a product. To support these two specific situations, two additional values have been added to each Assessment line: *Not Applicable* and *Unknown*. So, *Not Applicable* means that the factor must not be considered in the assessment of the product because there are evidences that the factor does not impact in the product.

*Unknown* value means that there are no evidences about the impact of the factor: it could impact in some degree or even it could not be applicable under certain circumstances. The existence of *Unknown* factors is relevant during the assessment process because they could derive in three different situations: (i) the factor is not applicable, so that is should not be considered during the assessment; (ii) the factor is applicable with the most positive impact; and (iii) the factor is applicable with the most negative impact.

Figure 6.2 shows an screen-dump of the questionnaire build to perform the product innovation assessment. This questionnaire is available at <http://pia-tool.eui.upm.es/piassessment/>

### 6.2 Skype assessment

Skype©was created in 2003 by two entrepreneurs from Sweden and Denmark: Niklas Zennström and Janus Friis. Skype is a software product that supports several types of communications over IP (VoIP), such as text communications, voice and video. When it first came into the market, Skype was entirely based on a peer-to-peer architecture. Apart from the servers used to download the software and authenticate users, the application ran entirely on users' computers. As a result of this structure, adding a new user costs to Skype one-tenth of a cent, as it was reported in Fortune magazine in 2004 [40]. However, Skype was not the first Internet-telephony application; it was not

even the first one based on a peer-to-peer architecture[105]. However, the experience that the Skype team gained developing KaZaA and a clear focus on voice quality and ease of use resulted in an application that surpassed the quality of existing Internet-telephony applications and was offered for free. Thus, one of its main strengths is voice communication that is free of cost between Skype users anywhere in the world. It also supports special calls, at a very low cost, between a computer and land-line or mobile. In less than two years after its launch, the Skype peer-to-peer solution for VoIP attained leadership in the global market in VoIP. Therefore, Skype is an exemplar innovative product and this is why it is interesting to analyze it through the product innovation assessment model.

### 6.2.1 Data collection methodology

A literature review (LR) was conducted to collect available information regarding innovation factors that could have impacted if the success of Skype. Following the guidelines published by Kitchenham [53], adapted to accept handmade search, the LR comprised three main phases: planning the review, which aims to develop a review protocol; conducting the review, which executes the planned protocol in the previous phase; and reporting the review, which involves relating the review steps to the community. The review protocol mainly involves defining the objective, the formal search strategy to identify the entire population of material to be considered, in the case of few search results in some factors, a hand search will be performed; and, finally, the data extraction and synthesis strategies.

For the SLR of Skype, the review objective was to identify those factors characterizing the innovation of Skype. To that end, we conducted a search in the set of electronic databases and consultants shown in Table 6.2 and defined the inclusion criteria (IC) and exclusion criteria (EC) to determine whether every potential material should be considered for the SLR. Finally, the extraction process involved identifying the data required to fulfil the review objective. Toward this end, we used Atlas.ti® that facilitates the collection of studies to be reviewed, as well as the qualitative data analysis of these studies by providing capabilities for storing and categorizing key concepts. Documents were processed making quotations to paragraphs and assigning codes related to innovation factors. The synthesis process involved product innovation factors of Skype from the innovation perspective. As Table 6.2 shows, in the search for material on Skype, we retrieved over 321 results, from which we selected 18 studies relevant to the review objective according to the inclusion and exclusion criteria.

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Data source	Retrieved	Excluded	Included
Electronic Databases			
ACM Digital library	74	74	0
IEEE Xplore	5	3	2
Springer Link	27	26	1
ScienceDirect	11	8	3
White papers	20	0	0
Consultants			
Tech Republic	74	73	1
Gartner	1	1	0
Digital Library Tech	9	9	0
Mckinsey Quarterly	17	17	0
The Register	1	1	0
Safari Books ProQuest	72	71	1
Hand searches	10	0	10
Total	321	303	18

**Table 6.2:** Data sourcesSLR

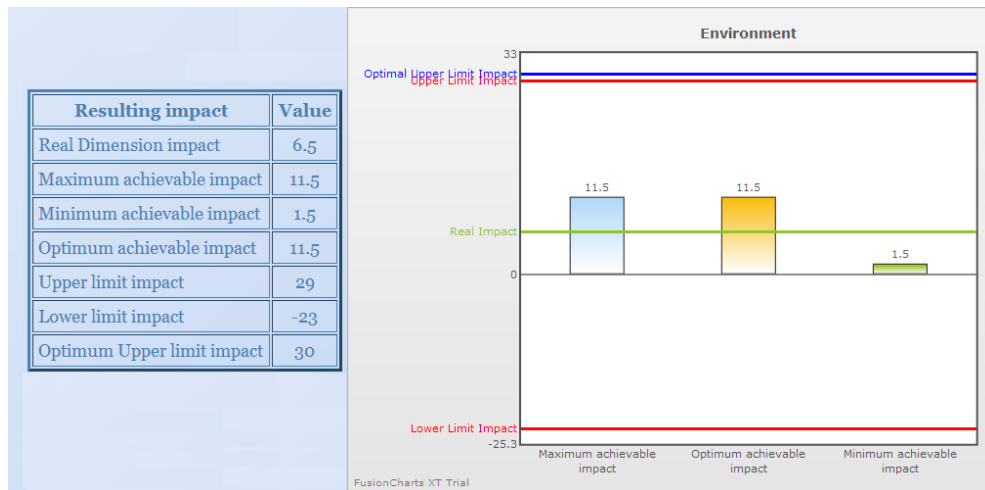
After analysing and processing these studies, we obtained evidences of factors using Atlas.ti®. The number of evidences for each factor is represented in tables Annex III.1, 1, 2, 3 and 4 in the column labelled *Skype Evidence*. Each evidence represents a part of the document that is referring the innovation factor.

Next subsections present results obtained from the evaluation of Skype on each dimension: Environment, Market, Organization and Technology.

### 6.2.2 Environment dimension assessment

The environment dimension has been assessed through the list factors listed in Annex III.1, Table 1. The total number of evidences obtained from the document to support the assessment of this dimension was 19. Table 6.3 shows a summary of the results gathered in the Skype assessment. All the factors were applicable to Skype but there is only one factor, *Public interest on product* that was not able to get evidences to provide an assessment value for it. Even when Skype has been considered as a useful software product, there are no evidences about the interest of public sectors on using Skype. A deep analysis of factors pointed out that concerning those factors that could have both types of impact, two of them *Political/Social factors* and *Government Regula-*

tions presented negative impact in the product. So, some Asian and Latin American countries banned Skype services to limit the freedom to collect and talk about political information which is unfavourable to the government[20]. Also some countries limited Skype to access to their markets through the establishment of specific regulations to protect local telecommunication companies [20, 107].



**Figure 6.3:** Skype environment dimension assessment results.

Factors impacting positively in the environment dimension *Available Resources* or *Raw material* and *Risk Distribution* have been rated as *Very High* what represent that they were highly relevant in the success of Skype. The experience acquired in previous projects and the fact of contracting the same development team that developed KaZaA contributed to build a successful product [65]. The use of Internet to distribute free downloadable versions of the Skype also helped to stand out very fast from others IP telephony providers[89]. Only one factor presented negative impact *Product liability*. It was assessed with *Very Few* impact due to the risk of injuries produced by using Skype is very limited [48].

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Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	2	1	0	3	0,43
High	0	0	0	0	0,00
Medium	0	0	0	0	0,00
Low	0	1	0	1	0,14
Very Low	0	1	1	2	0,29
Unknown	0	1	0	1	0,14
Not Applicable	0	0	0	0	0,00
Total				7	1,00

**Table 6.3:** Skype assessment: statistics for Environment dimension

With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.3. The impact of Environment in Skype is 6.5, but one of the factors *Public interest on product* was rated as *Unknown*. Considering that this factor could impact positively or negatively the final impact of Skype could change depending on the assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 11.5, and in the case with the most negative impact, the minimum achievable impact is 1.5.

Due to the existence of factors that could have negative impact in the innovation, the lower limit for the impact is -23. The upper limit for the impact is 30, therefore, as the impact obtained for the environment dimension is 6.5, it means that the impact is around the 50% of the maximum expected. This value represents that factors with negative impact are affecting in a significant way in the product.

### 6.2.3 Market dimension assessment

The market dimension has been assessed through the 21 factors listed in Annex III.1, Table 2. The total number of evidences obtained from the documents to support the assessment of this dimension was 107. Table 6.4 shows a summary of the results gathered in the Skype assessment. All the factors were applicable to Skype but 4 factors, *Life cycle of product*, *Market analysis*, *Early analysis of market and competitors* and *Slow growth market* were not able to get evidences to provide an assessment value for them.



Figure 6.4: Skype market dimension assessment results.

A deep analysis of factors pointed out that most of the factors with positive impact (almost 80%) were assessed as *High* or *Very High* highlighting the relevance of the market dimension in the Skype success. For those factors with both types of impact, two of them *Competitive environment* and *Meet customer needs/wants* obtained the highest positive value. In the case of *Competitive environment* VoIP was a new family of products and the entrance barriers were low even when there were more competitors but approaching from different routes [89]. In the case of *Meet customer needs/wants* Skype provides features to satisfy needs of many different types of users letting them flexibility in the way to use Skype [65, 89]. Concerning the other two factors, *Life cycle of product*, *Market analysis* no evidences about the scheduled life cycle of the product or the market analysis performed by Skype founders were found.

In the case of factors with negative impact, *Early to market* was assessed as *Few* impact because even though the VoIP market was starting, there were some other solutions facilitating the market growth [80, 65]. The other two factors and *Slow growth market* were assessed as *Unknown*. The first one, *Early analysis of market and competitors*, because it was not possible to get access (if exists) to the analysis of market and competitors performed by the company and the second one *Slow growth market* because the evidences found pointed out the opposite, that is, a fast growth of the market; so it is expected that, at the end, this factor were assessed as *Not applicable*.

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Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	6	2	0	8	0,38
High	5	0	0	5	0,24
Medium	3	0	0	3	0,14
Low	0	0	1	1	0,05
Very Low	0	0	0	0	0,00
Unknown	0	2	2	4	0,19
Not Applicable	0	0	0	0	0,00
Total				21	1,00

**Table 6.4:** Skype assessment: statistics for Market dimension

With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.4. The impact of Market in Skype is 67. Considering the *Unknown* factors the final impact of Skype could change depending on their assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 75, and in the case with the most negative impact, the minimum achievable impact is 47. Considering that two unknown factors have negative impact, the optimal impact achievable value could be 77 in the case of both factors were assessed as *Not applicable* to Skype.

Due to the existence of factors that could have negative impact in the innovation, the lower limit for the impact is -21. The upper limit for the impact is 90, therefore, as the impact obtained for the environment dimension is 67, it means that the impact is around the 80% of the maximum expected. This value represents that factors with negative impact are not affecting in a significant way in the product and factors with positive impact have had a high influence in the development of Skype.

### 6.2.4 Organization dimension

The organization dimension has been assessed through the 36 factors listed in Annex III.1, Table 3. The total number of evidences obtained from the documents to support the assessment of this dimension was 79. Table 6.5 shows a summary of the results gathered in the Skype assessment. Only one factor *Quantitative project selection* was not applicable and the rest factors were applicable to Skype but 12 (33%) factors were not able to get evidences to provide an assessment value for them. It is a high value



and it could be derived from two main causes: a wrong search or that companies due to their public/private policies do not publish their sensible information. *Quantitative project selection* was not applicable because Skype was the only project of the company when it was founded, so that no competition with other projects happened.

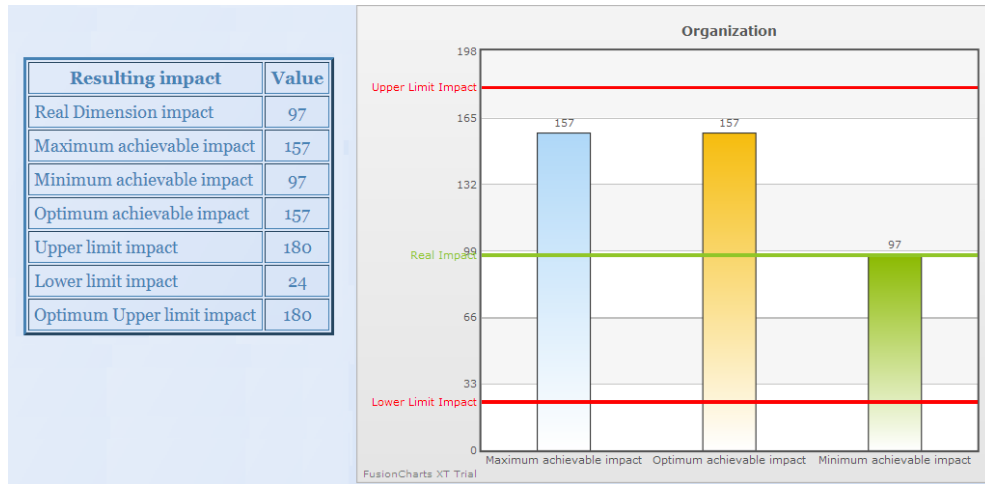


Figure 6.5: Skype organization dimension assessment results.

A deep analysis of factors pointed out that none of the factors have *Very few* or *Few* impact, highlighting that organizational factors were also important in the success of Skype. For those factors with both types of impact, two of them *Understanding market* and *Use outside communication* were assessed as *Unknown*. The *Newness to firm* factor was rated as *Very High* because the product was not completely new for the company because the had some background [65] that let the company to develop the right product for the targeted market.

In the case of factors with positive impact, for those that evidences were found, most of them were assessed with *High* or *Very High* impact. Highly relevant factors discussed in the analyzed literature about Skype were related with the technical background from the organizational perspective. So *Technology tied to business strategy*, *Technological background of managers* and *Training and Experience of own people* were three of the factors with more evidences. This is due to the great influence of the technology in the product in a company created around the product [65, 89, 80]. It also relevant to highlight the number of evidences about the factor *Effects on other business*, highlighting that the Skype project did not had internal competitions and some new business opportunities were opened [35, 65, 89].

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Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	11	1	0	12	0,33
High	4	0	0	4	0,11
Medium	7	0	0	7	0,19
Low	0	0	0	0	0,00
Very Low	0	0	0	0	0,00
Unknown	10	2	0	12	0,33
Not Applicable	1	0	0	1	0,03
Total				36	1,00

**Table 6.5:** Skype assessment: statistics for Organization dimension

With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.5. The impact of Organization in Skype is 97. Considering the *Unknown* factors the final impact of Skype could change depending on their assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 157, and in the case with the most negative impact, the minimum achievable impact is 97. The minimum and the real impact are the same due to there are no negative factors unknown.

The lower limit for the impact is 24. The upper limit for the impact is 180, therefore, as the impact obtained for the environment dimension is 97, it means that the impact is around the 54% of the maximum expected. This value represents that organization factors did not have the greatest impact in the development of Skype. They influenced, but they were not the key of the Skype success.

### 6.2.5 Technology dimension assessment

The technology dimension has been assessed through the 13 factors listed in Annex III.1, Table 4. The total number of evidences obtained from the documents to support the assessment of this dimension was 34. Table 6.6 shows a summary of the results gathered in the Skype assessment. All the factors were applicable to Skype but two factors, *Problem definition* and *Directions for scientific development* were not able to get evidences to provide an assessment value for them. Only one factor presented negative impact *Product liability*. It was assessed with *Very Few* impact due to the risk

of injuries produced by using Skype is very limited [48].

A deep analysis of factors pointed out that concerning those factors that could have



Figure 6.6: Skype technology dimension assessment results.

both types of impact, *Utility* presented positive impact in the product because Skype was perceived as a useful software product [65]. Demand *Pull vs Technology push* was rated as *Medium* because even though technology was pushing it was over an existing market, therefore both approaches were considered with the same importance [20, 65, 89, 80].

In the case of factors with positive impact most of them (7 of 8) for those that evidences were found, were assessed with *Very High* impact what highlights the relevance of technology factors in Skype what is also demonstrated by the large number of patents of the company [47]. The *Technology route*, *Probability of technical success*, *Innovative product* and *Incremental product* were factors with a relevant number of evidences. The fact of join together two disruptive paradigms VoIP and P2P represented a challenge and a risk for Skype [89]. Skype was the first company to deliver clear and consistent calls over the Internet, and as a result, Skype is used in almost every country in the world [65] adding continuously value to its customers [89].

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Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	7	1	0	8	0,62
High	0	0	0	0	0,00
Medium	1	1	0	2	0,15
Low	0	0	0	0	0,00
Very Low	0	0	1	1	0,08
Unknown	2	0	0	2	0,15
Not Applicable	0	0	0	0	0,00
Total				13	1,00

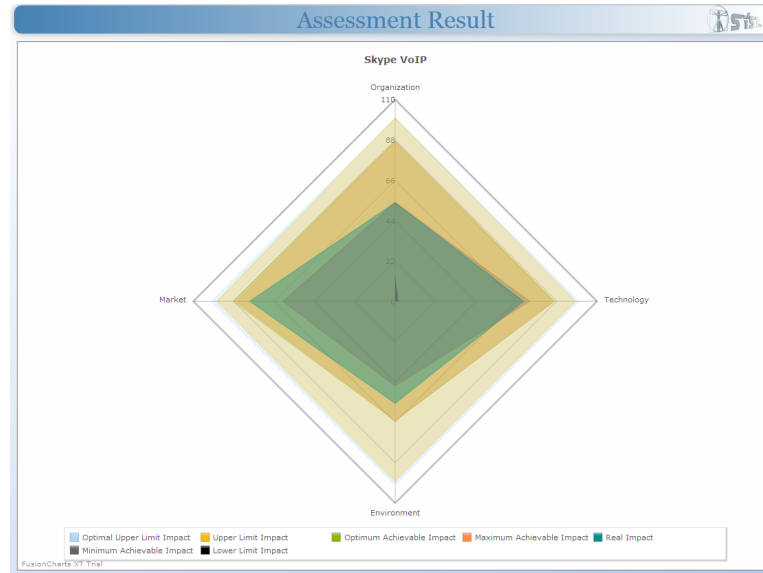
**Table 6.6:** Skype assessment: statistics for Technology dimension

With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.6. The impact of Technology in Skype is 42. Considering the *Unknown* factors the final impact of Skype could change depending on their assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 52, and in the case with the most negative impact, the minimum achievable impact is 44. In this case the minimum value is greater than the actual because in the case of application of the factor their positive impact increase the total value of the impact. The lower limit for the impact is 1. The upper limit for the impact is 59, therefore, as the impact obtained for the environment dimension is 42, it means that the impact is around the 70% of the maximum expected. This value represents that technology factors were very important in the development of Skype. The existence of factors with negative impact did not affect in a significant way to the success of Skype.

### 6.2.6 Assessment results

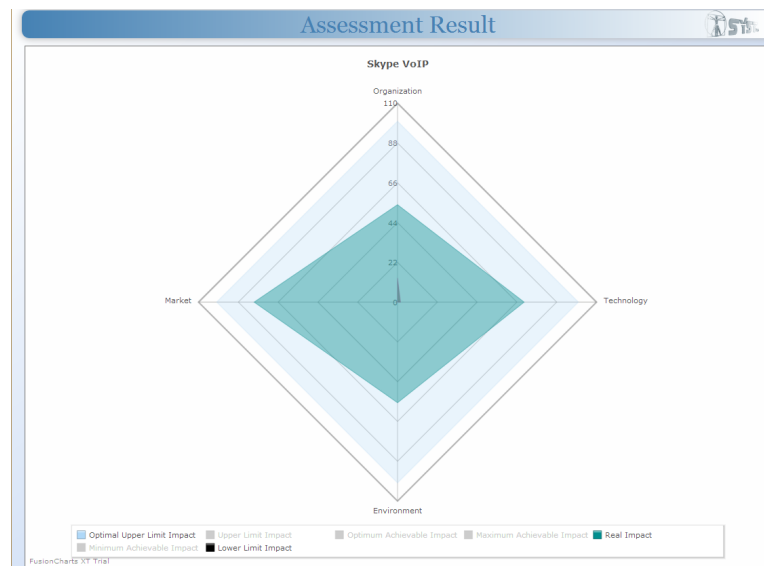
Impacts obtained in previous subsections have been combined to build a radar chart representing each dimension as radar axes. Figure 6.7 depicts a complete view of the impact obtained in the evaluation. The radar chart presents four axes: Environment, Market, Organization and Technology. Each dimension represents seven data series: Optimal upper limit, Upper limit, Optimal achievable, Maximum achievable, Real, Minimum achievable and Lower limit. A shape for each data series is coloured.

## 6.2 Skype assessment



**Figure 6.7:** Skype complete assessment results.

This chart compares the relevance of each dimension in relationship with other dimensions. Since each axis has a different number of factors and by extension different upper limits, to be able to compare the impact of each dimension, values have been normalized to a percentage scale. Therefore, the maximum value of each axis is 100%.



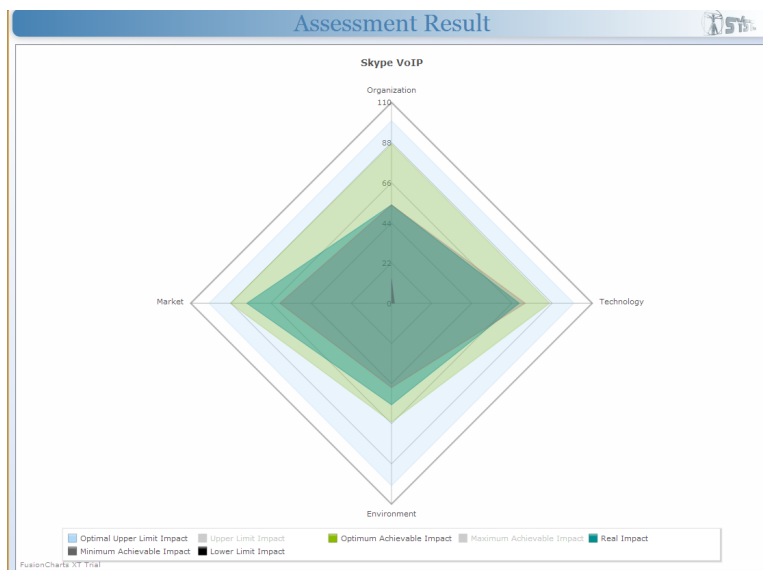
**Figure 6.8:** Skype assessment results. Real impact.

Figure 6.8 shows the real impact in relationship with the upper and lower impact

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of all the factors. Results highlight that Market (80%) and Technology(70%) were the most relevant dimensions characterizing the innovation of Skype. Organization (54%) and Environment (56%) were also important but impacted less than the others.



**Figure 6.9:** Skype assessment results. Maximum achievable results.

Figure 6.9 presents results considering the maximum and minimum impact in the case of having evidences for the unknown factors. This chart highlights that the impact of the *Organization* dimension could become as relevant as *Market* and *Technology*, therefore the way as Skype was organized could be very important in the success of Skype. In the case of the less favourable scenario Fig. 6.10 depicts that the situation remains in the behaviour of all dimensions.

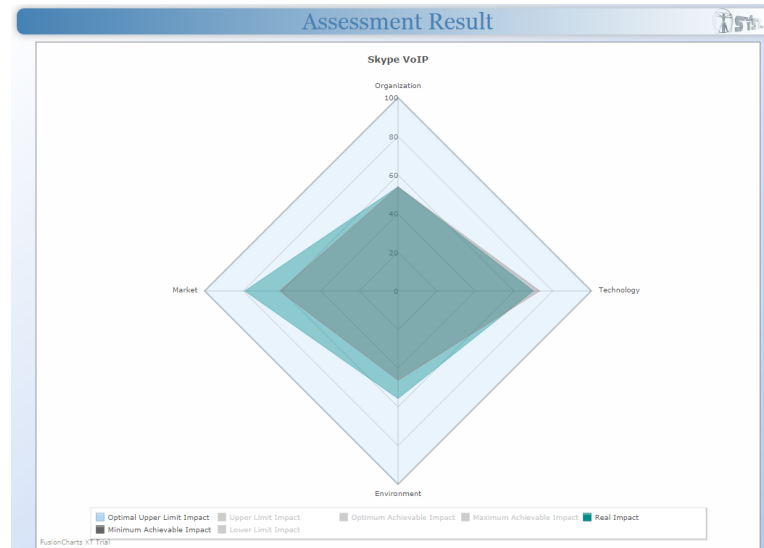


Figure 6.10: Skype assessment results. Minimum achievable results.

## 6.3 Google Wave assessment

Google Wave is a real-time communication and collaboration platform developed by Google. Google Wave incorporates several types of web technologies, including email, instant messaging (IM), wiki, online documents, and gadgets [1]. Google Wave itself represented a new approach aimed at improving communication and collaboration through the use of a combination of established and emerging web technologies.

Google Wave was boosted in 2009. This project was managed by Lars and Jens Rasmussen that were the managers of a previous success project “Google Maps” [38]. It was an innovative platform to collaborative software development integrating instant messaging, wikis and social networks.

Google Wave was considered one of the biggest failures, in 2010 it was discontinued and was definitively retired after three years in 2012.

### 6.3.1 Data collection methodology

A literature review was conducted to collect information about Google Wave. As it was retired in 2012 some two main type of documents were found: documents describing Google Wave features and how to work with it and documents analysing the arguments of its failure from different perspectives.

Following the guidelines published by Kitchenham [53], the literature review comprised

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three main phases: planning the review, conducting the review and reporting the review. The review protocol mainly involves defining the objective, the formal search strategy to identify the entire population of material to be considered, in the case of few search results in some factors, a hand search will be performed; and, finally, the data extraction and synthesis strategies.

For the SLR of Google Wave, the review objective was to identify those factors characterizing the innovation of Google Wave. To that end, we conducted a search in the set of electronic databases and consultants shown in Table 6.7 and defined the inclusion criteria (IC) and exclusion criteria (EC) to determine whether every potential material should be considered for the SLR. Finally, the extraction process involved identifying the date required to fulfil the review objective. Toward this end, we used Atlas.ti® that facilitates the collection of studies to be reviewed, as well as the qualitative data analysis of these studies by providing capabilities for storing and categorizing key concepts. Documents were processed making quotations to paragraphs and assigning codes related to innovation factors. The synthesis process involved product innovation factors of Google Wave from the innovation perspective. As Table 6.7 shows, in the search for material on Google Wave, we retrieved over 291 results, from which we selected 25 relevant references (books, research and white papers) to the review objective according to the inclusion and exclusion criteria. After analyzing and processing these studies,

Data source	Retrieved	Excluded	Included
ACM Digital library	196	196	0
IEEE Xplore	2	1	1
Springer Link	39	35	4
ScienceDirect	25	22	3
Gartner	4	0	4
Google books	10	7	3
Safari Books ProQuest	5	2	3
Hand searches	20	13	7
Total	301	276	25

**Table 6.7:** Data sourcesSLR

we obtained evidence of factors using Atlas.ti®. The number of evidences for each factor is represented in tables Annex III.1, 1, 2, 3 and 4 in the column labelled *Google Wave Evidence*. Each evidence represents a part of the document that is referring the innovation factor.



### 6.3 Google Wave assessment

Next subsections present results obtained from the evaluation of Google Wave on each dimension: Environment, Market, Organization and Technology.

#### 6.3.2 Environment dimension assessment

The environment dimension has been assessed through the list factors listed in Annex III.1, Table 1. The total number of evidences obtained from the document to support the assessment of this dimension was 7. Table 6.8 shows a summary of the results gathered in the Google Wave assessment. Not all the factors were applicable to Google

Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	1	0	0	1	0,14
High	0	0	0	0	0,00
Medium	0	0	0	0	0,00
Low	0	0	0	0	0,00
Very Low	1	1	0	2	0,29
Unknown	0	1	1	2	0,29
Not Applicable	0	2	0	2	0,29
Total				7	1,00

**Table 6.8:** Google Wave assessment: statistics for Environment dimension

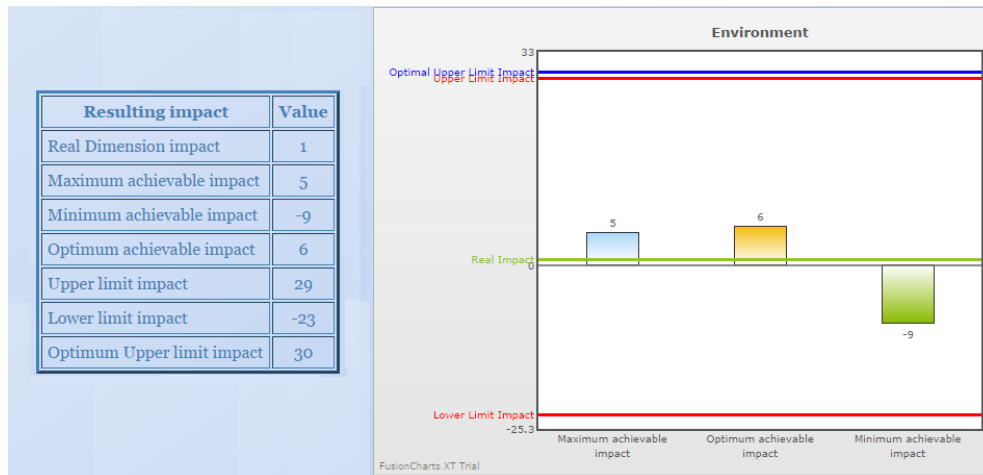
Wave; *Political/Social factors* and *Government regulation* were rated as *Not applicable*. Google wave did not depend of political factors, its target was software development teams. In addition, no specific regulations have been published to this type of software. Another two factors were rated as *Unknown* because it was not able to get evidences to provide an assessment value for them. So, *Public Interest on product* and *Product liability*. Even when Google Wave was considered as a useful software product, there are no evidences about the interest of public sectors on using it. It happens the same, there are no evidence about injuries for companies that adopted Google Wave derived to the fact of using the software.

Other two factors were rated with *Very low*: *Risk distribution* and *Industry restructure opportunity*. Google chose to limit the Google Wave users during its beta-version by means of invitation-only, and lately opened to all users but with the same invitation policy[52]. This distribution was a hype but limited the way on Google Wave could be adopted. The fact of existing many tools available in the market covering partially the same functionality than Google Wave reduced its impact. Google Wave by itself it was

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not better than the combination of the other tools [52].

Finally, only *Available Resources or Raw material* has been rated with *Very High* due to the previous successful experience in other project in the company and the use [18, 38].



**Figure 6.11:** Google Wave environment dimension assessment results.

With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.11. The impact of Environment in Google Wave is 1, but two factors were rated as *Unknown*. *Product liability* impacted negatively and *Public Interest on product* could impact positively or negatively the final impact of Google Wave; therefore the final impact could change depending on the assessment values. In the case of both having the maximum positive impact, the maximum achievable impact is 5, and in the case with the most negative impact, the minimum achievable impact is 9.

Due to the existence of factors that could have negative impact in the innovation, the lower limit for the impact is -23. The upper limit for the impact is 30, therefore, as the impact obtained for the environment dimension is 1, it means that the impact is around the 45% of the maximum expected. This value represents that Environment affected negatively to the innovation of Google Wave.

### 6.3.3 Market dimension assessment

The market dimension has been assessed through the 21 factors listed in Annex III.1, Table 2. The total number of evidences obtained from the documents to support the assessment of this dimension was 59. Table 6.9 shows a summary of the results gathered in the Google Wave assessment. All the factors were applicable to Google Wave but

### 6.3 Google Wave assessment

4 factors, *Early analysis of market and competitors*, *High contribution market*, *Market analysis* and *Sales/Profit potential* were not able to get evidences to provide an assessment value for them.

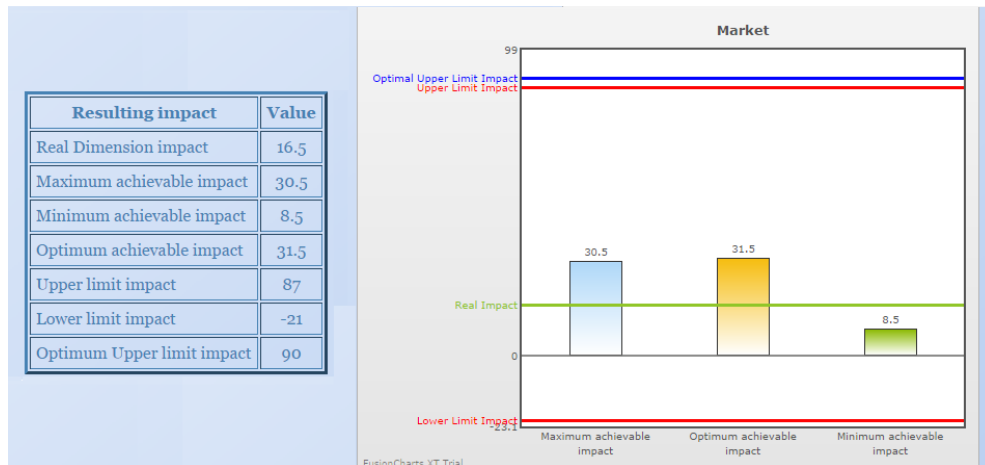


Figure 6.12: Google Wave market dimension assessment results.

A deep analysis of factors pointed out that very few factors were rated as *Very High* or *High* only 15 % of the factors, highlighting that the market was one of the dimensions where Google Wave had problems. For those factors with both types of impact, most of them had negative impact. Only *Market analysis* was rated as unknown, because there is no evidence about if Google performed that analysis or not.

One of the recurrent concerns about Google Wave was that their features were covered by other existing tools and the market was strong enough to limit the success of Google Wave [52, 18, 61]. As consequence, even the expectations created were very high, developers were not satisfied with the product deployed[52].

In the case of factors with negative impact, *Early to market* was assessed as *Medium* impact because it is possible that market in 2009 was not ready enough to have a framework integrating all the features provided by Google Wave [52, 27]. *Slow growth market* was assessed as *Medium* because even the market was quite mature in 2010, there were very few collaborative environments like Google Wave and Google distribution policies limited the impact of Google Wave.

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Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	2	0	0	2	0,10
High	1	0	0	1	0,05
Medium	3	1	2	6	0,28
Low	1	1	0	2	0,10
Very Low	5	1	0	6	0,28
Unknown	2	1	1	4	0,19
Not Applicable	0	0	0	0	0,00
Total				21	1,00

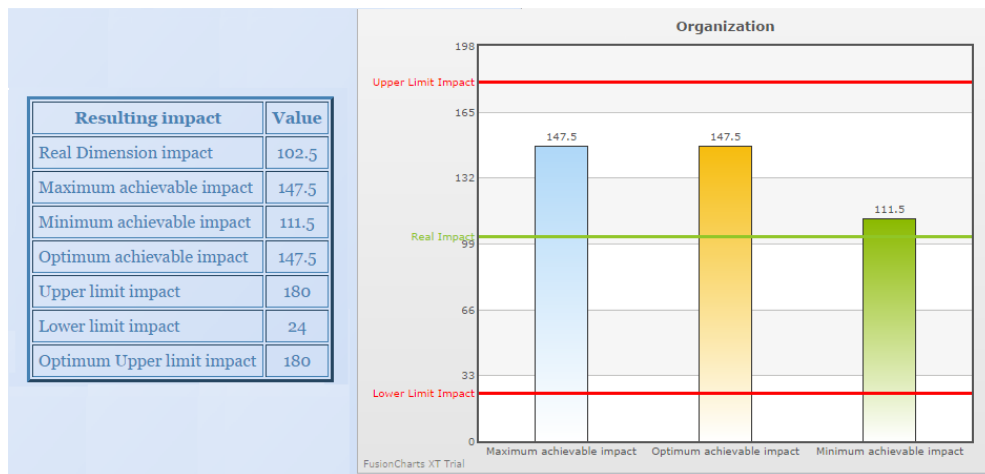
**Table 6.9:** Google Wave assessment: statistics for Market dimension

With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.12. The impact of Market in Google Wave is 16.5. Considering the *Unknown* factors the final impact of Skype could change depending on their assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 30.5, and in the case with the most negative impact, the minimum achievable impact is 8.5. Considering that one of the unknown factor has negative impact, the optimal impact achievable value could be 87 in the case of being assessed as *Not applicable* to Google Wave.

Due to the existence of factors that could have negative impact in the innovation, the lower limit for the impact is -21. The upper limit for the impact is 90, therefore, as the impact obtained for the environment dimension is 16.5, it means that the impact is less than 15% of the maximum expected. This fact emphasize the market dimension was one of the causes why Google Wave failed.

### 6.3.4 Organization dimension

The organization dimension has been assessed through the 36 factors listed in Table 3. The total number of evidences obtained from the documents to support the assessment of this dimension was 75. Table 6.10 shows a summary of the results gathered in the Google Wave assessment. All the factors were applicable to Google Wave but 9 (25%) factors were not able to get evidence to provide an assessment value for them. It is a high value and it could be derived from two main causes: a wrong search or that companies due to their public/private policies do not publish their sensible information.



**Figure 6.13:** Google Wave organization dimension assessment results.

A deep analysis of factors pointed only 5 factors (15%) were rated as *Very few* or *Few* impact. For those factors with both types of impact, two of them *Understanding market* and *Newness to firm* were rated as *Medium* due to the numeric values assigned to each qualitative data imply that they are not impacting very in the organization dimension; *Use outside communication* were rated as *Few* what represents a negative impact over the organization dimension. The fact of distributing beta-versions of Google Wave did not were useful to detect that the product was not achieving the expectations of developers [52].

In the case of factors with positive impact, all the *Unknown* factors belongs to this type. This is relevant because this fact represents that the innovation impact is, in the worst case the impact of this dimension is the obtained value. Highly relevant factors discussed in the analyzed literature about Google Wave related with the technical background from the organizational perspective but none concerning to internal details of the project plan. So, *Create, Make market interface, Markets and Technique are strength* and *Correct distribution channel* were three of the factors with more evidences. This is due to the great influence of the market dimension over the product [52, 18, 61]. It is also relevant the high number of factor rated as *Very High*: 13 (36%) what highlight the huge relevance of the organization dimension in the building process of Google Wave. With values gathered from the questionnaire, the result of the assessment is depicted in Figure 6.13. The impact of Organization in Skype is 102.5. Considering the *Unknown* factors the final impact of Google Wave could change depending on their assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 147.5, and in the case with the most negative impact, the minimum achievable

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Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	13	0	0	13	0,36
High	3	0	0	3	0,08
Medium	4	2	0	6	0,17
Low	0	1	0	1	0,03
Very Low	4	0	0	4	0,11
Unknown	9	0	0	9	0,25
Not Applicable	0	0	0	0	0,00
Total				36	1,00

**Table 6.10:** Google Wave assessment: statistics for Organization dimension

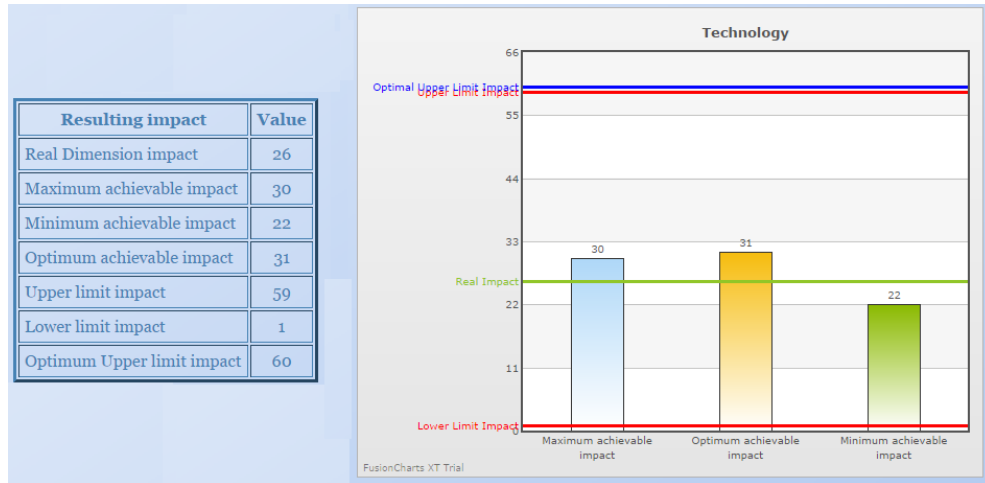
impact is 111.5. Both values are greater than the obtained value due to the fact of all *Unknown* factors present positive impact in this dimension.

The lower limit for the impact is 24. The upper limit for the impact is 180, therefore, as the impact obtained for the environment dimension is 97, it means that the impact is around the 65% of the maximum expected. This value represents that organization factors were very important in the development of Google Wave.

### 6.3.5 Technology dimension assessment

The technology dimension has been assessed through the 13 factors listed in Table 4. The total number of evidences obtained from the documents to support the assessment of this dimension was 27. Table 6.11 shows a summary of the results gathered in the Google Wave assessment. All the factors were applicable to Google Wave but two factors, *High performance/cost proportion* and *Product liability* were not able to get evidences to provide an assessment value for them. Only one factor presented negative impact *Product liability* it was assessed as *Unknown* impact due to there are no evidence about injuries for companies that adopted Google Wave derived to the fact of using the software.

A deep analysis of factors pointed out that concerning those factors that could have both types of impact, had different assessment while *Utility* presented positive impact in the product because Google Wave was perceived as a useful software product but very complex to use [52, 61]. *Demand Pull vs Technology push* was rated as *Very Few* because Google Wave was influenced more by the existing technologies and tools than by new user needs [101, 38].



**Figure 6.14:** Skype technology dimension assessment results.

In the case of factors with positive impact, they did not presented a uniform distribution, three of them were assessed with *Very High* or *High* values, other three with *Few* or *Very Few* and most of them, 5 with *Medium* value. This fact, pointed out that technology was not the main driver of this product. The number of distinct evidences is not very large, the same arguments have highlighted several times by different authors citing the same sources. Google Wave architecture and the Federation Protocol were the main contributions Google Wave. [38, 101, 18] With values gathered from the

Value	Positive impact	Both impacts	Negative impact	Total	Rate
Very High	1	0	0	1	0,09
High	1	1	0	2	0,15
Medium	5	0	0	5	0,38
Low	1	0	0	1	0,08
Very Low	1	1	0	2	0,15
Unknown	1	0	1	2	0,15
Not Applicable	0	0	0	0	0,00
Total				13	1,00

**Table 6.11:** Google Wave assessment: statistics for Technology dimension

questionnaire, the result of the assessment is depicted in Figure 6.14. The impact of Technology in Skype is 26. Considering the *Unknown* factors the final impact of Google

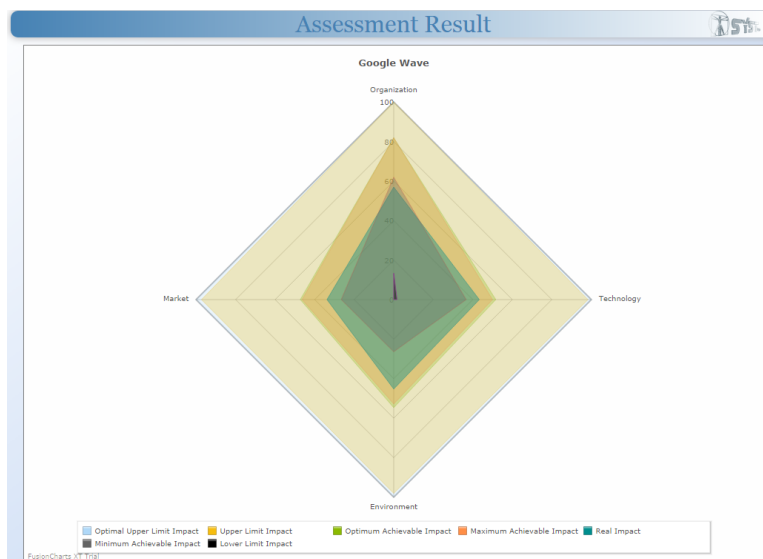
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Wave could change depending on their assessment values. In the case of having the maximum positive impact, the maximum achievable impact is 30, and in the case with the most negative impact, the minimum achievable impact is 22. Due to the collected values, variations will not be very large.

The lower limit for the impact is 1. The upper limit for the impact is 59, therefore, as the impact obtained for the environment dimension is 42, it means that the impact is around the 45% of the maximum expected. This value represents that technology factors were not very important in the development of Google Wave.

### 6.3.6 Assessment results

Impacts obtained in previous subsections have been combined to build a radar chart representing each dimension as radar axes. Figure 6.15 depicts a complete view of the impact obtained in the evaluation. The radar chart presents four axes: Environment, Market, Organization and Technology. Each dimension represents seven data series: Optimal upper limit, Upper limit, Optimum achievable, Maximum achievable, Real, Minimum achievable and Lower limit. A shape for each data series is coloured. This



**Figure 6.15:** Google Wave complete assessment results.

chart compares the relevance of each dimension in relationship with other dimensions. Since each axis has a different number of factors and by extension different upper limits, to be able to compare the impact of each dimension, values have been normalized to a percentage scale. Therefore, the maximum value of each axis is 100%. Figure 6.16



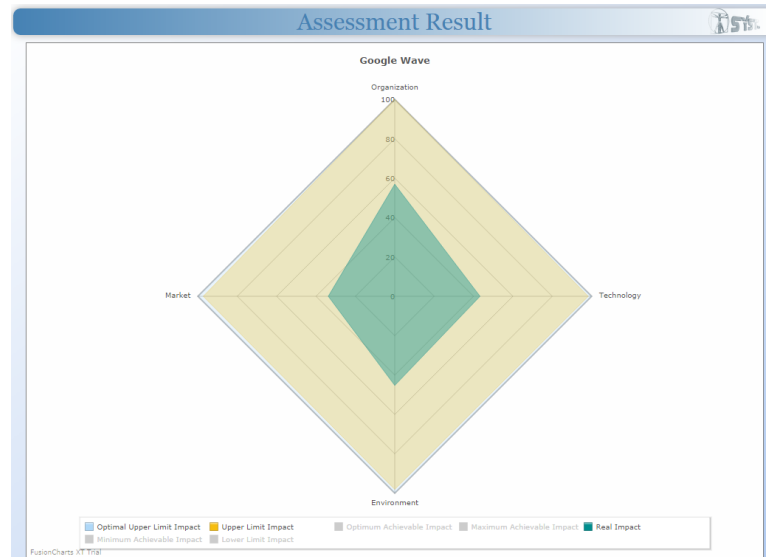


Figure 6.16: Google Wave assessment results. Real impact.

shows the real impact in relationship with the upper and lower impact of all the factors. Results highlight that that only the Organization dimension have a relevant impact, and from the innovation point of view, neither Market nor Technology nor Environment have a great innovation impact. Considering the most favourable scenario for those *Unknown* factors the situation is improving, but the situation is still unbalanced having organization as the unique dimension that is driving the innovation. This situation is the same in the case of considering the less favourable scenario, where Organization maintains its promising behaviour and the rest of dimension get worse. Fig. 6.17 and Fig. 6.18 depict this behaviour.

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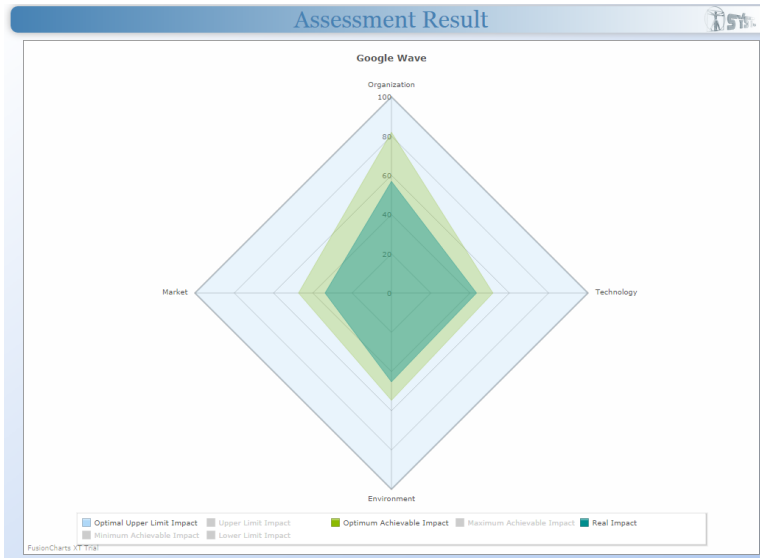


Figure 6.17: Google Wave assessment results. Maximum achievable results.

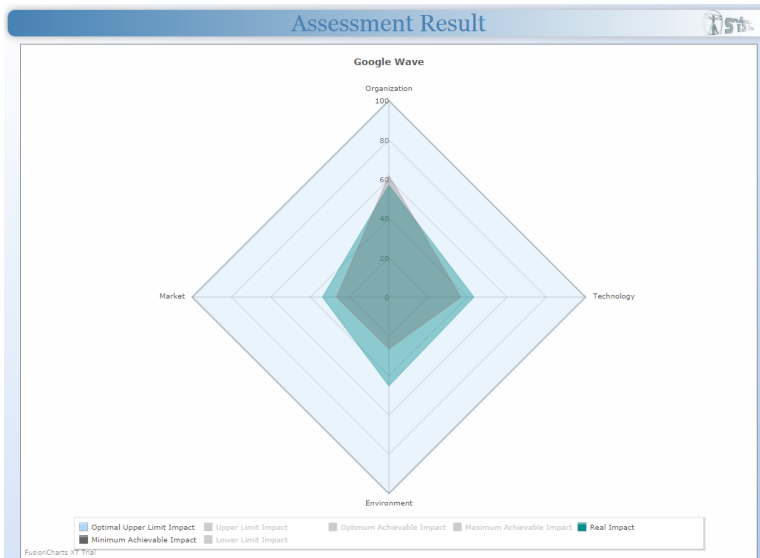


Figure 6.18: Google Wave assessment results. Minimum achievable results.

## Chapter 7

# Conclusions

This chapter presents and analyses the main contributions of this thesis. Conclusions are framed respecting to the objectives proposed at the beginning of the research and formulated as research questions.

It also presents future research to extend results that have already been obtained.

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### 7.1 Conclusions

This thesis was focused on the identification of the elements to permit the assessment of Software intensive System from the innovation point of view. As result of this research the following conclusions have been obtained.

This thesis represents a first step to assess systematically product innovation of Software intensive Systems through the definition of a framework for software product innovation assessment. This framework comprises: a reference model and an assessment tool that, based on instances of the reference model, enables the assessment and positioning the innovation of a product.

This reference model that has been proposed is based on a combination of innovation factors and dimensions to produce product innovation models. The reference model also includes components to support the building of assessment questionnaires and data collection to perform the assessment of innovation. The reference model is valid by construction as it was justified in Chapter 4. The reference model has been rigorously built from the existing knowledge in other application domains and following the guidelines of Design Science combined with Thematic Synthesis and Conceptual Modelling. The reference model was built to be complete, correct, minimal and understandable. It is complete and correct because it contains all concepts present in any component schema correctly. It is minimal because for each concept referred in the literature that is represented in more than one schema, it has been included only once in the reference model. Finally, the reference model has been represented using UML diagrams to increase its understandability.

The reference model has been modelled to assess innovation of Software intensive Systems due to it was reported in Chapter 2.1 that there were no assessment models specifically defined to software. The reference model has been built based on concepts and dimensions documented in the existing literature related to different application domains. In consequence, the proposed reference model is valid for SiS but it is also applicable to other application domains.

A compilation of definitions of innovation factors and their corresponding interpretation to software has been also performed. Based on these factors and dimensions, the reference model has been instantiated to perform the assessment of SiS. The instance was based in the innovation model proposed by Balachandra et al. [9] and a questionnaire has been built to collect data of the assessment of software products. Two software products have been assessed: Skype and Google Wave. Skype has been selected as an example of successful product from the innovation perspective. Skype was selected

to check if it is possible to represent the innovation impact in the case of successful products. Google Wave has been also selected but as an example of a failed product. In both cases, the assessment based on the reference model provided values to understand which were the factors and dimensions that impacted more positively and negatively in their success or failure.

An assessment tool has been built to automate the assessment process. This tool provides two levels of assessment: dimension and positioning. Assessment at level of dimension let researchers to know the impact of innovation factors in a dimension when they are applied to a specific product. Positioning provides a general overview of the impact of innovation for a product. Positioning let researchers to know which dimension or dimensions have impacted more deeply in a product. Due to the nature of software and the multiple perspectives that could be considering while assessing software products, the assessment tool has been built to be adaptive and customizable.

- Adaptive means that new factors impacting SiS and new questionnaires to collect data could be added without changes in the framework. This need is imposed because software market is changing very fast and innovation in software product is a live body of knowledge that must be adapted.
- Customizable means that researchers are able to customize both the list of factors and dimension to assess product innovation and the mechanisms to data gathering depending on the specific goals of research.

Software Product Innovation is affected by external circumstances that hamper the impact to be an accuracy measure. So that to enclose the impact of product innovation when some innovation factors are still unknown, three additional measures were defined *Maximum impact value*, *Minimum impact value* and *Optimal impact value*. In addition, the assessment tool also enables researchers to study the behaviour of the innovation impact in a product overtime due to the ability to store the history of the assessment performed to a product.

Finally, all the research questions have been addressed and could be resumed as follows. Software product innovation assessment has been characterized and formalized as a reference model. The reference model could be instantiated to perform the assessment of software products to cover two different approaches:

- Predictive, when the assessment is performed in first stages of the product development to know how innovation factors are impacting in the product.
- Analytic, when the assessment is performed when the development has been finished as it is applied to provide a better understanding of the influence of each

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innovation factor and to capture the knowledge behind the success or failure of the developed product.

Software product innovation assessment could also be applied at any organizational level, the reference model could be instantiated with different innovation factors to measure innovation at project level, at department level or at firm level.

The last, but not the least, the fact of having a reference model enables researchers to define and share product innovation assessment models with a common structure, so that results could be analysed and compared with a greater level of confidence on results than if they are analysing innovation assessment models with different structures.

### 7.2 Research contributions

This section presents the main results of this thesis, as well as the description of key publications resulting from this research.

#### 7.2.1 Results

These are the main results of this thesis:

1. A Systematic Literature Review of the product innovation assessment. The first step of this research was to conduct a systematic literature review (SLR) to analyse software product innovation. This paper presented the results of an analysis of the existing literature on software product evaluation models. The analysis addressed the main existing evaluation schemas and their elements in terms of dimensions, factors, strengths, and challenges.
2. A reference model of product innovation assessment. This reference model represents the information around product innovation assessment that is needed to define software product innovation assessment models providing a unified notation to represent them. It also provides a mechanism to automate questionnaires construction based on the product innovation assessment models. Questionnaires are used to perform the assessment of concrete products. To adapt the assessment to specific products or markets, questionnaire customization is possible based on the existing models. The reference model has been built based on currently available literature on product innovation assessment, built using a research methodology described within this paper, and taking special care of the quality of the model, so that it can be a trustworthy model. An XML-Schema has been defined to

represent instances of the reference model that will be used as inputs by the tool to assess and positioning product innovation. The XML-Schema validates instances of the XML files to provide consistence between the reference model and the product innovation assessment tool.

3. A tool for assessing and positioning product innovation. This tool uses software product innovation assessment models instantiated from the reference model and provides questionnaires to perform the assessment and, based on data gathered from the questionnaire, to position product innovation. The product innovation assessment tool provides a solution to the problem reported by Lester [58] when the required information is not always available. This fact has been addressed by the definition of three additional measures: *Maximum impact value*, *Minimum impact value* and *Optimal impact value*. These measures provide a clear range of values where the impact is enclosed.

### 7.2.2 Description of key publications

Results of this thesis have been published in international conferences and workshops authored or co-authored by the author of this thesis. Results that have not been published yet will also be submitted to international journals and conferences during this year. The list of publication is as follows:

(P1) Agustín Yagüe, Juan Garbajosa, Jennifer Pérez, Jessica Díaz: *Analyzing Software Product Innovation Assessment by Using a Systematic Literature Review. HICSS 2014: 5049-5058 (Nominated to Best Paper Award)*

This paper reported a systematic literature review of the specific topic of this thesis: the assessment of product innovation. Results of this publication identified that product innovation was impacted by factors organized into dimensions. It was also reported that two main assessment schemas were identified in the literature. This publication stated the basis for the next research activities focused on the definition of the model to characterize the assessment of product innovation and the implementation of a tool to assess and positioning product innovation based on the model.

(P2) Lilibeth Rodríguez, Jessica Díaz, Juan Garbajosa, Jennifer Pérez, Agustín Yagüe: *A Framework for Positioning and Assessing Innovation Capability from an Organizational Perspective. HICSS 2014: 3564-3573*

This paper stated the bases of framework for positioning and assessing product inno-

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vation from the organization perspective. The contribution of this paper to the thesis was the overall structure of the framework comprising: a model and a tool to assess and positioning innovation. Publication **P2** was focused only in one of the dimensions that impacts on product innovation and it covered both the innovation process and the product. In parallel, a deep analysis of the literature was conducted and reported in **P1**

*(P5) Carlos Fernández, Daniel López, Agustín Yagüe, Juan Garbajosa. Towards estimating the value of an idea. Profes '11: Proceedings of the 12th International Conference on Product Focused Software Development and Process Improvement*

This paper outlined a framework for innovation that will facilitate organizations to identify new ideas and to estimate their potential value. Two main results were achieved: the identification of sources of innovation and a short list of elements that could be needed to estimate the value of ideas.

*(P3) Jessica Díaz, Jennifer Pérez, Juan Garbajosa, Agustín Yagüe: Change-Impact Driven Agile Architecting. HICSS 2013: 4780-4789(Nominated to Best Paper Award)*  
This paper studied Change impact analysis technique applied to Agile Architecting. Publication **P3** was nominated to the Best Paper Award of the conference. Change Impact Analysis is a powerful tool that helps to determine the effects over a product resulting from changes on their characteristics. Even though it was a promising result, it was not in the main focus of this thesis about the assessment of product innovation and it was considered as future work to be done.

*(P4) César Gutiérrez, Juan Garbajosa, Jessica Díaz, Agustín Yagüe: Providing a Consensus Definition for the Term "Smart Product". ECBS 2013: 203-211*

This paper contributed to this research through the meta-model of the definition of "Smart Thing". Smart Things are defined in a context and can be represented as a set of characteristics. Characteristics that in the case of Smart Products could be instantiated among others as: self-organized, adaptiveness, autonomy, personalization or context-aware.

### 7.3 Further research

The proposed framework elements identified in this thesis will open additional researches to extend the work that has been performed.

The reference model characterizes product innovation assessment through factors and



dimensions. Additional work could be done to extend the reference model to manage variables associated to each innovation factor. In the reference model proposed in this research, Factors are seen as whole, but factors could also be considered as complex structures composed by variables. Therefore, additional exploratory research work is still needed to identify and the specific variables affecting each innovation factor.

Concerning to the PIA-Tool presented in this thesis, two main research lines are opened. The first is to research about the impact of innovation factors on different products and the study the impact of different weights related to innovation factors. The second one is related to extend the implemented tool to add new functionality such as:

- To add trending charts to show the evolution of a product positioning overtime.
- To add trending charts to show the evolution of factors between products and families overtime.
- To add product families to characterize product.
- To add automatic identification of accuracy limits for each dimension to optimize the size of questionnaires.
- To combine questionnaire results for assessed products to build composed views of product innovation assessment.

Additionally, it could be also interesting the integration of Change impact analysis over those innovation factors that are still unknown to improve the innovation impact over products and to assess companies in the adoption of some innovation factors. In the same direction, the application of technical debt principles to select those factors to improve to maximize the return on investment of companies.

PIA-tool could also be applied to instantiate more software products to create a knowledge base and to collect data to perform an statistical analysis of the impact of each factors over software products.

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## Declaration

I herewith declare that I have produced this paper without the prohibited assistance of third parties and without making use of aids other than those specified; notions taken over directly or indirectly from other sources have been identified as such. This paper has not previously been presented in identical or similar form to any other German or foreign examination board. The thesis work was conducted from 2011 to 2014 under the supervision of Dr. Juan Garbajosa at Universidad Politécnica de Madrid.

Madrid, July 10th, 2014

## ANNEXES

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# Annexes

## ANNEXES

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# Annex I. Definitions

This annex presents definitions available in the literature that have been considered relevant in the scope of this thesis.

## Annex I.1 Innovation

Below are described some relevant definitions of innovation available in the literature.

- The word “innovation” refers to creating or improving goods, services, or methods of production.[42]
- Innovation:application of the existing stock of knowledge in new combinations and new ways to meet some human need. [73]
- Schumpeter innovation is reflected in novel outputs: a new good or a new quality of a good; a new method of production; a new market; a new source of supply; or a new organizational structure, which can be summarized as doing things differently. [24]
- The Oxford dictionary defines of innovation as a new method, idea, product, etc.[84]
- innovation is the embodiment, combination, or synthesis of knowledge into a new idea, method, or device. [83]
- Another definition of innovation is a new idea, method, process, or device that creates a higher level of performance for the adopting user.[73]
- Innovation is the adoption of new practices in a community.[28]
- Innovation may not be limited to new ideas or a single view, but different views deal with different angles on innovation[81].

## Annex I.2 Software Intensive Systems

- Software-intensive systems are complex programmable systems exhibiting properties such as adaptive behaviour and dynamically changing structure. [114]
- Software-intensive systems are programmable systems that include: dynamic evolutionary systems, exhibit adaptive and anticipatory behaviour, process not only data but knowledge, are under user control. [114]
- A software intensive system (SIS) is a system where software represents a significant segment in any of the following points : system functionality, system cost, system development risk, development time. [88]
- Systems in which software interacts with other software, systems, devices, sensors and with people are called software-intensive systems.[115]
- A software-intensive system is any system where software contributes essential influences to the design, construction, deployment, and evolution of the system as a whole. IEEE Std 1471-2000. [46]

# Annex II. Research methodologies for building a reference-model

This annex describes the research methodologies combined to build a reference-model to assess product innovation. This annex is structured into four sections, Section 7.3 describes Design science as a research methodology. Section 7.3 presents the application of the guidelines provided by Hevner [43] to build the proposed reference-model. Section 7.3 describes Thematic Synthesis as a research methodology. Finally, Section 7.3 shows how the integration of both methodologies was applied to build the proposed reference-model.

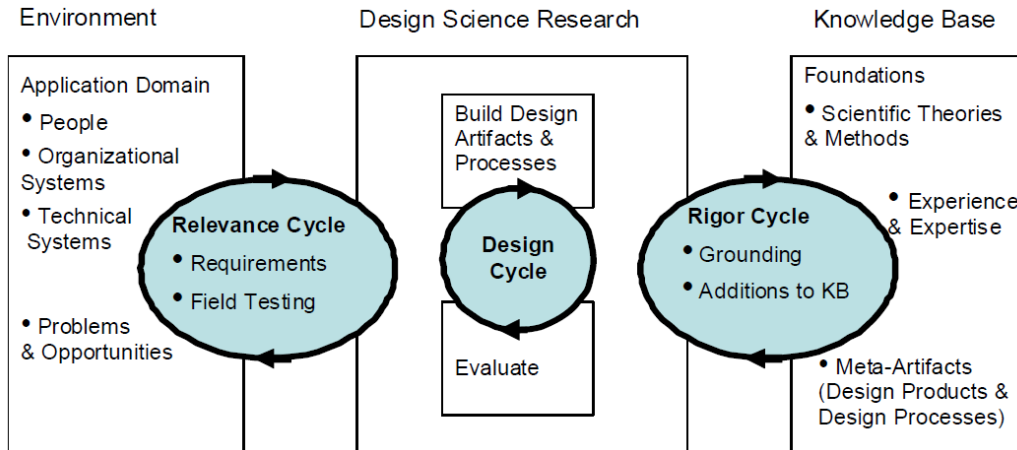


Figure 1: Design Science cycles.

## Annex II.1 Design Science

Design science [43] is an iterative research method based on the problem-solving paradigm to create and validate artefacts designed to solve a problem. Artefacts are built following existing natural laws and behavioural theories restricting the problem mixed with the intuition and other capabilities of researchers. Intuition during the design process represents a weak point of the methodology as long as it is directly dependent on researcher's personal skills without any support from a given method.

Design science is both a process and a product. The process is the sequence of activities to be performed to produce the artefact. The product is the desired artefact that is evaluated against a knowledge base providing feedback to improve the quality of the artefact or to get a better understanding of the product. Design science provides the following features: (i) it is systematic, Hevner [43] and Wieringa [111] justified why it is a method that can be specifically applied to build IT models; (ii) artefacts are constructed through cycles enabling that artefacts being adapted when the environment changes; (iii) as it is proposed by Wieringa [111] artefacts are constructed and validated against requirements and a knowledge base. Design Science defines feedback loops at different levels so that these artefacts are validated.

Summarizing, Design Science is a powerful research methodology providing a complete framework to design IT artefacts. The strength of this method is that the framework covers two research sides: structural components and the process to provide feedback and validate results. The weakness is the high dependence on the researcher's skills. The design science framework is depicted in Figure 1

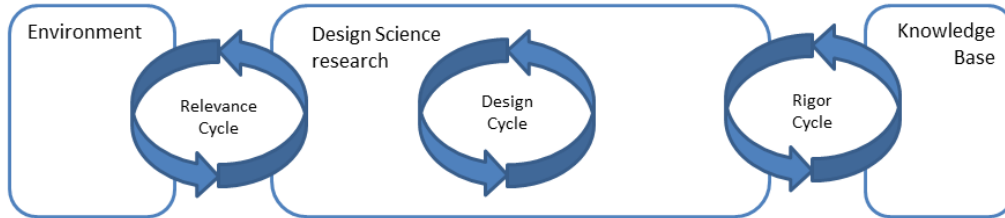
The application of Design science in the construction of IT artefact provides the following benefits: (i) the artefact built is strongly supported by a knowledge base containing the body of knowledge that have been previously validated by the community; (ii) the rigor is achieved by applying existing foundations and methodologies, therefore artefacts are validated while they are constructed; (iii) models are built using conceptual modelling as it is described by Wieringa [112].

Design science is composed by three main blocks: environment, design science research and knowledge base. Environment frames the problem under study. It imposes goal criteria and constraints upon the artefacts to be constructed [43]. It is concerned by different sources: people, organizations and technology. Environment provides the business needs as they are perceived and documented by people in the scope of organizations. Needs are assessed through organizations context (business strategy, culture, structure ...) and the available technology.

Summarizing, environment represents the problem as is perceived by researchers and it is affected by all the mentioned components. The knowledge base provides those concepts from and through Design Science research is accomplished [43] that is the basis for researchers to work on solutions. The knowledge base is composed by artefacts representing foundations and methodologies from prior research activities facilitating the inclusion of the existing knowledge and understanding of a problem domain when building artefacts. Methodologies provide computational and mathematical methods to evaluate the defined artefacts.

Results of design science research are evaluated against the existing environment and business needs. In the case of successful evaluation, results are added to the knowledge base for further research and practice. The core of the methodology is called Design Science Research. It has two main blocks: build design artefacts and processes and Evaluate. Build design artefacts and processes block is focused on the construction of artefacts and application of theories and methodologies. It is different if is applied to design systems or to design research. When designing systems, the existing knowledge to solve organizational problems is applied using those practices available in the knowledge base. In this situation, design-science research addresses unsolved problems or improves existing solutions through the existing knowledge.

Design science applied to design research provides artefacts and methods to increase the knowledge that later is used to solve other known problems. A common problem is that the existing knowledge is not always available or, even, is non-existent [87]. In that situation, efforts on trial-and-error have to be performed to create the new artefacts. The second block, Evaluate requires the definition of the appropriate metrics, data-



**Figure 2:** Design Science cycles.

gathering and analysis processes to evaluate the artefact under construction. Evaluation uses the methods available in the knowledge base like: observations, analytics, experiments, tests or descriptions. Design science research proposes three cycles so that feedback can be provided as is depicted in Figure 2: a) the relevance cycle boosts and drives the design cycle, b) the rigor cycle grounds and increases the knowledge base with results from the research, and c) the design cycle produces appropriate artefacts. The three cycles are presented in the following paragraphs.

**Relevance cycle.** The Design research starts at level of the application domain. It is represented in terms of research requirements describing a market opportunity, a new problem to be solved or any potential issue to be researched, representing the business needs. At the same time are defined the acceptance criteria for evaluation of design artefacts in the application domain. An important issue is that the relevance cycle captures the business needs that they are iteratively included in the research process. After the relevance cycle, the design cycle starts. When design is finished and research results are available, they are passed again to the environment through the relevance cycle to be assessed against the acceptance criteria defined at the business level. The cycle iterates to solve deficiencies detected in the developed artefact or if is needed to change/adapt research requirements. This loop is repeated until the research is considered finished.

**Design cycle.** It is the heart of Design science. It is a rapid iteration of activities to build and evaluate artefacts. This is considered as the hardest work of design science. Building is the activity to create/refine artefacts. This activity works at level of product (the generated artefact) or process (how the artefact is built). At the end of the iteration, artefacts are evaluated against the defined requirements to satisfy the acceptance criteria. They are studied under controlled environments to check that they are in the scope of the current research. Artefacts should be strongly grounded, and validated using the outcomes from previous cycles.

The cycle is repeated until the artefact is considered finished and ready for validation



in the application environment. While each cycle is running, new knowledge could be ready for the inclusion in the knowledge base. There are no specific rules to implement the design cycle and results could be grounded through different research methods. For each generated artefact, rigor should be assessed with respect to its applicability and generalizability in the environment.

**Rigor cycle.** The rigor cycle addresses how the research is conducted [43]. Rigor is derived from effective use of the knowledge base. Hevner [43, 44] stated that rigor cycle provides the past knowledge about a topic based on the state of the art and the existing artefacts. In conclusion, the main goal of this cycle is to design/maintain the knowledge base. This cycle is deeply dependent on the researcher skills. The expected outcomes to the knowledge base are: extension to theories, methods or existing artefacts, new artefacts and processes. The application of the rigor cycle should ensure that contributions generated in the design cycle are not merely interpretations of the existing knowledge.

**Design Science known limitations.** Design science presents also some known limitations identified by Hevner [44]. Design science is still very young compared to other disciplines. In addition, there are a small number of artefacts available in the knowledge base to represent accurately all the business environments. As a direct consequence, most of the advances in design science are based on the intuition of researchers and trial-and-error experiments. Another important challenge is that technology runs faster than research, and some design results are adopted by companies before they appear in the research literature, producing a lack of theoretical validation. In addition, there are no specific rules to implement the design cycle and results could be grounded through different research methods. This cycle is where design science could be combined with other empirical methods (qualitative or quantitative). Last but not the least, as pointed out by Markus [64] artefacts may not be generalized to different environments because they are obtained from a single project in a controlled environment. Therefore, more efforts are required to support the artefact generalization.

## Annex II.2 Guidelines to apply Design Science

This section presents how to build a reference-model applying design science following the guidelines proposed by Hevner [43]. In brief, these guidelines have been written to create innovative artefacts (Guideline 1, G1) in the context of an environment and to solve specific problems (G2). To validate the usefulness of the artefact is also important (G3); but as important as validation is to prove that artefacts built are innovative to

solve the problem (G4). Artefacts should be constructed in a rigorous way (G5) building a problem space and defining mechanisms to find an effective solution (G6). Finally, results should be communicated to audience (G7).

The following subsections describe how each guideline has been applied in the building of the reference-model.

### **Guideline 1: Design as artefact**

The first guideline proposed by Hevner [43] recommended designing solutions in terms of artefacts as mechanisms to solve problems. Hevner described that theories, models, constructs and methods applied in the development of information systems are the appropriate tools to build IT artefacts. The key of applying design science is to identify the artefacts and their types that will be built during the research.

In our research two are the main goals: the first is to build an IT artefact being a reference-model for product innovation assessment models. The second is to build a tool to enable the generation of questionnaires based on instances of the reference-model representing product innovation assessment models. The reference-model will be built based on the existing literature about the assessment of product innovation.

In addition, those instances built by instantiating the reference-model and assessments performed with these instances could also be considered IT artefacts.

Summarizing four main types of artefacts will be produced: the reference-model, instances of the reference-model to represent product innovation assessment models, a tool to generate questionnaires based on instances of the reference-model and, finally, assessments of products.

### **Guideline 2: Problem relevance**

The second guideline is focused on the problem to be solved and how to justify the need of the research. Problem relevance is related to describe the phenomena under study and its environment to enable and drive the development of the artefact. The phenomenon is the problem to solve described in terms of requirements. The problem is framed in an environment that imposes constraints upon a system [43]. The problem relevance could be defined in different ways: describing the actual state and the expected goals, describing processes among others.

In the case of our research, our interest is focused on product innovation assessment applied to Software intensive Systems (SiS) from different perspectives: assessment models, existing approaches, and the assessment process.

Innovation in SiS plays an important role enabling information and communication technologies (ICT) to contribute to be a driver of the global economic growth. In 2010, Organisation for Economic Co-operation and Development (OECD) pointed out that ICT innovation is driving the growth in some sectors, such as the Internet [77]. Other sectors like automotive or healthcare SiS are becoming complex [6] and innovation is opening new market opportunities [87, 7].

Therefore, there is a need in companies to understand the impact of innovation in their products, justifying the existence of models to assess product innovation. So, the environment and business needs in the assessment process determine the type of the assessment model, the dimensions and factors and their relationships that represent the assessment model.

### **Guideline 3: Design evaluation**

The third guideline is targeted in the validation of the artefacts designed. The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods. Evaluation is the most critical component of design science [43] because it analyses how the IT artefact is integrated with the environment. Due the nature of design science based on iterative and incremental processes, the evaluation feedback becomes essential in the design process. Design is complete and effective when it satisfies the requirements and constraints determined by the environment and business needs. Hevner [43] summarized typical evaluation methods like observational, analytical, experimental, testing or descriptive. In the case of our research a descriptive approach based on informed arguments is the most suitable. It consists of the use of information from knowledge base to provide arguments to demonstrate the utility of the artefacts. It was selected by the nature of the IT artefact that is expected to build and the systematic process applied while building.

In addition, artefacts will be experimentally validated. Instances of the reference-model will be built to check the feasibility of the reference-model and software products will be assessed through these instances to get evidences of the impact of innovation factors.

### **Guideline 4: Research contributions**

The fourth guideline provided by Hevner [43] was focused on the expected research contributions at the end of the process. Design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies. At least one of these three types of contributions is expected: the

artefact to solve the proposed problem; foundations to extend the existing knowledge in term of models, methods or instantiations; and methodologies.

In the case of our research, there are no further works either about product innovation assessment applied to software intensive systems or innovation factors to assess product innovation. Therefore, the following contributions are proposed: a reference-model based on dimensions and factors, a tool to build innovation assessment questionnaires based on instances of the reference-model and assessment of different software products. These contributions will help companies to advance our understanding of the impact of some innovation factors in the scope of SiS.

### **Guideline 5: Research rigor**

Rigor is the fifth guideline. Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact. Rigor addresses the way in which research is conducted. Hevner [43] reported that design science needs the application of rigorous methods in the construction and evaluation of the designed artefact.

One of the challenges of design science is how to conduct the design cycle. It has not been clearly defined and depending on how design is performed the rigor could be impacted.

In this stage and to increase the level of rigor in our research we propose to combine design science with thematic synthesis in the building process. In this way, the process to build the artefact is driven by the steps defined by thematic synthesis and the validation of the reference-model is done while the artefact is built. Additional validation is achieved by the instantiation of existing product innovation assessment models to demonstrate that feasibility of the artefact.

The inclusion of thematic synthesis does no impact directly on the design evaluation. Nevertheless, models designed with thematic synthesis must be built to be successful, with the acceptance criteria defined by the business needs. Therefore, the obtained model and the environment will depend on each other; this should be considered in the relevance cycle. The fact of applying thematic synthesis in the design cycle of design science provides an IT artefact build over a well-grounded research methodology.

Artefact validation is an important task. As it was proposed by Wieringa [110], in the building process of the reference-model two types of validity have been considered: Internal and external. Through the internal validation the reference-model it is checked against the defined requirements in the context of software products. External validity is based on the application of the reference-model to different application domains to

understand if the model is instantiated as it was predicted and to understand what would happen with changes in the model.

### **Guideline 6: Design as a search process**

The sixth guideline addresses the building process. Hevner [43] provided recommendations to drive the design activities. He proposed to consider the artefact design as a search process to discover an effective solution but no specific guidelines to drive the research were provided. Abstraction and representation techniques help researchers to build the appropriate artefacts. The integration of design science with other research methodology enrich the design process. This process is driven by the requirements that are defined and constrained by the environment.

In our research we complemented design science with thematic synthesis in the design activities. The fact of using thematic synthesis helps to build the artefact in an iterative and incremental way using conceptual modelling and view integration following the Wieringa recommendations [113]. The artefact design process was driven by the concepts identified in the product innovation assessment domain. Each new identified concept is added to the artefact and then the evolved artefact is evaluated against requirements to check that no constraints have been omitted. In the next section we will describe how the design process has been performed.

### **Guideline 7: Communication of research**

The last guideline proposed by Hevner [43] is related to how results will be disseminated. Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences. The communication research must describe how to use the artefacts build; but also the benefits offered by the artefact.

In the case of our research, two levels of communication will be managed: one to researchers and the other to business. The communication with researchers will cover details about how the reference-model has been developed, implemented and could be instantiated. This level enables other researchers to enrich and extend the reference-model. The second communication level is materialized in the assessment of products by instantiating the reference-model. The expected audience are those companies that are developing SiS and that they want to assess their products from the innovation point of view.

In addition, as one of the artefacts is a web tool to perform the assessment of products from the innovation perspective, the website will reinforce the communication channel.

The website will establish the repeatability of the assessment and will let researchers to build knowledge about the impact of innovation factors on software products.

### Annex II.3 Thematic Synthesis

Thematic Synthesis is research synthesis for identifying, analysing, and reporting patterns from data [25, 99]. As a research synthesis, it integrates findings concerning to a research question extracted from the observation of different sources. Thematic synthesis organizes data over different aspects and these data are enriched with details to facilitate their understanding and the reporting.

Thematic synthesis is built over steps. The first approach presented by Thomas and Harden [99] is based on three steps: coding, theme grouping and analytical themes. Later in 2011, Cruzes and Dyb enriched the approach with guides and recommendations for Software Engineering [25]. The approach proposed, and that was applied in this research, consists of five steps: extract data, code data, translate codes into themes, create a model of high order themes and assess the trustworthiness of the synthesis.

The first activity consists of document selection. It has two well identified actions: the first one is to select of a set papers obtained from search results satisfying the selection criteria. At this first stage is enough to read the title and the abstract. The second part consist of reading the entire papers and proceed with data extraction. Data extraction is a key part of the work. Before starting with data extraction is highly recommended to read the entire part of the publications get immersed with data. During this step, initial ideas and draft versions of patterns could be shaped.

Data extraction is based on the selection of texts to be analysed in an explicit and consistent way. These texts could be available in the knowledge base or if not, they could be added to it to increase the level of knowledge. The relevant information to be collected is: publication details (author, years, title, abstract, aims), context description(subject, technologies, environment) and findings (results, events, quotes).

Next step is Coding. It consists of identifying the relevant concepts across the data set previously selected. Each concept, category, finding or result have an assigned code. These codes could already exist in the knowledge base or could be added as new codes. Codes are descriptive labels that are applied to parts of the text under study[25]. A good code is one that captures the qualitative richness of the phenomenon [13]. Codes could refer either to concepts or links between concepts or context characteristics. Coding is a risky process because it is a critical step in thematic synthesis. Cruzes and Dybå[25] highlighted that the use of general codes, assigning codes out of the context

and identify what one wants to read and not what is written are the most typical problems when coding.

The third step is to translate code into themes. Codes represent the pieces of information valuable for the research, but they cover so many different points of view that they are not manageable. Therefore they should be translated into themes with higher level of abstraction. Codes provides significance and identity to a set of codes by capturing the nature of the experience as a whole[29]. Themes help researchers to elaborate cognitive maps of the phenomenon.

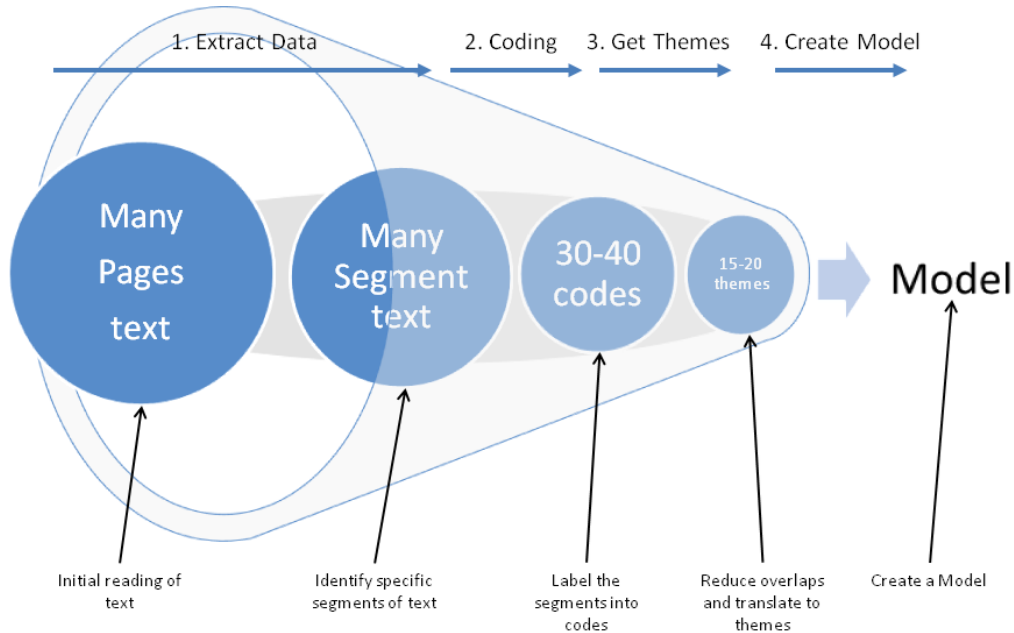
The fourth step is to create a model of higher-order themes. Researchers should explore codes and their relations to create a model of high order themes. The model should be driven by the original research questions and it is grounded in the emerged contents. As it was pointed out by Cruzes and Dybå[25], models can be represented in different ways: description of high order themes, taxonomies, a model or a theory. These outputs from qualitative studies can be helpful in the generation of hypothesis about causal links between analysed data[14]. Cruzes and Dybå[25] proposed to build the model in four steps:

1. Review theme by theme and mappings between codes and themes obtained in the previous step.
2. Identify the links between themes and annotating evidences.
3. Assess the obtained links with prior researches if they are available.
4. Create the appropriate outputs.

Last step, but not the least, is an attempt to assess the trustworthiness of the synthesis results. It depends on the quality and the quantity of the found evidences. The results to be trustworthy should be, at least, credible, conformable, stable over time and transferable. Presenting results in a way that allows readers to find other interpretations is a way to increase the trustworthiness of results because they will contribute to enrich readers knowledge about the research topic. Figure 3 depicts the steps of the methodology.

## **Annex II.4 Extending design science with thematic synthesis**

This section describes how both research methodologies have been integrated to provide a more powerful framework to build the product innovation assessment reference-model.



**Figure 3:** Thematic synthesis overview.

First subsection presents a brief overview of thematic synthesis and the second describes the integration of both research methodologies.

### Integrated research framework

Figure 10 shows the complete research framework extending design science with thematic synthesis to build a reference-model to assess innovation in Software intensive Systems. The artefact building process was driven by the guidelines provided by Hevner [43] to conduct design science research.

The first step is to determine the research environment where to apply design science. In the previous section and also reported in [117] were pointed out that there is need in the market to understand the factors that impacts on innovation when creating successful products but no global assessment models focused on product have been developed. Our goal in this research is fill this gap having an artefact representing a reference-model to support the product innovation assessment of software products. The environment for this research is represented by the existing literature about assessment models applied to product innovation. To determine the environment, a SLR was conducted and reported in [117]. As result of the SLR 13 publications were identified referring to product innovation assessment models, stating the problem relevance and



No.	Factor	Type	[4]	[5]	[10]	[32]	[38]	[39]	[56]
1	Av. of Resources, Raw Materials	E		+	+			+	+

**FACTOR**
**DIMENSION**
**IMPACT**

**Figure 4:** Example of free-line annotation and coding.

covering the guideline 2 proposed by Hevner [43].

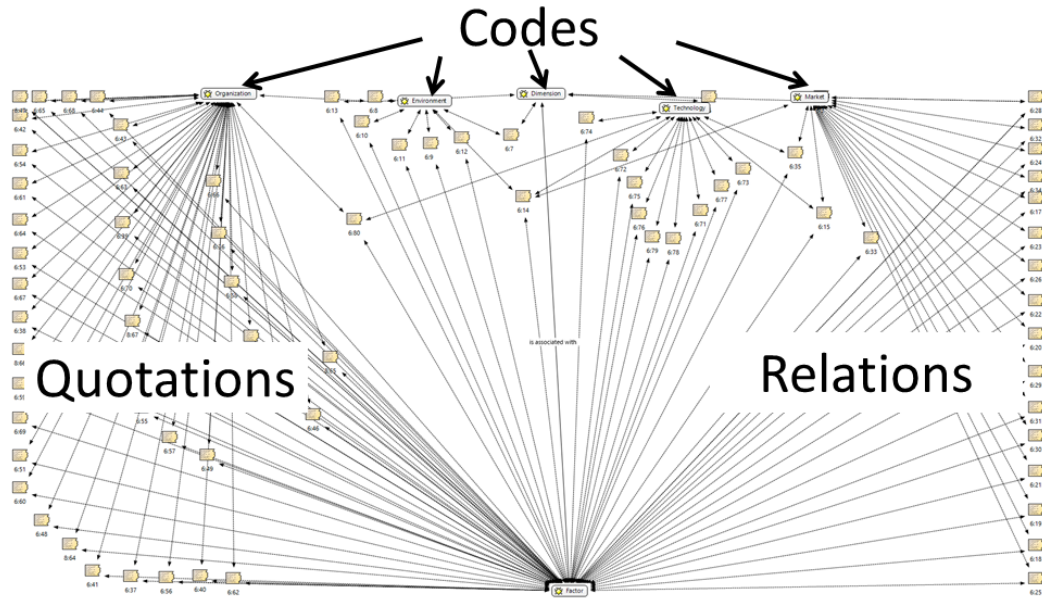
Those documents revealed that product innovation assessment is performed through factors classified into families and giving values to each factor on each dimension. It was also reported that depending on the weights assigned to factors two types of assessment are commonly used: un-weighted and weighted. If all of the factors have the same weight, the model is considered un-weighted, that is, all of them have the same impact. In the case of having different weights the assessment model is considered weighted.

The reference-model must support the instantiation of the existing assessment models to provide its validity what represents acceptance criteria for the developed artefact.

The next step is to start the design cycle. This cycle has been implemented by applying thematic synthesis. As Creswell reported [23] it is the most useful methodology to capture complexity from evidences. Thematic synthesis provides a rigorous constructionist method to provide answers to specific questions [25, 99]. Source data, representing evidences, are analysed through five steps to build high-order models.

The first two steps for data extracting and coding were performed by free-line annotation. The use of tools for qualitative analysis helps to manage a huge number of annotations and codes. In the case of our research, Atlas Ti® were used to handle the annotations (or quotation in Atlas.Ti® terminology) and codes. Each quotation could have assigned one or more codes depending on the number of concepts referred by the text. Figure 4 shows an example of the free-line annotation and coding. The line highlighted was quoted and labelled its elements: the name, dimension and impact of the factor.

The next step was to process codes and translating to themes. I.e., all the codes referring to innovation factors were grouped into a theme code Factor. The same was done with the rest of the concepts annotated in the analysed documents. At the end of the third step, all the documents representing the environment were annotated, coded and categorized. The fourth step was to create a model based on high-order concepts. It is not a simple task. As it is proposed by Dybå and Cruzes the use of visual representation and the building of thematic maps are highly recommended. These thematic maps were



**Figure 5:** Example of network of concepts built by Atlas.Ti.

built with the Atlas.Ti® facilities to build network of concepts to show relationships between themes. This process is performed to each document of the environment. Figure 5 depicts a view of the network obtained when processing the Balachandra et al. journal paper [9] representing product innovation.

The network is composed by three main elements: quotations obtained from the free-line annotation, codes and relationships between concepts. Increasing the level of abstraction from Figure 5 removing quotations, a more conceptual view is obtained and depicted in Figure 6.

Managing the networks for each document and integrating the obtained views, a high-order model was synthesized. For each concept existing on available views, it was analysed and integrated in the reference model to achieve: completeness, correctness and minimality. Therefore, each view was integrated into a global schema that will become the reference-model for product innovation assessment. This synthesis was accomplished by the integration of conceptual modelling with design science as it was explained by Wieringa in [113]. The reference-model obtained is depicted in Figure 7. The last step about trustworthiness of the synthesis it was achieved by the construction process. The obtained reference model is complete in the scope of the defined environment due to all the documents obtained in the SLR were processed and analysed. The reference-model is also correct in the scope of the environment because it satisfies the acceptance criteria defined with the environment. The product innovation assessment

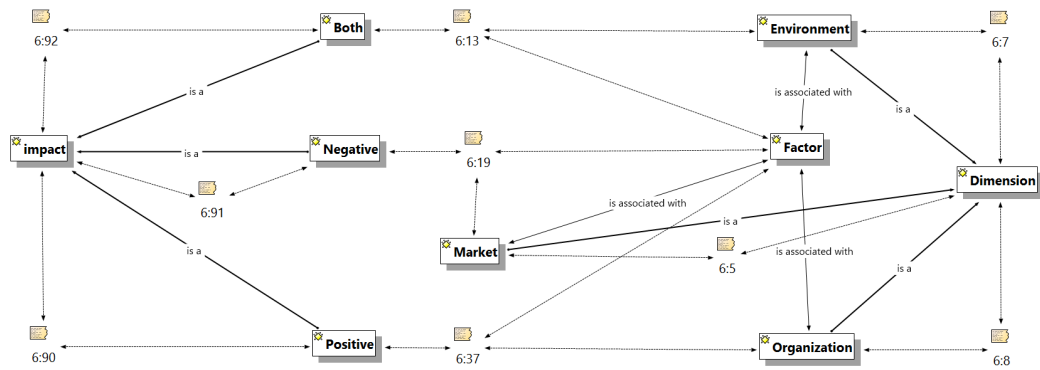


Figure 6: Abstraction obtained from a network of concepts.

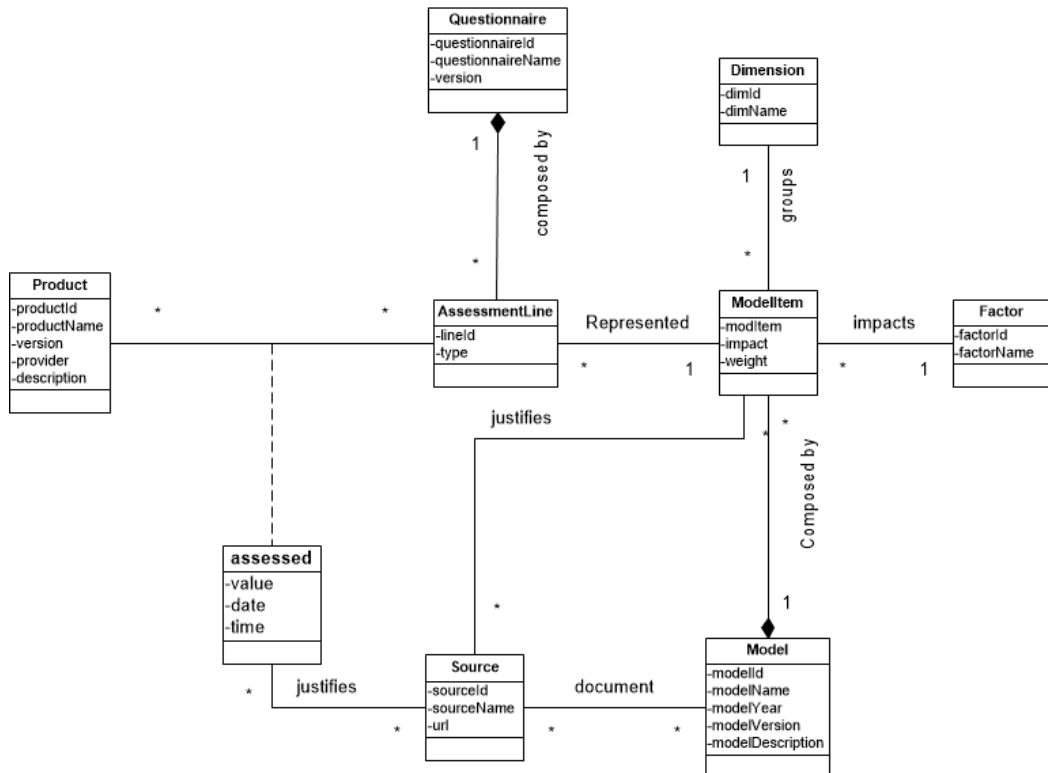


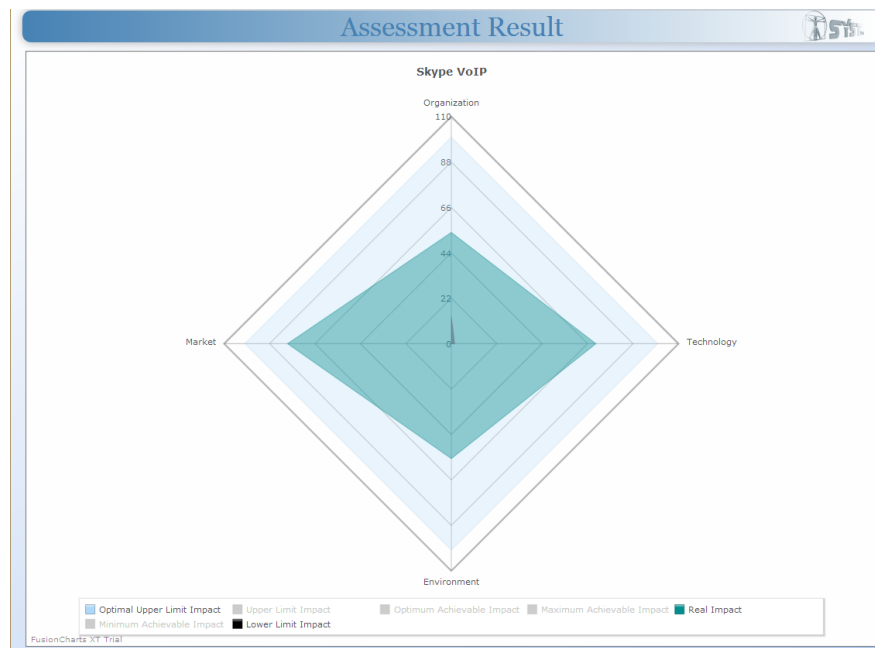
Figure 7: Reference-model for product innovation assessment.

The screenshot shows a web-based assessment questionnaire. At the top, there are tabs for 'Organization', 'Market', 'Environment', and 'Technology', with 'Environment' selected. Below this, there are three main sections: 'Available Resources or Raw material', 'Government Regulations', 'Industry restructure opportunity', and 'Political/Social factors'. Each section has a radio button for 'Unknown', 'Not Applicable', 'Very few', 'Few', 'Medium', 'High', and 'Very High'. There are also 'Add Files' buttons for each section. In the center, there is a 'Sources' section with 'Add url' and 'Add file' buttons, and an 'Add more' button. The 'Add file' button is currently disabled, showing 'Ningún archivo seleccionado'.

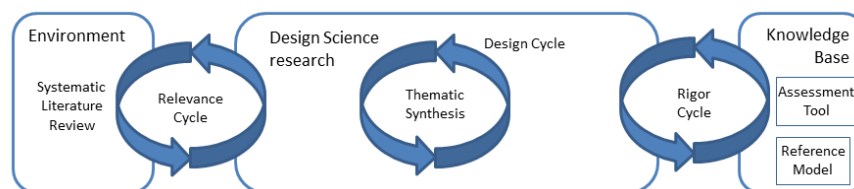
**Figure 8:** Assessment questionnaire built for the Balachandra et al. model [9].

models provided by the environment could be instantiated from the reference-model. And finally it is the minimal model that represents product innovation assessment models since each identified concept in the environment has been added once and only once in the model. Figure 8 shows the assessment questionnaire built by instantiating the reference-model for the model described by Balachandra et al. [9]; and Figure 9 shows the result of the assessment of Skype.

Finally artefacts produced in design science are included in the knowledge base. In the case of our research, two artefacts were added to the knowledge base: the reference-model for product innovation assessment and a tool to build questionnaires based on instances of the reference-model. Figure 10 shows the complete framework extending design science with thematic synthesis to identify the product innovation reference-model in Software intensive Systems. The environment is represented by the existing literature available in the market. Each document of the environment is analysed to identify the factors and dimensions applying thematic synthesis in the design cycle. Finally when artefacts are validated against the environment they are included in the knowledge base.



**Figure 9:** Result of the product innovation assessment of Skype.



**Figure 10:** Proposed framework integrating Design science and thematic synthesis.

## ANNEXES

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## Annex III. Description of factors

This annex describes the innovation factors that have been applied in the evaluation of software products described in Chapter 6. This annex is structured into two sections, Section 7.3 presents the list of factors for each dimension considered in the assessment of software products. The list of factors was proposed by Balachandra et al. [9] and they represent factors that are identified in the literature as factors that impact in product innovation. Factors are organized into four dimensions: *Environment*, *Market*, *Organization* and *Technology*.

The description of each factor is available in the literature, but these definitions are not specific to software products. Section 7.3 presents each factor as it is described in the literature and in the case of different meanings applied to software, an interpretation is provided. So, each factor is represented by its general definition, impact, interpretation in the case of SiS and, finally, guidelines to rate the impact of the factor.

### Annex III.1 List of factors

This annex presents a table with the list of factors impacting on each dimension. These tables are structured as follows: column *Factor* represents the name of the factor, column *Effect* represents the type of impact of each factor. It could be positive (represented by +), negative (represented by -) or both (represented by \*). Column *Freq.* (Frequency) represents how many times a factor has been considered relevant by the literature analysed by Balachandra et al [9]. Column *Rate* represents the ratio between its frequency and the total number of factors citation of the table, this value provides additional information about the relevance of the factor. Column *Aggreg. Rate* (Aggregate Rate) obtain the accumulated sum of rates. Column *Skype* contains values obtained in the evaluation of Skype. Finally, column *Evidences* represents the number of evidences of each factor identified in the literature to support the results for Skype. All the tables are sorted by column *Frequency*. The last row on each table represents the total number of factors citations and evidences; they are obtained as the sum of columns *Rate* and *Evidences*.

The analysis of the evolution of the aggregate rate, reveals an asymptotic behaviour of this value. Fig 11 shows this behaviour in the case of the factors proposed by Balachandra et al. [9]. This behaviour permits that when the number of factors is large, such as for organization or market dimensions, to define an accuracy limit, to determine the number of factors that could be used in the evaluation to achieve a determined level of confidence [8]. This method ensures that those factors with the highest frequency have been considered in the evaluation. Therefore, not all the factors are used in the assessment process. There is a bold line on each table to represent that accuracy limit around 70%. It was reported by [117] that the average to achieve this accuracy rate is 50% of the factors. This means that with only 50% of the factors with the highest frequencies is achieved an accuracy limit of 70% for each dimension.



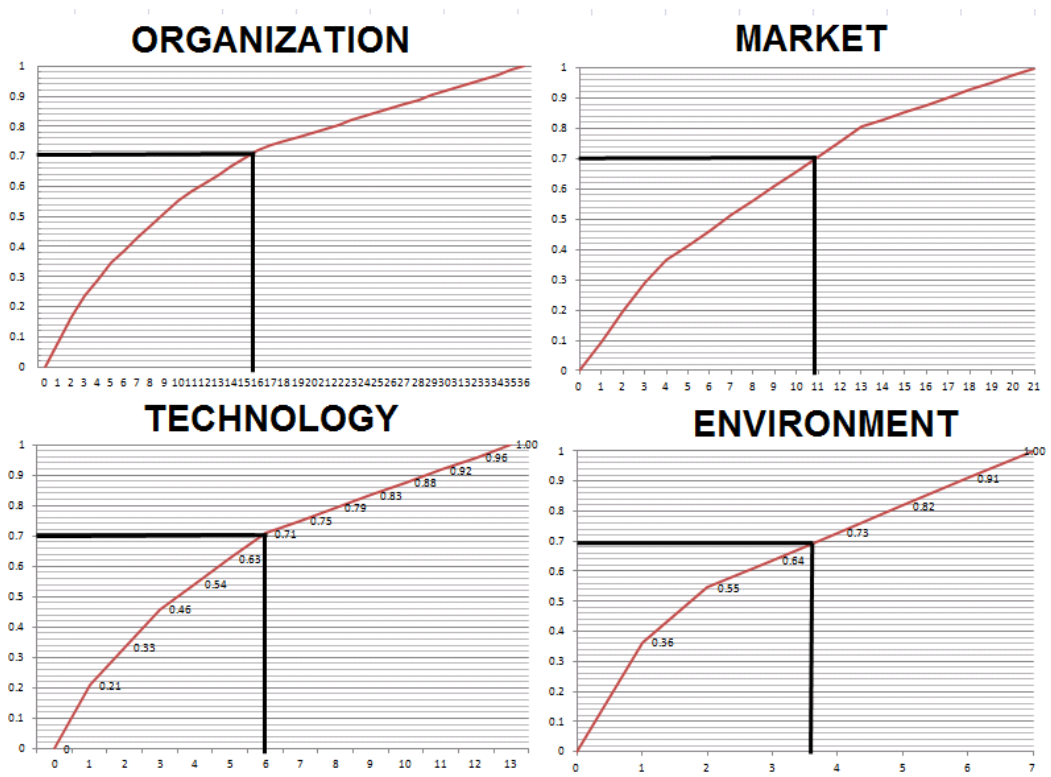


Figure 11: Design Science cycles.

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
Available Resources or Raw material	+	4	0.36	0.36	Very High	2	Very High	1
Political/Social factors	*	2	0.18	0.55	Very Few	3	Not Applicable	1
Risk Distribution	+	1	0.09	0.64	Very High	3	Very Few	5
Product liability	-	1	0.09	0.73	Very Few	1	Unknown	0
Public interest on product	*	1	0.09	0.82	Unknown	0	Unknown	0
Government Regulations	*	1	0.09	0.91	Few	6	Not Applicable	1
Industry restructure opportunity	*	1	0.09	1.00	Very High	4	Very Few	3
	Total	11	1.00		Total	19		7

Table 1: Factors of the Environment dimension.

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
Competitive environment	*	4	0.10	0.10	Very High	19	Very Few	3
Lower cost	+	4	0.10	0.20	Very High	12	Medium	2
Market existence	+	4	0.10	0.30	Very High	12	Medium	5
High Contribution margin	+	3	0.07	0.37	High	2	Unknown	0
Life cycle of product	*	2	0.05	0.42	Unknown	0	Medium	2
Market analysis	*	2	0.05	0.47	Unknown	0	Unknown	0
Meet customer needs/wants	*	2	0.05	0.52	Very High	7	Few	3
Number of end users	+	2	0.05	0.57	Very High	7	Very Few	3
Perceived value	+	2	0.05	0.62	Very High	3	Very Few	4
Probability of commercial success	+	2	0.05	0.67	Medium	3	Very High	3
Rate of new product introduction	+	2	0.05	0.72	High	5	Medium	2
Sales/profit potential	+	2	0.05	0.77	High	2	Unknown	0
Strength of market	+	2	0.05	0.82	High	3	Very High	3
Risk Distribution	+	1	0.02	0.85	Very High	3	Very Few	5
Competitor analysis	+	1	0.02	0.88	Medium	3	Very Few	5

Factors of the Market dimension. Continue next page.

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
Early analysis of market and competitors	-	1	0.02	0.90	Unknown	0	Unknown	0
Early to market	-	1	0.02	0.92	High	7	Medium	1
Few competitors	+	1	0.02	0.94	Medium	3	Very Few	8
Response to growing markets	+	1	0.02	0.96	Very High	20	High	2
Slow growth market	-	1	0.02	0.98	Unknown	0	Medium	1
Client acceptance	+	1	0.02	1.00	High	1	Few	2
	Total	41	1		Total	107		59

Table 2: Factors of the Market dimension.

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
High Level Management support	+	6	0.09	0.09	Very High	2	Very High	2
R&D process well planned	+	6	0.08	0.17	Unknown	0	Unknown	0
Emphasize Marketing	+	5	0.07	0.24	Unknown	0	Very Few	2
Markets and Technique are strength	+	4	0.06	0.30	Medium	2	Very High	8
Timing	+	4	0.06	0.36	Unknown	0	Medium	2
Commitment of project workers	+	3	0.04	0.40	Medium	2	Unknown	0
Create, Make market interface	+	3	0.04	0.44	Medium	4	Very High	9
Management and other skills	+	3	0.04	0.48	Unknown	0	Very High	3
Technology tied to business strategy	+	3	0.04	0.52	High	10	Very High	1
Training and Experience of own people	+	3	0.04	0.56	Very High	5	Very High	2
Communication	+	2	0.03	0.59	Medium	4	High	4
Demand for quick result	+	2	0.03	0.62	High	3	Very Few	6
Error free production	+	2	0.03	0.65	Unknown	0	3	Unknown

Factors of the Organization dimension. Continue next page.

ANNEXES

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
Meeting cost schedules	+	2	0.03	0.68	Unknown	0	Unknown	0
Project Manager as a project champion	+	2	0.03	0.71	Unknown	0	Very High	2
Technology route	+	2	0.03	0.74	Very High	5	Medium	1
Correct distribution channel	+	1	0.01	0.75	High	3	Very High	6
Effectiveness of project manager	+	1	0.01	0.76	High	2	Unknown	0
Effects on other business	+	1	0.01	0.77	Medium	10	Very Few	3
Inexpensive development	+	1	0.01	0.78	Very High	2	Unknown	0
Internal competition	+	1	0.01	0.79	Medium	2	Medium	1
Monitoring and feedback	+	1	0.01	0.80	Medium	2	Unknown	0
Newness to firm	*	1	0.01	0.81	Very High	1	Medium	2
Organization plans	+	1	0.01	0.83	Very High	5	Unknown	0
Potential interest of technical staff	+	1	0.01	0.85	Very High	1	Very High	3
Project mission	+	1	0.01	0.86	Very High	1	High	2

Factors of the Organization dimension. Continue next page.

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
Project schedule	+	1	0.01	0.88	Unknown	0	Unknown	0
Qualified project manager	+	1	0.01	0.89	Very High	1	Very High	2
Quantitative project selection	+	1	0.01	0.90	Not Applicable	1	Very High	1
Source of project ideas	+	1	0.01	0.92	Very High	4	High	1
Staff of professionals	+	1	0.01	0.93	Very High	2	Very High	2
Strong sales force	+	1	0.01	0.94	Unknown	0	Very High	1
Technological background of managers	+	1	0.01	0.96	Very High	5	Very High	2
Trouble shooting	+	1	0.01	0.97	Unknown	0	Unknown	0
Understanding market	*	1	0.01	0.99	Unknown	0	Very High	3
Use outside communication	*	1.00	0.01	1.00	Unknown	0	Few	2
Total	Total	74	1.00		Total	79		72

Table 3: Factors of the Organization dimension.

Factor	Effect	Freq.	Rate	Aggreg. rate	Skype Results	Skype Evidence	Google Wave Results	Google Wave Evidence
Probability of technical success	+	5	0.21	0.21	Very High	3	Medium	2
Demand Push vs Technology push	+	3	0.13	0.34	Medium	14	Very Few	4
High performance/cost proportion	+	3	0.13	0.47	Medium	1	Unknown	0
Innovative product	+	2	0.08	0.55	Very High	3	High	2
Problem definition	+	2	0.08	0.63	Unknown	0	Medium	2
Technology route	+	2	0.08	0.71	Very High	5	Medium	1
Risk Distribution	+	1	0.04	0.75	Very High	3	Very Few	5
Product liability	-	1	0.04	0.79	Not Applicable	1	Unknown	0
Client acceptance	+	1	0.04	0.83	Very High	1	Few	2
Directions for scientific development	+	1	0.04	0.87	Unknown	0	Medium	1
Incremental product	+	1	0.04	0.91	Very High	9	Very High	4
Patents	+	1	0.04	0.95	Very High	2	Medium	1
Utility	*	1	0.04	1.00	Very High	1	High	3
Total	Total	24	1.00		Total	42		27

Table 4: Factors of the Technology dimension.



## Annex III.2 Factor's definition

The complete list of references for each factor is available in literature review performed by Balachandra et al.[9] in Table III. These definitions have been obtained from the referred literature and, in some cases, additional references have been included. Each factor is presented as follows: first a brief factor explanation, then the impact type (positive, negative or both), the third how the factor could be interpreted from the Software Intensive System perspective, and finally how to measure the factor considering a discrete scale composed by five values: *very low*, *low*, *medium*, *high* and *very high*.

### Annex III.2.1 Environment

#### Available Resources or Raw material

- *Explanation:* Raw material is a material or substance used in the primary production or manufacturing of a good. The more certain the supply of necessary raw materials or components, the greater are the chances of business success.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it concerns with the components (software and hardware) and their stability needed to implement the system.
- *Values:* It should be rated with *Very high* when all the components are available and stable and with *Very low* when most of the needed resources will be provided by external companies or when they are not mature enough.

#### Government Regulations

- *Explanation:* It represents when the legislative and executive branches set and enact laws that determine how a specific task, business, or industry are supposed to run.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when government regulations are defined and no changes are expected and with *Very low* when there are no government regulations yet but they are expected to be defined in the future what could require companies to make extensive changes resulting in greatly Increased costs for the final product. In this case *Very low* represents a negative impact.

### Industry restructure opportunity

- *Explanation:* A new entrant can become the dominant competitor when it makes technological breakthroughs in a stagnant industry, particularly when the new entrant has strong patent protection and competitors are small and fragmented. Also a basic innovation in an existing market offers opportunities to capture downstream use or application markets.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is breaking the market and competitors are small and fragmented and with *Very low* when the product is part of a market with many competitors. In this case *Very low* represents a negative impact.

### Political/Social factors

- *Explanation:* It represents political or social factors that could impact in product development like Antitrust, Ecology, Foreign exchange, Geography or Sovereign rights.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when product development is not affected by political or social factors outside the company and with *Very low* when product development depends on political or social institutions. In this case *Very low* represents a negative impact.

### Public interest on product

- *Explanation:* Public interest is a principle by which the government can request that sensitive documents are not used as evidence in a trial, on the grounds that to do so would be against the public or national interest [86]. It represents in which the whole society has a stake and which warrants recognition, promotion, and protection by the government and its agencies.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is considered as relevant to a mass population or market and with *Very low* when the product is targeted to a tight market or population.

**Product liability**

- *Explanation:* The legal liability a manufacturer or trader incurs for producing or selling a faulty product; in that case the product could be innovative but the impact is reduced. It measures the responsibility of the company to ensure that products are safe and do not cause injury to users [70, 85].
- *Impact type:* Negative.
- *SiS interpretation:* In the case of SiS, however, is now the principle controlling element in many industrial and consumer products. It is so pervasive that it is found in just about every product that is labelled electronic. Software can cause products to do strange and even terrifying things. Software bugs and errors could mean injuries or damages.
- *Values:* It should be rated with *Very high* when the risk of injuries is high and with *Very low* when the risk of injuries is very low, but they could happen. In the case of no injuries risk, this factor should be rated as *Not Applicable*.

**Risk Distribution**

- *Explanation:* The commercial success of the product does not depend on the narrow line of production and market. Therefore, it measures how the environment could affect to the product distribution.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it measures if the product success is independent of distribution channel or if the distribution channel is limiting the product.
- *Values:* It should be rated with *Very high* when the product could be distributed by many distribution channels and markets and with *Very low* when the distribution channel is very restrictive.

### Annex III.2.2 Market

#### Competitive environment

- *Explanation:* The competitive environment, also known as the market structure, is the dynamic system in which business competes. The state of the system as a whole limits the flexibility of your business. It describes the ease of market entry.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the market entry barriers are low and with *Very low* when it is hard to access to the market.

#### Competitor analysis

- *Explanation:* It is a strategic technique used to evaluate outside competitors. The analysis seeks to identify weaknesses and strengths that a company's competitors may have, and then use that information to improve efforts within the company. Three factors are important in analyzing the competition. The first is the ability of a competitor to take defensive measures; a well-managed company with low costs and a strong cash flow might easily fend off competitors. The second is patent protection; an innovation is likely to have more success if it has strong patent protection against competitors. The third is the pace of change in the technology; if innovation occurs quickly in an area, a new development may be obsolete in only a few years.
- *Impact type:* positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when very few competitors are in the market and with *Very low* there are several competitors providing similar products or services.

#### Early analysis of market and competitors

- *Explanation:* It measures if a market analysis has been performed in advance. The competitor analysis may give the toughest time, especially if the company is new to the marketplace.
- *Impact type:* Negative.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.

- *Values:* It should be rated with *Very high* when a market analysis has not been performed in advance to the product development and with *Very low* when a market analysis has been performed before.

**Early to market**

- *Explanation:* It measures if the market is mature enough to accept the product.
- *Impact type:* Negative.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the market is not mature to accept the product because the product is disruptive and with *Very low* when the market is mature to accept the new product.

**Few competitors**

- *Explanation:* Few competitors mean fewer firms are competing for the same customers and resources. “Relatively Few Competitors” will have a long-term positive impact, which adds to its value. This statements will have a short-term positive impact, which adds to its value. This qualitative factor will lead to a decrease in costs.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when few competitors are in the market and with *Very low* too many competitors are in the market.

**High Contribution margin**

- *Explanation:* The contribution margin is the marginal profit per unit sale, and is the sum of a company’s turnover minus their direct costs. This factor measures how flexible is the contribution margin.
- *Impact type:* Positive.
- *SiS interpretation:*In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the company has flexibility to fix the marginal profit and with *Very low* when the profit is fixed by the market and the existing competitors.

**Life cycle of product**

- *Explanation:* If the product is in the growth phase of its life cycle the rate of new product introduction will be high, which leads to a higher degree of success . If it is in the infancy stage the product may still not be fully developed resulting in many false starts. On the other hand, a mature product will require enormous resources in order to introduce new variations. Most high technology projects are in the infancy or the growth stage.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is in the growth phase and with *Very low* when the product is in the infancy or the market is too mature.

### Lower cost

- *Explanation:* It measures if the product is providing a lower cost than other competitors existing in the same category. Will the product offer to the customer in terms of unique features the lower cost?
- *Impact type:* positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when it is able to put on the market the product at lower prices than competitors with the same features and with *Very low* when there are some other products from competitors with the same features and at lower prices.

### Market analysis

- *Explanation:* An evaluation of the market for a company's goods and services. Research that offers assistance in forecasting price trends for stocks and bonds. Market analysis may concentrate on fundamental factors including earnings, inflation, and costs, or it may be directed at technical considerations such as trading volume and price charts.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the company has performed a market analysis for the product before to be put in the market and with *Very low* when there is not a market analysis for the product. It means a high risk.

**Market existence**

- *Explanation:* It measures if there is any existing market or if this product is creating a new market. An existing marketing and distribution system which can present and distribute the new product is a real asset to a project.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it could be interpreted as if the market is ready to accept the new functionality provided the product.
- *Values:* It should be rated with *Very high* when the market is mature enough or is requesting new functionalities and it is ready to accept new products and with *Very low* when the market is comfortable with the existing products and it is not demanding new functionalities.

**Meet customer needs/wants**

- *Explanation:* It measures if the product is developed because there is an identified customer need/want.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is driven by a customer who has a need and with *Very low* when there is no final customer defining the product.

**Number of end users**

- *Explanation:* It measures the number of end users in relationship with the market size. In their enthusiasm, the originators may perceive their new idea to be applicable in a number of widely unconnected markets. Unfortunately, much fruitless effort will be spent in designing a general product which can be used in a variety of situations. This results in a loss of focus in product design.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the number of users is enough to keep the product focused and with *Very low* when the number of users is small, so that companies tend to design a general product reducing the innovation.

### Perceived value

- *Explanation:* A customer's opinion of a product's value to him or her. It may have little or nothing to do with the product's market price, and depends on the product's ability to satisfy his or her needs or requirements. It is an important marketing concept. It lies at the heart of marketing and deals solely with the customer's perception of a product. Perceived value is a consolidated measure because it takes into account subjective perceptions with limits placed on it by price and other objective costs.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the user consider that product is providing a high value and customers perceive that the product will help them and with *Very low* when it is not clear how much value is providing the product.

### Probability of commercial success

- *Explanation:* Even when the allocation of funding into different classifications increases the odds of funding a riskier R&D project, it is still necessary to allocate funds within each classification. A possible approach for deciding between projects is to use expected commercial value (ECV), which amalgamates the probabilities of success into a more standard net present value calculation.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when it is expected a commercial success and with *Very low* when it is unknown or it is not clear the commercial success.

### Rate of new product introduction

- *Explanation:* If new products or significant adaptations are introduced In the market fairly regularly, say once in six months or less, it demonstrates that there is a great deal of product Innovation taking place and that the market has not stabilized. Therefore, any new product with improvements over existing products has a good chance of being successful . For example if one is in the digital watch industry, any new gimmick on a new watch



design, provided it meets other market considerations, has a good chance of success . Moreover, since so many different designs are being introduced, another new one is unlikely to be seriously hurt in the market.

- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS the time frame is less than six month. It is typical to launch new versions every three months. Due to the nature of software the rate of new product could be high in opening market.
- *Values:* It should be rated with *Very high* when the number of product introduction is growing for a market and with *Very low* the number of new products in the market is very low or even null.

#### **Response to growing markets**

- *Explanation:* Emerging markets are those countries that have growing economies and a growing middle class. Some of these countries were once poor, and some still have high rates of poverty. Many are undergoing profound social and political change for the better. A sector of the economy experiencing a higher-than-average growth rate. Growth industries are often associated with new or pioneer industries that did not exist in the past and their growth is related to consumer demand for the new products or services offered by the firms within the industry.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS growing markets are not related with growing economies but to new sectors where SiS are applied.
- *Values:* It should be rated with *Very high* when the product is become a pioneer in the market and with *Very low* the product does not belong to a growing market but a well established market.

#### **Risk Distribution**

- *Explanation:* The commercial success of the product does not depend on the narrow line of production and market. Therefore, it measures how the environment could affect to the product distribution.
- *Impact type:* Positive. *SiS interpretation:* In the case of SiS it measures if the product success is independent of distribution channel or if the distribution channel is limiting the product.
- *Impact type:* positive.

- *SiS interpretation:* In the case of SiS it measures if the product success is independent of distribution channel or if the distribution channel is limiting the product accessing to the market.
- *Values:* It should be rated with *Very high* when the market is accessible without limitation of the existing distribution channels and with *Very low* when the market distribution channel is very restrictive.

### Sales/profit potential

- *Explanation:* It measures if the gross sale decreases that also affect the profits by decreasing them because the gross sales are the total amount of the sale before any discounts or allowances are made on the sale. If the gross sales increase then the amount of profit also increases because the more company sells the more the company has the potential to make more profit. If the project will not be profitable enough around 40% before-tax return it should be abandoned.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the factor is greater than 40 % and with *Very low* when the factor is less than 40%

### Slow growth market

- *Explanation:* An increase in the demand for a particular product or service over time. Market growth can be slow if consumers do not adopt a high demand or rapid if consumers find the product or service useful for the price level. For example, a new technology might only be marketable to a small set of consumers, but as the price of the technology decreases and its usefulness in every day life increases, more consumers could increase demand. A market that currently exhibits low trading volumes and/or low volatility levels. The term slow market can be used to describe a market with few issues coming up for sale to investors through initial public offerings and secondary offerings in the equity markets, or through new issuance in the corporate bond market.
- *Impact type:* Negative.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the market growth is very slow considering a mature market and with *Very low* when the growth is slow but the market is quite new.

**Strength of market**

- *Explanation:* Market strength is a broad term that can mean a lot of things, depending on how we define it. Market strength can be a measure of a market's power to perform either on a relative basis (vs. other markets) or on an absolute basis (vs. its own historical levels of momentum and investor participation).
- *Impact type:* positive.
- *SiS interpretation:* In the case of SiS it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the market has a huge amount of potential users and there are some other products in the market and with *Very low* when the market is not solid or it is starting.

**Client acceptance**

- *Explanation:* It refers to the final stage in the implementation process, at which time the ultimate efficacy of the project is to be determined. Too often project managers make the mistake of believing that if they handle the other stages of the implementation process well, the client (either internal or external to the organization) will accept the resulting project. In fact, client acceptance is a stage in project implementation that must be managed like any other.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is the last stage of development and with *Very low* when the product is still under development.

### Annex III.2.3 Organization

#### Commitment of project workers

- *Explanation:* It is the perception among the project team than the project is going to be completed successfully. Some factors contributing to commitment include loyalty to project leader, ego satisfaction, and a sense of liking for the project and the resulting new product.
- *Impact type:* Positive.
- *SiS interpretation:*. In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the team has the perception about the success of the project and with *Very low* it is not clear if the project is going to be finished.

#### Communication

- *Explanation:* The need for adequate communication channels is extremely important in creating an atmosphere for successful project implementation. Communication is not only essential within the project team itself, but between the team and the rest of the organization as well as with the clients.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product could be developed with very few or none communication dependency with the customer and with *Very low* when communication with customer or development team is critical for the project success.

#### Correct distribution channel

- *Explanation:* The path through which product and services travel from the vendor to the consumer or payments for those products travel from the consumer to the vendor. A distribution channel can be as short as a direct transaction from the vendor to the consumer, or may include several interconnected intermediaries along the way such as wholesalers, distributors, agents and retailers. Each intermediary receives the item at one pricing point and moves it to the next higher pricing point until it reaches the final buyer.
- *Impact type:* Positive.

- *SiS interpretation:* In the case of SiS, it is focused on the different distribution channels and the impact that these channels have in the product distribution. Is the product available to direct download from Internet? Do customer need special channels to access to the product?
- *Values:* It should be rated with *Very high* when the success does not depends on the distribution channel and with *Very low* when the product success depends on the distribution channel.

#### **Create, Make market interface**

- *Explanation:* It determines the dependency relationship between the market and the product and how the product will/is accessing to the market.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the access to the market already exists and the product is going to use it and with *Very low* when it is critical to have a clear interface to access to the market and the product should create the interface.

#### **Demand for quick result**

- *Explanation:* An important part of evaluating the chances of carrying a project through to a successful conclusion is evaluating the patience of the supporting organization. Projects which start paying off soon are, everything else being equal, to be preferred over projects that have a distant payout. If there is not going to be enough patience, it may be best not to start. One of the worst mistakes that can be made in starting a project is to adopt, under pressure, an impossible time schedule and then miss the time check points built into the schedule.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when there is patience enough to start paying off and with *Very low* when there is not going to be enough patience to start paying off soon.

#### **Effectiveness of project manager**

- *Explanation:* In high-tech firms the design features of the product can change a number of times due to the changing nature of the technology, and to

unexpected events in the wider environment. If the project manager cannot effectively handle these changes and incorporate them into the design, the project may become obsolete even before its completion. The effectiveness with which the project manager handles changes in the technology and adapts to the environment is a key factor in the successful completion of the project.

- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the project requires that the project manager handle changes in the environment and technology very fast; therefore the project manager needs to have the ability to handle changes in a fast way and with *Very low* when the project does not require to react in a fast way when the environment or technology is changing and therefore, the project manager does not need to be able to handle changes.

### Effects on other business

- *Explanation:* When successful completion of a new project would put the sponsoring organization in competition with one of its good customers for another product. A perception that introducing a new project might hurt existing profitable businesses will almost certainly defeat proposals that the new project be implemented. One should try to identify such conflicts early.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when there are no other projects at the same time for the same team in competition in the same company and with *Very low* when there are other projects in competition in the same company.

### Emphasize Marketing

- *Explanation:* It determines if product type/innovation strategy is related to R&D/marketing programs and the market environment, and that R&D/marketing decisions, market characteristics, and product type/innovation strategy all influence new product sales performance.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.

- *Values:* It should be rated with *Very high* when sales do not depend on marketing campaigns and with *Very low* when marketing decisions have a deep impact on product sales.

#### **Error free production**

- *Explanation:* To measure how sensible is the product to errors while producing it.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, this factor measures the level of testing performed to assure that the product is error free.
- *Values:* It should be rated with *Very high* when the product is going to be tested exhaustively previous to be on the market and with *Very low* when no specific testing processes are needed.

#### **High Level Management support**

- *Explanation:* Top management's support of the project may involve aspects such as allocation of sufficient resources (including financial, manpower, time, etc.) as well as project management's confidence in their support in the event of crisis. It represents how confident is the Top management in the success of the project.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the Top management of the company is supporting the project and with *Very low* when the project is supported by departments but there is not a clear support from the company's structure.

#### **Inexpensive development**

- *Explanation:* It measures the investment needed to develop the product.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way. Could the product be developed with the resources available in the company?.
- *Values:* It should be rated with *Very high* when the company has resources enough to develop the product and with *Very low* when the company does not have resources enough and it should make an investment to develop the product.

### Internal competition

- *Explanation:* Competition from another project for similar resources, in many cases, can act as a catalyst for successful project completion. The demand for the resources can force the project leader and his team to put in extra effort to complete the project successfully. Even if the groups are not working on the same project, the simple presence of multiple demands for resources may enhance the motivation of the project team.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is receiving synergies from existing or previous development in the company and with *Very low* when the project is not receiving synergies from other projects from the company.

### Management and other skills

- *Explanation:* It measures if the company has people involved to cover all the skills that are needed in the product development.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when all the skills needed for the project are covered by the company and with *Very low* when most of the requested skills are missing.

### Meeting cost schedules

- *Explanation:* It measures how frequently schedules are revised. As much revision the cost is increased.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the project is managed in a way where very few review meetings are need and schedules are revised very few and with *Very low* when schedules are revised frequently.

### Markets and Technique are strength

- *Explanation:* It measures the company strength in market and techniques. As much strength is the company as better results will be obtained and it will be easy to access to the market.



- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the company is strength in the market and the technology needed to develop the product and with *Very low* both market and technology are new for the company.

### **Monitoring and feedback**

- *Explanation:* Monitoring and feedback refer to the project control process by which, at each stage of the project implementation, key personnel receive feedback on how the project is comparing to initial projections. Making allowances for adequate monitoring and feedback mechanisms gives the project manager the ability to anticipate problems, to oversee corrective measures, and to ensure that no deficiencies are overlooked. For our model, Monitoring and Feedback refers not only to project schedule and budget, but also to monitoring performance of members of the project team.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is developed with fast feedback loops and with *Very low* when the product is developed without any feedback.

### **Newness to firm**

- *Explanation:* It measures if the product is new to the company or not. A product that is new to the firm is not a plus.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is not completely new because the company has a background and with *Very low* when the product is completely new and, therefore, the knowledge about both the product and market is limited.

### **Organization plans**

- *Explanation:* It measures if the organization has defined ideas about the types of business it wants to be in and the directions in which it wants to grow. These ideas are defined in long range plans, policies, statements of

objectives and so forth. A project will be much more warmly received if it fits these stated perceptions of the type of projects desired.

- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the company has established plans to develop the product and with *Very low* when there are no clear directions in which the company wants to grow.

### **Potential interest of technical staff**

- *Explanation:* In the evaluation of technical feasibility, the adequacy of technical staff resources to carry out a project are considered. The Environment question is whether the project is likely to attract the interest and enthusiasm of the technical staff. If the technical staff does become interested in a project, the members will work nights as well as days, improve their skills related to doing the project and take an active rather than a passive role in solving problems. The chances of a project succeeding are greatly enhanced by real technical staff interest.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the technical staff is interested in the project and with *Very low* when there is no special interest in the staff about the project.

### **Project mission**

- *Explanation:* It measures if the product has clear and understandable goals as well as ultimate benefits at the outset, not only by the project team involved, but by the other departments in the organization. The goals of the project are in line with the general goals of the organization.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the goal of the product are clearly stated and aligned with the company and with *Very low* when the neither the goals are stated nor the product is aligned with the company strategy.

### **Project schedule**

- *Explanation:* Project schedule refers to the importance of developing a detailed plan of the required stages of the implementation process. As developed in our model, Project Schedule/Plan refers to the degree to which time schedules, milestones, manpower, and equipment requirements are specified. Further, the schedule should include a satisfactory measurement system as a way of judging actual performance against budget and time allowances.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product development has been scheduled before starting the project and with *Very low* when the schedule is being built as the product is developed.

#### **Project Manager as a project champion**

- *Explanation:* It focuses on the project champion by suggesting that the most auspicious champion is the project manager himself and that his importance becomes most critical toward the end of the development phase. It measures the ability of the top management to push the project to become champion.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when there is a project leader or a team with the ability to push the project when the development is stuck and with *Very low* when no one has the ability to push the project.

#### **Qualified project manager**

- *Explanation:* It measures if the company has a qualified project manager to lead the product to be successful.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the project manager is skilled enough to lead the project. He knows the product and the market and with *Very low* when the project manager does not know the scope of the project.

#### **Quantitative project selection**

- *Explanation:* A quantitative project selection system-based on estimates of project cost, duration, and probability of technical completion and market estimates of sales and product life-was instituted by firms.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the project was selected being the best evaluated considering among others: cost, duration or market and with *Very low* when no quantitative data supports the project selection.

### **R&D process well planned**

- *Explanation:* It measures if the R&D activities that are needed to develop the product has been properly scheduled. It is only applied when the project needs R&D activities.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when R&D activities are scheduled and with *Very low* when R&D activities are performed as they happen.

### **Source of project ideas**

- *Explanation:* It analyses where ideas come from. Two-thirds of the R&D projects stemmed from the R&D department. But it does not mean a high probability of technical completion. The projects stemming from the R&D department may be less firmly based on market realities than those submitted by the marketing (and other) departments, so they may be more likely to be stopped short of technical completion because of lack of potential profitability. On the other hand, because the R&D department understands the technical aspects of R&D projects so well, it tends to be a better judge than other departments of what is technically feasible.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the project is pushed by the same department that proposed the idea and it has the skills enough to develop the project and with *Very low* when the idea is proposed and developed by different departments.

### **Staff of professionals**

- *Explanation:* It measures the level of qualification required to the staff.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the staff is composed by professional and with *Very low* when the staff does not have special skills.

### **Strong sales force**

- *Explanation:* It measures the availability of a strong sales force to put the product into the market.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way. All the existing distribution channels to put SiS in the market should be considered.
- *Values:* It should be rated with *Very high* when the company has a strong sales department to distribute the product and with *Very low* the company does not have a strong sales department.

### **Technology tied to business strategy**

- *Explanation:* Technology-push projects tend to be more ambitious and aimed at larger potential payoffs, the probability of economic success (given commercialization) may decrease as the percentage of R&D expenditures devoted to demand-pull projects increases. Technology-push projects are harder to sell to marketing, production, and other parts of the firm than those of demand-pull projects.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the technology needed to develop the product is part of the strategy of the company and with *Very low* when the technology needed is not aligned with the company strategy.

### **Technological background of managers**

- *Explanation:* It measures if managers have a technological background facilitating the development of the product.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.

- *Values:* It should be rated with *Very high* when managers know the technology needed to develop the product and with *Very low* when managers are not familiar with the technology.

### Timing

- *Explanation:* It measures if the product is developed when the interest in it is high. There will be times when it is avoid for new projects and other times when it has little interest in them. A new project surely has a better Environment for acceptance when its timing is right.
- *Impact type:* Positive.
- *SiS interpretation:* In the case if SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when it is the right time in terms off commitment, expenditures and satisfaction in the product line and with *Very low* when the company is more focused on other product lines.

### Training and Experience of own people

- *Explanation:* It measure if the project could be performed by the actual staff of the company or if it depends on external people.
- *Impact type:* Positive.
- *SiS interpretation:* In the case if SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product could be developed with the available resources in the company and with *Very low* when new people should be enrolled to the company to perform the product.

### Trouble shooting

- *Explanation:* It is impossible to foresee every trouble area or problem that could possibly arise. As a result, it is important that the project manager make adequate initial arrangements for Trouble-Shooting mechanisms to be included in the implementation plan. Such mechanisms would make it easier to not only react to problems as they arise, but to foresee and possibly forestall potential problems areas in the implementation process.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way and also considering different technological alternatives for implementing the product.

- *Values:* It should be rated with *Very high* when product metrics have been defined to prevent and detect problems and with *Very low* when no risk analysis has been performed and there are no metrics to control the product development.

#### **Understanding market**

- *Explanation:* Growing business without understanding your competitors is risky. Market research can prepare you for changing markets and prevent the product being left behind by the competition.
- *Impact type:* Both.
- *SiS interpretation:* In the case if SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the market and the target for the product have been clearly identified and with *Very low* when the market has not been studied in advance to product development.

#### **Use outside communication**

- *Explanation:* It measure the impact of using external communication and additional communication channels to develop the product.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when no outside communication has been applied to develop the product; that is team did not needed additional communication channels to develop the product and with *Very low* when additional communication channels have been required in the development delaying or increasing the complexity of the development.

### Annex III.2.3 Technology

#### Client acceptance

- *Explanation:* It refers to the final stage in the implementation process, at which time the ultimate efficacy of the project is to be determined. Too often project managers make the mistake of believing that if they handle the other stages of the implementation process well, the client (either internal or external to the organization) will accept the resulting project. In fact, client acceptance is a stage in project implementation that must be managed like any other.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is the last stage of development and with *Very low* when the product is still under development.

#### Demand Pull vs Technology push

- *Explanation:*  
Technology-push projects tend to be more ambitious and aimed at larger potential payoffs. Demand-pull means that there is market behind the product. Technology-push projects are harder to sell to marketing, production, and other parts of the firm than those of demand-pull projects. It is quite likely that technology-push projects tend to be more risky than demand-pull projects.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product could be categorized as demand-pull and with *Very low* when the product could be categorized as technology-push.

#### Directions for scientific development

- *Explanation:* It measures if the product is opening new directions for scientific development. These directions will promote new patents or new objects.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way but extending the concept of patents to copyrighted software.



- *Values:* It should be rated with *Very high* when new copyrights could be derived from the product and the new directions and with *Very low* when no new directions were associated to the product.

### High performance/cost ratio

- *Explanation:* The cost-performance ratio is an equation used to balance the cost of an item against its effectiveness. This process can help buyers with making purchasing decisions by assigning rankings to a series of items based on a variety of factors. Cost-performance can also be used to analyze trends in production.
- *Impact type:* Positive.
- *SiS interpretation:* It is also known as price/performance ratio. The most desirable outcome is that the item is low cost, but high performance. In the middle of the scale are products that are either high performance and high cost, or low performance and low cost. The least desirable ranking tends to be for a product that is high cost, but low performance. As technology has advanced, products have become more powerful and increasingly more accessible to consumers.
- *Values:* It should be rated with *Very high* when the product provides as much performances as expected by customers with the lowest cost and with *Very low* when the cost of the product is still high.

### Incremental product

- *Explanation:* Incremental product innovation concerns an existing product whose performance has been significantly enhanced or upgraded. This again can take two forms. A simple product may be improved (in terms of improved performance or lower cost) through use of higher performance components or materials, or a complex product which consists of a number of integrated technical subsystems may be improved by partial changes to one of the subsystems.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when product could be put into the market in an incremental way by adding new features and with *Very low* when the product can not be put into the market incrementally.

### Innovative product

- *Explanation:* it measures if the product was highly innovative-totally new to the market.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is completely new to the market and with *Very low* when the product does not provide any new features or it has very few new features.

### Patents

- *Explanation:* Protected by a trademark or a brand name so as to establish proprietary rights analogous to those conveyed by letters patent or a patent.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, a software patent is a patent that is provided to enhance computer performance by means of a computer application. There is no legal or conclusive definition for a software patent. This and the topic of related intellectual property (IP) protection rights have been intensely debated at all levels in the tech world. Different countries have different restrictions on patenting software innovations.
- *Values:* It should be rated with *Very high* when the software has many new components that have been copyrighted and with *Very low* when the intellectual property is not relevant to the product.

### Problem definition

- *Explanation:* It measures if the product is properly defined. Customer needs for new products are difficult to articulate and sort out, because the customers themselves may not be sure, the knowledge itself is often tacit, and that knowledge may be embedded in a context of use and not retrievable except by hands-on interaction with that context. To put problem definition more positively, successful new products have more market knowledge than failed ones.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when product features are well defined and the product is goal is clear and with *Very low* when product features are not defined or if the product does not have clear goals.

**Probability of technical success**

- *Explanation:* If the project is proceeding along a fairly well defined technological route, and there are not many unsolved technological problems the probability of success will remain the same as before or may even increase. On the other hand, technological problems in some key area may make the project unfeasible.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product technological route is well defined and they are feasible and with *Very low* when there is a high technological risk, that is, technology is not available and it is expected some delays due to technology.

**Product liability**

- *Explanation:* The legal liability a manufacturer or trader incurs for producing or selling a faulty product. It measures the responsibility of the company to ensure that products are safe and do not cause injury to users [70, 85].
- *Impact type:* Negative.
- *SiS interpretation:* In the case of SiS, however, is now the principle controlling element in many industrial and consumer products. It is so pervasive that it is found in just about every product that is labelled electronic. Software can cause products to do strange and even terrifying things. Software bugs and errors could mean injuries or damages.
- *Values:* It should be rated with *Very high* when the risk of injuries derived from the technology used is very low, but they could happen and with *Very low* when the risk of injuries derived from the technology used is high. In the case of no injuries risk, this factor should be rated as *Not Applicable*.

**Risk Distribution**

- *Explanation:* The commercial success of the product does not depend on the narrow line of production and market. Therefore, it measures how technology could affect to the product distribution. It is related to risk that customers may suffer product/service disruptions.
- *Impact type:* Positive.

- *SiS interpretation:* In the case of SiS, it measures how the environment could affect to the product distribution. If the product success is independent of distribution channel technology or if the distribution channel technology is limiting the product.
- *Values:* It should be rated with *Very high* when the product could be distributed by many distribution channels and markets and with *Very low* the distribution channel is very restrictive.

### Utility

- *Explanation:* It represents if the developed product is perceived as useful by customers, that may result from a project is the utility of the product to those who will buy and use it. It measures the level of utility of the product. Utility should be judged in relation to other products the customer may use to fulfill a need.
- *Impact type:* Both.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product is considered as useful to a wide range of customers and with *Very low* when it is not clear how useful is to customers or it is only useful to a small group of customers.

### Technology route

- *Explanation:* A clear understanding of the technological route is a prerequisite for the success of a project. However in the high tech area the technological route tends to be disjointed as new developments come on the horizon fairly quickly. Nevertheless, the project should stay on the original technological track and not veer widely from that route. This is very important in high tech firms.
- *Impact type:* Positive.
- *SiS interpretation:* In the case of SiS, it is interpreted in the same way.
- *Values:* It should be rated with *Very high* when the product technological route is well defined and with *Very low* there was no agreement about the technological route to be taken.

## **Annex IV. XML files**

This annex presents the XML files that are referred in the thesis. Section 7.3 presents the source XML-Schema file containing the product innovation assessment language. Section 7.3 presents the source XML file with an instance of a product innovation assessment model.

## Annex IV.1 Product innovation assessment language

This section presents the XML-Schema of the product innovation assessment language.

---

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  elementFormDefault="qualified"
  attributeFormDefault="unqualified">
  <xs:element name="innovation_assessment_model"
    type="Tinnovation_assessment_model" />
  <!-- Start Definition of types needed to formalize concepts -->
  <xs:complexType name="Tdimension">
    <xs:attribute name="dimid1" type="xs:string" />
    <xs:attribute name="dimName" type="xs:string" />
  </xs:complexType>
  <xs:complexType name="Tdimensions">
    <xs:sequence>
      <xs:element name="dimension" type="Tdimension"
        maxOccurs="unbounded" />
    </xs:sequence>
  </xs:complexType>
  <xs:complexType name="Tfactor">
    <xs:attribute name="factorId" type="xs:string" />
    <xs:attribute name="name" type="xs:string" />
    <xs:attribute name="definition" type="xs:string" />
  </xs:complexType>
  <xs:complexType name="Tfactors">
    <xs:sequence>
      <xs:element name="factor" type="Tfactor"
        maxOccurs="unbounded" />
    </xs:sequence>
  </xs:complexType>
  <xs:complexType name="Tconcepts">
    <xs:sequence>
      <xs:element name="dimensions" type="Tdimensions"
        maxOccurs="1" />
      <xs:element name="factors" type="Tfactors" maxOccurs="1" />
    </xs:sequence>
  </xs:complexType>
  <!-- End Definition of types needed to formalize concepts -->
  <!-- Start Definition of types needed to formalize innovation
```

```
models -->
<xs:complexType name="Tmodel">
  <xs:attribute name="modelId" type="xs:string" />
  <xs:attribute name="modelName" type="xs:string" />
  <xs:attribute name="modelYear" type="xs:int" />
  <xs:attribute name="modelVersion" type="xs:string" />
  <xs:attribute name="modelDescription" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tmodel_item">
  <xs:attribute name="modItemId" type="xs:string" />
  <xs:attribute name="modelId" type="xs:string" />
  <xs:attribute name="dimid1" type="xs:string" />
  <xs:attribute name="factorId" type="xs:string" />
  <xs:attribute name="impact" type="xs:string" />
  <xs:attribute name="weight" type="xs:float" />
  <xs:attribute name="interpretation" type="xs:string" />
  <xs:attribute name="help" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tmodel_items">
  <xs:sequence>
    <xs:element name="model_item" type="Tmodel_item"
      maxOccurs="unbounded" />
  </xs:sequence>
</xs:complexType>
<xs:complexType name="Tinnovation_model">
  <xs:sequence>
    <xs:element name="model" type="Tmodel" maxOccurs="1" />
    <xs:element name="model_items" type="Tmodel_items"
      maxOccurs="1" />
  </xs:sequence>
</xs:complexType>
<!-- End Definition of types needed to formalize innovation
models -->
<!-- Start Definition of types needed to formalize assessment -->
<xs:complexType name="Tassessment_line">
  <xs:attribute name="lineId" type="xs:string" />
  <xs:attribute name="questionnaireId" type="xs:string" />
  <xs:attribute name="modItemId" type="xs:string" />
  <xs:attribute name="type" type="xs:string" />
</xs:complexType>
<xs:complexType name="Tassessment_lines">
```

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```
<xs:sequence>
  <xs:element name="assessment_line" type="Tassessment_line"
    maxOccurs="unbounded" />
</xs:sequence>
</xs:complexType>
<xs:complexType name="Tquestionnaire">
  <xs:sequence>
    <xs:element name="assessment_lines" type="Tassessment_lines"
      maxOccurs="1" />
  </xs:sequence>
  <xs:attribute name="questionnaireId"
    type="xs:string"></xs:attribute>
  <xs:attribute name="modelId" type="xs:string"></xs:attribute>
  <xs:attribute name="name" type="xs:string"></xs:attribute>
  <xs:attribute name="version" type="xs:string"></xs:attribute>
</xs:complexType>
<xs:complexType name="Tassessment_questionnaire">
  <xs:sequence>
    <xs:element name="questionnaire" type="Tquestionnaire"
      maxOccurs="unbounded" />
  </xs:sequence>
</xs:complexType>
<!-- End Definition of types needed to formalize assessment -->
<xs:complexType name="Tinnovation_assessment_model">
  <xs:sequence>
    <xs:element name="concepts" type="Tconcepts" maxOccurs="1" />
    <xs:element name="innovation_model" type="Tinnovation_model"
      maxOccurs="1" />
    <xs:element name="assessment_questionnaires"
      type="Tassessment_questionnaire" maxOccurs="1" />
  </xs:sequence>
</xs:complexType>
</xs:schema>
```

---



---

## Annex IV.2 Example of a product innovation assessment reference-model instance

This section presents the XML source file representing an instance of a product innovation assessment model. This file is the instance that was applied to assess Skype and that was deeply described in Chapter 6.

---

```
<?xml version="1.0" encoding="UTF-8"?>
<innovation_assessment_model>
  <concepts>
    <dimensions>
      <dimension dimid1 = "dim01" dimName = "Organization" />
      <dimension dimid1 = "dim02" dimName = "Market" />
      <dimension dimid1 = "dim03" dimName = "Environment" />
      <dimension dimid1 = "dim04" dimName = "Technology" />
    </dimensions>
    <factors>
      <factor factorId = "factor01" name = "Commitment of project
        workers" definition = "It is the perception among the
        project team than the project is going to be completed
        successfully. Some factors contributing to commitment
        include loyalty to project leader, ego satisfaction, and
        a sense of liking for the project and the resulting new
        product." />
      <factor factorId = "factor02" name = "Communication"
        definition = "The need for adequate communication
        channels is extremely important in creating an atmosphere
        for successful project implementation. Communication is
        not only essential within the project team itself, but
        between the team and the rest of the organization as well
        as with the clients." />
      <factor factorId = "factor03" name = "Correct distribution
        channel" definition = "The path through which product and
        services travel from the vendor to the consumer or
        payments for those products travel from the consumer to
        the vendor. A distribution channel can be as short as a
        direct transaction from the vendor to the consumer, or
        may include several interconnected intermediaries along
        the way such as wholesalers, distributors, agents and
        retailers. Each intermediary receives the item at one
        pricing point and moves it to the next higher pricing
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    point until it reaches the final buyer." />
<factor factorId = "factor04" name = "Create, Make market
  interface" definition = "It determines the dependency
  relationship between the market and the product and how
  the product will/is accessing to the market." />
<factor factorId = "factor05" name = "Demand for quick
  result" definition = "An important part of evaluating the
  chances of carrying a project through to a successful
  conclusion is evaluating the patience of the supporting
  organization. Projects which start paying off soon are,
  everything else being equal, to be preferred over
  projects that have a distant payout. If there is not
  going to be enough patience, it may be best not to start.
  One of the worst mistakes that can be made in starting a
  project is to adopt, under pressure, an impossible time
  schedule and then miss the time check points built into
  the schedule." />
<factor factorId = "factor06" name = "Effectiveness of
  project manager" definition = "In high-tech firms the
  design features of the product can change a number of
  tunes due to the changing nature of the technology, and
  to unexpected events in the wider environment. If the
  project manager cannot effectively handle these changes
  and incorporate them into the design, the project may
  become obsolete even before its completion. The
  effectiveness with which the project manager handles
  changes in the technology and adapts to the environment
  is a key factor in the successful completion of the
  project." />
<factor factorId = "factor07" name = "Effects on other
  business" definition = "When successful completion of a
  new project would put the sponsoring organization in
  competition with one of its good customers for another
  product. A perception that introducing a new project
  might hurt existing profitable businesses will almost
  certainly defeat proposals that the new project be
  implemented. One should try to identify such conflicts
  early." />
<factor factorId = "factor08" name = "Emphasize Marketing"
  definition = "It determines if product type/innovation
  strategy is related to R&D/marketing programs and the
```

```
market environment, and that R&D/marketing decisions,
market characteristics, and product type/innovation
strategy all influence new product sales performance." />
<factor factorId = "factor09" name = "Error free production"
definition = "To measure how sensible is the product to
errors while producing it." />
<factor factorId = "factor10" name = "High Level Management
support" definition = "Top management\'s support of the
project may involve aspects such as allocation of
sufficient resources (including financial, manpower,
time, etc.) as well as project management\'s confidence
in their support in the event of crisis. It represents
how confident is the Top management in the success of the
project." />
<factor factorId = "factor11" name = "Inexpensive
development" definition = "It measures the investment
needed to develop the product." />
<factor factorId = "factor12" name = "Internal competition"
definition = "Competition from another project for
similar resources, in many cases, can act as a catalyst
for successful project completion. The demand for the
resources can force the project leader and his team to
put in extra effort to complete the project successfully.
Even if the groups are not working on the same project,
the simple presence of multiple demands for resources may
enhance the motivation of the project team." />
<factor factorId = "factor13" name = "Management and other
skills" definition = "It measures if the company has
people involved to cover all the skills that are needed
in the product development." />
<factor factorId = "factor14" name = "Meeting cost schedules"
definition = " It measures how frequently schedules are
revised. As much revisions the cost is increased." />
<factor factorId = "factor15" name = "Markets and Technique
are strength" definition = "It measures the company
strength in market and techniques. As much strength is
the company as better results will be obtained and it
will be easy to access to the market."/>
<factor factorId = "factor16" name = "Monitoring and
feedback" definition = "Monitoring and feedback refer to
the project control process by which, at each stage of
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the project implementation, key personnel receive feedback on how the project is comparing to initial projections. Making allowances for adequate monitoring and feedback mechanisms gives the project manager the ability to anticipate problems, to oversee corrective measures, and to ensure that no deficiencies are overlooked. For our model, Monitoring and Feedback refers not only to project schedule and budget, but also to monitoring performance of members of the project team."/>

```
<factor factorId = "factor17" name = "Newness to firm"
  definition = " It measures if the product is new to the
  company or not. A product that is new to the firm is not
  a plus." />
```

```
<factor factorId = "factor18" name = "Organization plans"
  definition = "It measures if the organization has
  definite ideas about the types of business it wants to be
  in and the directions in which it wants to grow. These
  ideas are defined in long range plans, policies,
  statements of objectives and so forth. A project will be
  much more warmly received if it fits these stated
  perceptions of the type of projects desired." />
```

```
<factor factorId = "factor19" name = "Potential interest of
  technical staff" definition = "In the evaluation of
  technical feasibility, the adequacy of technical staff
  resources to carry out a project are considered. The
  Environment question is whether the project is likely to
  attract the interest and enthusiasm of the technical
  staff. If the technical staff does become interested in a
  project, the members will work nights as well as days,
  improve their skills related to doing the project and
  take an active rather than a passive role in solving
  problems. The chances of a project succeeding are greatly
  enhanced by real technical staff interest." />
```

```
<factor factorId = "factor20" name = "Project mission"
  definition = "It measures if the product has clear and
  understandable goals as well as ultimate benefits at the
  outset, not only by the project team involved, but by the
  other departments in the organization. The goals of the
  project are in line with the general goals of the
  organization." />
```

```
<factor factorId = "factor21" name = "Project schedule"
```

```
definition = "Project schedule refers to the importance
of developing a detailed plan of the required stages of
the implementation process. As developed in our model,
Project Schedule/Plan refers to the degree to which time
schedules, milestones, manpower, and equipment
requirements are specified. Further, the schedule should
include a satisfactory measurement system as a way of
judging actual performance against budget and time
allowances." />
<factor factorId = "factor22" name = "Project Manager as a
project champion" definition = "It focuses on the project
champion by suggesting that the most auspicious champion
is the project manager himself and that his importance
becomes most critical toward the end of the development
phase. It measures the ability of the top management to
push the project to become champion." />
<factor factorId = "factor23" name = "Qualified project
manager" definition = "It measures if the company has a
qualified project manager to lead the product to be
successful." />
<factor factorId = "factor24" name = "Quantitative project
selection" definition = "A quantitative project selection
system-based on estimates of project cost, duration, and
probability of technical completion and market estimates
of sales and product life-was instituted by firms." />
<factor factorId = "factor25" name = "R&D process well
planned" definition = "It measures if the R&D
activities that are needed to develop the product has
been properly scheduled. It is only applied when the
project needs R&D activities." />
<factor factorId = "factor26" name = "Source of project
ideas" definition = "It analyses where ideas come from.
Two-thirds of the R&D projects stemmed from the
R&D department. But it does not mean a high
probability of technical completion. The projects
stemming from the R&D department may be less firmly
based on market realities than those submitted by the
marketing (and other) departments, so they may be more
likely to be stopped short of technical completion
because of lack of potential profitability. On the other
hand, because the R&D department understands the
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```
    technical aspects of R&D projects so well, it tends
    to be a better judge than other departments of what is
    technically feasible." />
<factor factorId = "factor27" name = "Staff of professionals"
  definition = "It measures the level of qualification
  required to the staff." />
<factor factorId = "factor28" name = "Strong sales force"
  definition = "It measures the availability of a strong
  sales force to put the product into the market." />
<factor factorId = "factor29" name = "Technology tied to
  business strategy" definition = "Technology-push projects
  tend to be more ambitious and aimed at larger potential
  payoffs, the probability of economic success (given
  commercialization) may decrease as the percentage of
  R&D expenditures devoted to demand-pull projects
  increases. Technology-push projects are harder to sell to
  marketing, production, and other parts of the firm than
  those of demand-pull projects." />
<factor factorId = "factor30" name = "Technological
  background of managers" definition = "It measures if
  managers have a technological background facilitating the
  development of the product." />
<factor factorId = "factor31" name = "Timing" definition =
  "It measures if the product is developed when the
  interest in it is high. There will be times when it is
  avoid for new projects and other times when it has little
  interest in them. A new project surely has a better
  Environment for acceptance when its timing is right."/>
<factor factorId = "factor32" name = "Training and Experience
  of own people" definition = "It measure if the project
  could be performed by the own people or if it depends on
  external people." />
<factor factorId = "factor33" name = "Trouble shooting"
  definition = "It is impossible to foresee every trouble
  area or problem that could possibly arise. As a result,
  it is important that the project manager make adequate
  initial arrangements for Trouble-Shooting mechanisms to
  be included in the implementation plan. Such mechanisms
  would make it easier to not only react to problems as
  they arise, but to foresee and possibly forestall
  potential problems areas in the implementation process."
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    />
<factor factorId = "factor34" name = "Understanding market"
  definition = "Growing business without understanding your
  competitors is risky. Market research can prepare you for
  changing markets and prevent the product being left
  behind by the competition." />
<factor factorId = "factor35" name = "Use outside
  communication" definition = "It measure the impact of
  using external communication and additional communication
  channels to develop the product." />
<factor factorId = "factor36" name = "Technology route"
  definition = "A clear understanding of the technological
  route is a prerequisite for the success of a project.
  However in the high tech area the technological route
  tends to be disjointed as new developments come on the
  horizon fairly quickly. Nevertheless, the project should
  stay on the original technological track and not veer
  widely from that route . This is very important in high
  tech firms." />
<factor factorId = "factor37" name = "Risk Distribution"
  definition = "The commercial success of the product does
  not depend on the narrow line of production and market."/>
<factor factorId = "factor38" name = "Competitive
  environment" definition = "The competitive environment,
  also known as the market structure, is the dynamic system
  in which business competes. The state of the system as a
  whole limits the flexibility of your business. It
  describes the ease of market entry." />
<factor factorId = "factor39" name = "Competitor analysis"
  definition = "It is a strategic technique used to
  evaluate outside competitors. The analysis seeks to
  identify weaknesses and strengths that a company\'s
  competitors may have, and then use that information to
  improve efforts within the company. Three factors are
  important in analyzing the competition. The first is the
  ability of a competitor to take defensive measures; a
  well-managed company with low costs and a strong cash
  flow might easily fend off competitors. The second is
  patent protection; an innovation is likely to have more
  success if it has strong patent protection against
  competitors. The third is the pace of change in the
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    technology; if innovation occurs quickly in an area, a
    new development may be obsolete in only a few years." />
<factor factorId = "factor40" name = "Early analysis of
market and competitors" definition = "It measures if a
market analysis has been performed in advance. The
competitor analysis may give the toughest time,
especially if the company is new to the marketplace."/>
<factor factorId = "factor41" name = "Early to market"
definition = "It measures if the market is mature enough
to accept the product." />
<factor factorId = "factor42" name = "Few competitors"
definition = "Few competitors mean fewer firms are
competing for the same customers and resources.
Relatively Few Competitors will have a long-term positive
impact, which adds to its value. This statements will
have a short-term positive impact, which adds to its
value. This qualitative factor will lead to a decrease in
costs."/>
<factor factorId = "factor43" name = "High Contribution
margin" definition = "The contribution margin is the
marginal profit per unit sale, and is the sum of a
company\'s turnover minus their direct costs. This factor
measures how flexible is the contribution margin." />
<factor factorId = "factor44" name = "Life cycle of product"
definition = "If the product is in the growth phase of
its life cycle the rate of new product introduction will
be high, which leads to a higher degree of success . If
it is in the infancy stage the product may still not be
fully developed resulting in many false starts. On the
other hand, a mature product will require enormous
resources in order to introduce new variations. Most high
technology projects are in the infancy or the growth
stage." />
<factor factorId = "factor45" name = "Lower cost" definition
= "It measures if the product is providing a lower cost
than other competitors existing in the same category.
Will the product offer to the customer in terms of unique
features the lower cost?" />
<factor factorId = "factor46" name = "Market analysis"
definition = " An evaluation of the market for a
company\'s goods and services. Research that offers
```



assistance in forecasting price trends for stocks and bonds. Market analysis may concentrate on fundamental factors including earnings, inflation, and costs, or it may be directed at technical considerations such as trading volume and price charts." />

```
<factor factorId = "factor47" name = "Market existence"
  definition = " It measures if is there any existing
  market or if this product is creating a new market. An
  existing marketing and distribution system which can
  present and distribute the new product is a real asset to
  a project." />
```

```
<factor factorId = "factor48" name = "Meet customer
  needs/wants" definition = "It measures if the product is
  developed because there is a identified of customer
  needs\wants." />
```

```
<factor factorId = "factor49" name = "Number of end users"
  definition = "It measures the number of end users in
  relationship with the market size. In their enthusiasm,
  the originators may perceive their new idea to be
  applicable in a number of widely unconnected markets .
  Unfortunately, much fruitless effort will be spent in
  designing a general product which can be used in a
  variety of situations . This results in a loss of focus
  in product design." />
```

```
<factor factorId = "factor50" name = "Perceived value"
  definition = "A customer\'s opinion of a product\'s value
  to him or her. It may have little or nothing to do with
  the product\'s market price, and depends on the
  product\'s ability to satisfy his or her needs or
  requirements. It is an important marketing concept. It
  lies at the heart of marketing and deals solely with the
  customer\'s perception of a product. Perceived value is a
  consolidated measure because it takes into account
  subjective perceptions with limits placed on it by price
  and other objective costs." />
```

```
<factor factorId = "factor51" name = "Probability of
  commercial success" definition = "Even when the
  allocation of funding into different classifications
  increases the odds of funding a riskier R&D project,
  it is still necessary to allocate funds within each
  classification. A possible approach for deciding between
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projects is to use expected commercial value (ECV), which
amalgamates the probabilities of success into a more
standard net present value calculation." />
<factor factorId = "factor52" name = "Rate of new product
introduction" definition = "If new products or
significant adaptations are introduced In the market
fairly regularly, say once in six months or less, it
demonstrates that there is a great deal of product
Innovation taking place and that the market has not
stabilized. Therefore, any new product with improvements
over existing products has a good chance of being
successful . For example if one is in the digital watch
industry, any new gimmick on a new watch design, provided
it meets other market considerations, has a good chance
of success . Moreover, since so many different designs
are being introduced, another new one is unlikely to be
seriously hurt in the market." />
<factor factorId = "factor53" name = "Response to growing
markets" definition = "Emerging markets are those
countries that have growing economies and a growing
middle class. Some of these countries were once poor, and
some still have high rates of poverty. Many are
undergoing profound social and political change for the
better. A sector of the economy experiencing a
higher-than-average growth rate. Growth industries are
often associated with new or pioneer industries that did
not exist in the past and their growth is related to
consumer demand for the new products or services offered
by the firms within the industry." />
<factor factorId = "factor54" name = "Sales/profit potential"
definition = "It measures if the gross sale decreases
that also affect the profits by decreasing them because
the gross sales are the total amount of the sale before
any discounts or allowances are made on the sale. If the
gross sales increase then the amount of profit also
increases because the more company sells the more the
company has the potential to make more profit. It the
project will not be profitable enough around 40%
before-tax return it should be abandoned." />
<factor factorId = "factor55" name = "Slow growth market"
definition = " An increase in the demand for a particular
```

product or service over time. Market growth can be slow if consumers do not adopt a high demand or rapid if consumers find the product or service useful for the price level. For example, a new technology might only be marketable to a small set of consumers, but as the price of the technology decreases and its usefulness in every day life increases, more consumers could increase demand. A market that currently exhibits low trading volumes and/or low volatility levels. The term slow market can be used to describe a market with few issues coming up for sale to investors through initial public offerings and secondary offerings in the equity markets, or through new issuance in the corporate bond market."/>

```
<factor factorId = "factor56" name = "Strength of market"
  definition = "Market strength is a broad term that can
  mean a lot of things, depending on how we define it.
  Market strength can be a measure of a market\'s power to
  perform either on a relative basis (vs. other markets) or
  on an absolute basis (vs. its own historical levels of
  momentum and investor participation)." />
```

```
<factor factorId = "factor57" name = "Client acceptance"
  definition = "It refers to the final stage in the
  implementation process, at which time the ultimate
  efficacy of the project is to be determined. Too often
  project managers make the mistake of believing that if
  they handle the other stages of the implementation
  process well, the client (either internal or external to
  the organization) will accept the resulting project. In
  fact, client acceptance is a stage in project
  implementation that must be managed like any other." />
```

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<factor factorId = "factor58" name = "Available Resources or
Raw material" definition = "Raw material is a material or
substance used in the primary production or manufacturing
of a good. The more certain the supply of necessary raw
materials or components, the greater are the chances of
business success." />
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<factor factorId = "factor59" name = "Government Regulations"
  definition = "It represents when the legislative and
  executive branches set and enact laws that determine how
  a specific task, business, or industry is supposed to
  run." />
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<factor factorId = "factor60" name = "Industry restructure
  opportunity" definition = "A new entrant can become the
  dominant competitor when it makes technological
  breakthroughs in a stagnant industry, particularly when
  the new entrant has strong patent protection and
  competitors are small and fragmented. Also a basic
  innovation in an existing market offers opportunities to
  capture downstream use or application markets." />
<factor factorId = "factor61" name = "Political/Social
  factors" definition = "It represents political or social
  factors that could impact in product development like
  Antitrust, Ecology, Foreign eXchange, Geography or
  Sovereign rights." />
<factor factorId = "factor62" name = "Public interest on
  product" definition = "Public interest is a principle by
  which the government can request that sensitive documents
  are not used as evidence in a trial, on the grounds that
  to do so would be against the public or national
  interest. It represents in which the whole society has a
  stake and which warrants recognition, promotion, and
  protection by the government and its agencies."/>
<factor factorId = "factor63" name = "Product liability"
  definition = "The legal liability a manufacturer or
  trader incurs for producing or selling a faulty product.
  It measures the responsibility of the company to ensure
  that products are safe and do not cause injury to users."
  />
<factor factorId = "factor64" name = "Demand Pull vs
  Technology push" definition = "Technology-push projects
  tend to be more ambitious and aimed at larger potential
  payoffs. Demand-pull means that there is market behind
  the product. Technology-push projects are harder to sell
  to marketing, production, and other parts of the firm
  than those of demand-pull projects. It is quite likely
  that technology-push projects tend to be more risky than
  demand-pull projects." />
<factor factorId = "factor65" name = "Directions for
  scientific development" definition = "It measures is the
  product is opening new directions for scientific
  development. These directions will promote new patents or
  new objects." />
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<factor factorId = "factor66" name = "High performance/cost
proportion" definition = "The cost-performance ratio is
an equation used to balance the cost of an item against
its effectiveness. This process can help buyers with
making purchasing decisions by assigning rankings to a
series of items based on a variety of factors.
Cost-performance can also be used to analyze trends in
production." />
<factor factorId = "factor67" name = "Incremental product"
definition = "Incremental product innovation concerns an
existing product whose performance has been significantly
enhanced or upgraded. This again can take two forms. A
simple product may be improved (in terms of improved
performance or lower cost) through use of higher
performance components or materials, or a complex product
which consists of a number of integrated technical
subsystems may be improved by partial changes to one of
the subsystems." />
<factor factorId = "factor68" name = "Innovative product"
definition = "It measures if the product was highly
innovative-totally new to the market." />
<factor factorId = "factor69" name = "Patents" definition =
"Protected by a trademark or a brand name so as to
establish proprietary rights analogous to those conveyed
by letters patent or a patent." />
<factor factorId = "factor70" name = "Problem definition"
definition = "it measures if the product is properly
defined. Customer needs for new products are difficult to
articulate and sort out, because the customers themselves
may not be sure, the knowledge itself is often tacit, and
that knowledge may be embedded in a context of use and
not retrievable except by hands-on interaction with that
context. To put problem definition more positively,
successful new products have more market knowledge than
failed ones." />
<factor factorId = "factor71" name = "Probability of
technical success" definition = "If the project is
proceeding along a fairly well defined technological
route, and there are not many unsolved technological
problems the probability of success will remain the same
as before or may even increase. On the other hand,
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    technological problems in some key area may make the
    project unfeasible. " />
<factor factorId = "factor72" name = "Utility" definition =
    "It represents if the developed product is perceived as
    useful by customers, that may result from a project is
    the utility of the product to those who will buy and use
    it. It measures the level of utility of the product.
    Utility should be judged in relation to other products
    the customer may use to fulfill a need." />
</factors>
</concepts>
<innovation_model>
<model modelId="modelBa1997u" modelName="Balachandra"
    modelYear="1997" modelVersion="1.0"
    modelDescription="Balachandra product innovation model
    unweighted" />
<model_items>
<model_item modItemId = "mid201" modelId="modelBa1997u"
    dimid1="dim01" factorId="factor01" impact="positive"
    weight="1" interpretation = "In the case of SiS, it is
    interpreted in the same way." help = " It should be rated
    with &lt;i&gt;Very high&lt;/i&gt; when the team has the
    perception about the success of the project and with
    &lt;i&gt;Very low&lt;/i&gt; it is not clear if the
    project is going to be finished." />
<model_item modItemId = "mid202" modelId="modelBa1997u"
    dimid1="dim01" factorId="factor02" impact="positive"
    weight="1" interpretation = "In the case of SiS, it is
    interpreted in the same way." help = " It should be rated
    with &lt;i&gt;Very high&lt;/i&gt; when the product could
    be developed with very few or none communication
    dependency with the customer and with &lt;i&gt;Very
    low&lt;/i&gt; when communication with customer or
    development team is critical for the project success."/>
<model_item modItemId = "mid203" modelId="modelBa1997u"
    dimid1="dim01" factorId="factor03" impact="positive"
    weight="1" interpretation = "In the case of SiS, it is
    focused on the different distribution channels and the
    impact that these channels have in the product
    distribution. Is the product available to direct download
    from Internet? Do customer need special channels to
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access to the product?" help = "It should be rated with
<i></i>Very high</i> when the success does not
depends on the distribution channel and with
<i></i>Very low</i> when the product success
depends on the distribution channel." />
<model_item modItemIid = "mid204" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor04" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = " It should be rated
  with <i></i>Very high</i> when the access to the
  market already exists and the product is going to use it
  and with <i></i>Very low</i> when it is critical
  to have a clear interface to access to the market and the
  product should create the interface." />
<model_item modItemIid = "mid205" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor05" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i></i>Very high</i> when there is patience
  enough to start paying off and with <i></i>Very
  low</i> when there is not going to be enough
  patience to start paying off soon." />
<model_item modItemIid = "mid206" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor06" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i></i>Very high</i> when the project
  requires that the project manager handle changes in the
  environment and technology very fast; therefore the
  project manager needs to have the ability to handle
  changes in a fast way and with <i></i>Very
  low</i> when the project does not require to react
  in a fast way when the environment or technology is
  changing and therefore, the project manager does not need
  to be able to handle changes." />
<model_item modItemIid = "mid207" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor07" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i></i>Very high</i> when there are no other
  projects at the same time for the same team in
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    competition in the same company and with <i>Very
    low</i> when there are other projects in
    competition in the same company." />
<model_item modItemId = "mid208" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor08" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when sales do not
  depend on marketing campaigns and with <i>Very
  low</i> when marketing decisions have a deep impact
  on product sales." />
<model_item modItemId = "mid209" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor09" impact="positive"
  weight="1" interpretation = "In the case of SiS, this
  factor measures the level of testing performed to assure
  that the product is error free." help = "It should be
  rated with <i>Very high</i> when the product
  is going to be tested exhaustively previous to be on the
  market and with <i>Very low</i> when no
  specific testing processes are needed." />
<model_item modItemId = "mid210" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor10" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = " It should be rated
  with <i>Very high</i> when the Top management
  of the company is supporting the project and with
  <i>Very low</i> when the project is supported
  by departments but there is not a clear support from the
  company\'s structure." />
<model_item modItemId = "mid211" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor11" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way. Could the product be
  developed with the resources available in the company?."
  help = "It should be rated with <i>Very
  high</i> when the company has resources enough to
  develop the product and with <i>Very low</i>
  when the company does not have resources enough and it
  should make an investment to develop the product." />
<model_item modItemId = "mid212" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor12" impact="positive"
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weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the product is
receiving synergies from existing or previous development
in the company and with <i>Very low</i> when
the project is not receiving synergies from other
projects from the company." />
<model_item modItemId = "mid213" modelId="modelBa1997u"
dimid1="dim01" factorId="factor13" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when all the skills
needed for the project are covered by the company and
with <i>Very low</i> when most of the
requested skills are missing." />
<model_item modItemId = "mid214" modelId="modelBa1997u"
dimid1="dim01" factorId="factor14" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way" help = "It should be rated
with <i>Very high</i> when the project is
managed in a way where very few review meetings are need
and schedules are revised very few and with <i>Very
low</i> when schedules are revised frequently."/>
<model_item modItemId = "mid215" modelId="modelBa1997u"
dimid1="dim01" factorId="factor15" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the company is
strength in the market and the technology needed to
develop the product and with <i>Very low</i>
both market and technology are new for the company."/>
<model_item modItemId = "mid216" modelId="modelBa1997u"
dimid1="dim01" factorId="factor16" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the product is
developed with fast feedback loops and with <i>Very
low</i> when the product is developed without any
feedback." />
<model_item modItemId = "mid217" modelId="modelBa1997u"
dimid1="dim01" factorId="factor17" impact="both"
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weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = " It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the product is not
completely new because the company has a background and
with &lt;i&gt;Very low&lt;/i&gt; when the product is
completely new and, therefore, the knowledge about both
the product and market is limited." />
<model_item modItemIid = "mid218" modelId="modelBa1997u"
dimid1="dim01" factorId="factor18" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the company has
established plans to develop the product and with
&lt;i&gt;Very low&lt;/i&gt; when there are no clear
directions in which the company wants to grow." />
<model_item modItemIid = "mid219" modelId="modelBa1997u"
dimid1="dim01" factorId="factor19" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the technical
staff is interested in the project and with &lt;i&gt;Very
low&lt;/i&gt; when there is no special interest in the
staff about the project." />
<model_item modItemIid = "mid220" modelId="modelBa1997u"
dimid1="dim01" factorId="factor20" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the goal of the
product are clearly stated and aligned with the company
and with &lt;i&gt;Very low&lt;/i&gt; when the neither the
goals are stated nor the product is aligned with the
company strategy." />
<model_item modItemIid = "mid221" modelId="modelBa1997u"
dimid1="dim01" factorId="factor21" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = " It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the product
development has been scheduled before starting the
project and with &lt;i&gt;Very low&lt;/i&gt; when the
schedule is being built as the product is developed."/>
<model_item modItemIid = "mid222" modelId="modelBa1997u"
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dimid1="dim01" factorId="factor22" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when there is a project
leader or a team with the ability to push the project
when the development is stack and with <i>Very
low</i> when no one has the ability to push the
project." />
<model_item modItemIid = "mid223" modelId="modelBa1997u"
dimid1="dim01" factorId="factor23" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = " It should be rated
with <i>Very high</i> when the project
manager is skilled enough to lead the project. He knows
the product and the market and with <i>Very
low</i> when the project manager does not know the
scope of the project."/>
<model_item modItemIid = "mid224" modelId="modelBa1997u"
dimid1="dim01" factorId="factor24" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the project was
selected being the best evaluated considering among
others: cost, duration or market and with <i>Very
low</i> when no quantitative data supports the
project selection." />
<model_item modItemIid = "mid225" modelId="modelBa1997u"
dimid1="dim01" factorId="factor25" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = " It should be rated
with <i>Very high</i> when R&D activities
are scheduled and with <i>Very low</i> when
R&D activities are performed as they happen." />
<model_item modItemIid = "mid226" modelId="modelBa1997u"
dimid1="dim01" factorId="factor26" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the project is
pushed by the same department that proposed the idea and
it has the skills enough to develop the project and with
<i>Very low</i> when the idea is proposed and
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    developed by different departments." />
<model_item modItemId = "mid227" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor27" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the staff is
  composed by professional and with <i>Very
  low</i> when the staff does not have special
  skills." />
<model_item modItemId = "mid228" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor28" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way. All the existing
  distribution channels to put SiS in the market should be
  considered." help = "It should be rated with
  <i>Very high</i> when the company has a
  strong sales department to distribute the product and
  with <i>Very low</i> the company does not
  have a strong sales department." />
<model_item modItemId = "mid229" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor29" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the technology
  needed to develop the product is part of the strategy of
  the company and with <i>Very low</i> when the
  technology needed is not aligned with the company
  strategy." />
<model_item modItemId = "mid230" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor30" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when managers know the
  technology needed to develop the product and with
  <i>Very low</i> when managers are not
  familiar with the technology." />
<model_item modItemId = "mid231" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor31" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when it is the right
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time in terms off commitment, expenditures and
satisfaction in the product line and with <i>Very
low</i> when the company is more focused on other
product lines." />
<model_item modItemIid = "mid232" modelId="modelBa1997u"
dimid1="dim01" factorId="factor32" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = " It should be rated
with <i>Very high</i> when the product could
be developed with the available resources in the company
and with <i>Very low</i> when new people
should be enrolled to the company to perform the
product." />
<model_item modItemIid = "mid233" modelId="modelBa1997u"
dimid1="dim01" factorId="factor33" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way and also considering
different technological alternatives for implementing the
product." help = "It should be rated with <i>Very
high</i> when product metrics have been defined to
prevent and detect problems and with <i>Very
low</i> when no risk analysis has been performed
and there are no metrics to control the product
development." />
<model_item modItemIid = "mid234" modelId="modelBa1997u"
dimid1="dim01" factorId="factor34" impact="both"
weight="1" interpretation = "In the case if SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the market and the
target for the product have been clearly identified and
with <i>Very low</i> when the market has not
been studied in advance to product development." />
<model_item modItemIid = "mid235" modelId="modelBa1997u"
dimid1="dim01" factorId="factor35" impact="both"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when no outside
communication has been applied to develop the product;
that is team did not needed additional communication
channels to develop the product and with <i>Very
low</i> when additional communication channels have
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        been required in the development delaying or increasing
        the complexity of the development." />
<model_item modItemId = "mid236" modelId="modelBa1997u"
  dimid1="dim01" factorId="factor36" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product
  technological route is well defined and with
  <i>Very low</i> there was no agreement about
  the technological route to be taken." />
<model_item modItemId = "mid237" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor38" impact="both"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the market entry
  barriers are low and with <i>Very low</i>
  when it is hard to access to the market." />
<model_item modItemId = "mid238" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor39" impact="positive"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when very few
  competitors are in the market and with <i>Very
  low</i> there are several competitors providing
  similar products or services." />
<model_item modItemId = "mid239" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor40" impact="negative"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = " It should be rated
  with <i>Very high</i> when a market analysis
  has not been performed in advance to the product
  development and with <i>Very low</i> when a
  market analysis has been performed before." />
<model_item modItemId = "mid240" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor41" impact="negative"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the market is not
  mature to accept the product because the product is
  disruptive and with <i>Very low</i> when the
  market is mature to accept the new product." />
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<model_item modItemIid = "mid241" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor42" impact="positive"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when few competitors
  are in the market and with &lt;i&gt;Very low&lt;/i&gt;
  too many competitors are in the market." />
<model_item modItemIid = "mid242" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor43" impact="positive"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when the company has
  flexibility to fix the marginal profit and with
  &lt;i&gt;Very low&lt;/i&gt; when the profit is fixed by
  the market and the existing competitors." />
<model_item modItemIid = "mid243" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor44" impact="both"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when the product is in
  the growth phase and with &lt;i&gt;Very low&lt;/i&gt;
  when the product is in the infancy or the market is too
  mature." />
<model_item modItemIid = "mid244" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor45" impact="positive"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when it is able to put
  on the market the product at lower prices than
  competitors with the same features and with &lt;i&gt;Very
  low&lt;/i&gt; when there are some other products from
  competitors with the same features and at lower prices."
  />
<model_item modItemIid = "mid245" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor46" impact="both"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when the company has
  performed a market analysis for the product before to be
  put in the market and with &lt;i&gt;Very low&lt;/i&gt;
  when there is not a market analysis for the product. It
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means a high risk." />
<model_item modItemId = "mid246" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor47" impact="positive"
  weight="1" interpretation = " In the case of SiS it could
  be interpreted as if the market is ready to accept the
  new functionality provided the product. " help = "It
  should be rated with &lt;i&gt;Very high&lt;/i&gt; when
  the market is mature enough or is requesting new
  functionalities and it ready to accept new products and
  with &lt;i&gt;Very low&lt;/i&gt; when the market is
  comfortable with the existing products and it is not
  demanding new functionalities." />
<model_item modItemId = "mid247" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor48" impact="both"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when the product is
  driven by a customer who has a need and with
  &lt;i&gt;Very low&lt;/i&gt; when there is no a final
  customer defining the product." />
<model_item modItemId = "mid248" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor49" impact="positive"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when the number of
  users is enough to keep the product focused and with
  &lt;i&gt;Very low&lt;/i&gt; when the number of users is
  small, so that companies tend to design a general product
  reducing the innovation." />
<model_item modItemId = "mid249" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor50" impact="positive"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with &lt;i&gt;Very high&lt;/i&gt; when the user consider
  that product is providing a high value and customers
  perceive that the product will help them and with
  &lt;i&gt;Very low&lt;/i&gt; when it is not clear how much
  value is providing the product." />
<model_item modItemId = "mid250" modelId="modelBa1997u"
  dimid1="dim02" factorId="factor51" impact="positive"
  weight="1" interpretation = " In the case of SiS it is
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interpreted in the same way." help = "It should be rated
with <i>Very high</i> when it is expected a
commercial success and with <i>Very low</i>
when it is unknown or it is not clear the commercial
success." />
<model_item modItemIid = "mid251" modelId="modelBa1997u"
dimid1="dim02" factorId="factor52" impact="positive"
weight="1" interpretation = "In the case of SiS the time
frame is less than six month. It is typical to launch new
versions every three months. Due to the nature of
software the rate of new product could be high in opening
market." help = "It should be rated with <i>Very
high</i> when the number of product introduction is
growing for a market and with <i>Very low</i>
the number of new products in the market is very low or
even null." />
<model_item modItemIid = "mid252" modelId="modelBa1997u"
dimid1="dim02" factorId="factor53" impact="positive"
weight="1" interpretation = "In the case of SiS growing
markets are not related with growing economies but to new
sectors where SiS are applied." help = "It should be
rated with <i>Very high</i> when the product
is become a pioneer in the market and with <i>Very
low</i> the product does not belong to a growing
market but a well established market." />
<model_item modItemIid = "mid253" modelId="modelBa1997u"
dimid1="dim02" factorId="factor54" impact="positive"
weight="1" interpretation = " In the case of SiS it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the factor is
greater than 40 \% and with <i>Very low</i>
when the factor is less than 40\%" />
<model_item modItemIid = "mid254" modelId="modelBa1997u"
dimid1="dim02" factorId="factor55" impact="negative"
weight="1" interpretation = "In the case of SiS it is
interpreted in the same way." help = "It should be rated
with <i>Very high</i> when the market growth
is very slow considering a mature market and with
<i>Very low</i> when the growth is slow but
the market is quite new." />
<model_item modItemIid = "mid255" modelId="modelBa1997u"
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dimid1="dim02" factorId="factor56" impact="positive"
weight="1" interpretation = "In the case of SiS it is
interpreted in the same way." help = "It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the market has a
huge amount of potential users and there are some other
products in the market and with &lt;i&gt;Very
low&lt;/i&gt; when the market is not solid or it is
starting." />
<model_item modItemIid = "mid256" modelId="modelBa1997u"
dimid1="dim02" factorId="factor57" impact="positive"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
with &lt;i&gt;Very high&lt;/i&gt; when the product is the
last stage of development and with &lt;i&gt;Very
low&lt;/i&gt; when the product is still under
development." />
<model_item modItemIid = "mid257" modelId="modelBa1997u"
dimid1="dim02" factorId="factor37" impact="positive"
weight="1" interpretation = "In the case of SiS it
measures if the product success is independent of
distribution channel or if the distribution channel is
limiting the product accessing to the market." help = "It
should be rated with &lt;i&gt;Very high&lt;/i&gt; when
the market is accessible without limitation of the
existing distribution channels and with &lt;i&gt;Very
low&lt;/i&gt; when the market distribution channel is
very restrictive." />
<model_item modItemIid = "mid258" modelId="modelBa1997u"
dimid1="dim03" factorId="factor58" impact="positive"
weight="1" interpretation = "In the case of SiS, it
concerns with the components (software and hardware) and
their stability needed to implement the system." help = "
It should be rated with &lt;i&gt;Very high&lt;/i&gt; when
all the components are available and stable and with
&lt;i&gt;Very low&lt;/i&gt; when most of the needed
resources will be provided by external companies or when
they are not mature enough." />
<model_item modItemIid = "mid259" modelId="modelBa1997u"
dimid1="dim03" factorId="factor59" impact="both"
weight="1" interpretation = "In the case of SiS, it is
interpreted in the same way." help = "It should be rated
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with <i>Very high</i> when government
regulations are defined and no changes are expected and
with <i>Very low</i> when there are no
government regulations yet but they are expected to be
defined in the future what could require companies to
make extensive changes resulting in greatly Increased
costs for the final product. In this case <i>Very
low</i> represents a negative impact."/>
<model_item modItemIid = "mid260" modelId="modelBa1997u"
  dimid1="dim03" factorId="factor60" impact="both"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product is
  breaking the market and competitors are small and
  fragmented and with <i>Very low</i> when the
  product is part of a market with many competitors. In
  this case <i>Very low</i> represents a
  negative impact." />
<model_item modItemIid = "mid261" modelId="modelBa1997u"
  dimid1="dim03" factorId="factor61" impact="both"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when product
  development is not affected by political or social
  factors outside the company and with <i>Very
  low</i> when product development depends on
  political or social institutions. In this case
  <i>Very low</i> represents a negative
  impact."/>
<model_item modItemIid = "mid262" modelId="modelBa1997u"
  dimid1="dim03" factorId="factor62" impact="both"
  weight="1" interpretation = "In the case of SiS it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product is
  considered as relevant to a mass population or market and
  with <i>Very low</i> when the product is
  targeted to a tight market or population."/>
<model_item modItemIid = "mid263" modelId="modelBa1997u"
  dimid1="dim03" factorId="factor63" impact="negative"
  weight="1" interpretation = "In the case of SiS, however,
  is now the principle controlling element in many
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industrial and consumer products. It is so pervasive that
it is found in just about every product that is labelled
electronic. Software can cause products to do strange and
even terrifying things. Software bugs and errors could
mean injuries or damages." help = "It should be rated
with <i>Very high</i> when the risk of
injuries is high and with <i>Very low</i>
when the risk of injuries is very low, but they could
happen. In the case of no injuries risk, this factor
should be rated as <i>Not Applicable</i>." />
<model_item modItemId = "mid264" modelId="modelBa1997u"
  dimid1="dim03" factorId="factor37" impact="positive"
  weight="1" interpretation = "In the case of SiS it
  measures if the product success is independent of
  distribution channel or if the distribution channel is
  limiting the product." help = "It should be rated with
  <i>Very high</i> when the product could be
  distributed by many distribution channels and markets and
  with <i>Very low</i> when the distribution
  channel is very restrictive." />
<model_item modItemId = "mid265" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor64" impact="both"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product could
  be categorized as demand-pull and with <i>Very
  low</i> when the product could be categorized as
  technology-push." />
<model_item modItemId = "mid266" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor65" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way but extending the concept of
  patents to copyrighted software." help = " It should be
  rated with <i>Very high</i> when new
  copyrights could be derived from the product and the new
  directions and with <i>Very low</i> when no
  new directions were associated to the product." />
<model_item modItemId = "mid267" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor66" impact="positive"
  weight="1" interpretation = "It is also known as
  price/performance ratio. The most desirable outcome is
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that the item is low cost, but high performance. In the middle of the scale are products that are either high performance and high cost, or low performance and low cost. The least desirable ranking tends to be for a product that is high cost, but low performance. As technology has advanced, products have become more powerful and increasingly more accessible to consumers."

help = "It should be rated with <i>Very high</i> when the product provides as much performances as expected by customers with the lowest cost and with <i>Very low</i> when the cost of the product is still high." />

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<model_item modItemId = "mid268" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor67" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when product could be
  put into the market in an incremental way by adding new
  features and with <i>Very low</i> when the
  product can not be put into the market incrementally." />
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<model_item modItemId = "mid269" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor68" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product is
  completely new to the market and with <i>Very
  low</i> when the product does not provide any new
  features or it has very few new features." />
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<model_item modItemId = "mid270" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor69" impact="positive"
  weight="1" interpretation = "In the case of SiS, a
  software patent is a patent that is provided to enhance
  computer performance by means of a computer application.
  There is no legal or conclusive definition for a software
  patent. This and the topic of related intellectual
  property (IP) protection rights have been intensely
  debated at all levels in the tech world. Different
  countries have different restrictions on patenting
  software innovations." help = "It should be rated with
  <i>Very high</i> when the software has many
  new components that have been copyrighted and with
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<i>Very low</i> when the intellectual
property is not relevant to the product." />
<model_item modItemId = "mid271" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor70" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when product features
  are well defined and the product is goal is clear and
  with <i>Very low</i> when product features
  are not defined or if the product does not have clear
  goals." />
<model_item modItemId = "mid272" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor71" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product
  technological route is well defined and they are feasible
  and with <i>Very low</i> when there is a high
  technological risk, that is, technology is not available
  and it is expected some delays due to technology." />
<model_item modItemId = "mid273" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor72" impact="both"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product is
  considered as useful to a wide range of customers and
  with <i>Very low</i> when it is not clear how
  useful is to customers or it is only useful to a small
  group of customers." />
<model_item modItemId = "mid274" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor36" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = "It should be rated
  with <i>Very high</i> when the product
  technological route is well defined and with
  <i>Very low</i> there was no agreement about
  the technological route to be taken." />
<model_item modItemId = "mid275" modelId="modelBa1997u"
  dimid1="dim04" factorId="factor57" impact="positive"
  weight="1" interpretation = "In the case of SiS, it is
  interpreted in the same way." help = " It should be rated
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with <i>Very high</i> when the product is the
last stage of development and with <i>Very
low</i> when the product is still under
development." />
<model_item modItemIid = "mid276" modelId="modelBa1997u"
dimid1="dim04" factorId="factor37" impact="positive"
weight="1" interpretation = "In the case of SiS, it
measures how the environment could affect to the product
distribution. If the product success is independent of
distribution channel technology or if the distribution
channel technology is limiting the product." help = "It
should be rated with <i>Very high</i> when
the product could be distributed by many distribution
channels and markets and with <i>Very low</i>
the distribution channel is very restrictive." />
<model_item modItemIid = "mid277" modelId="modelBa1997u"
dimid1="dim04" factorId="factor63" impact="negative"
weight="1" interpretation = "In the case of SiS, however,
is now the principle controlling element in many
industrial and consumer products. It is so pervasive that
it is found in just about every product that is labelled
electronic. Software can cause products to do strange and
even terrifying things. Software bugs and errors could
mean injuries or damages." help = "It should be rated
with <i>Very high</i> when the risk of
injuries derived from the technology used is very low,
but they could happen and with <i>Very
low</i> when the risk of injuries derived from the
technology used is high. In the case of no injuries risk,
this factor should be rated as <i>Not
Applicable</i>." />
</model_items>
</innovation_model>
<assessment_questionnaires>
<questionnaire questionnaireId = "quest_u_1" modelId =
"modelBa1997u" name="complete" version="1.0">
<assessment_lines>
<assessment_line lineId = "line_u_1_01" questionnaireId =
"quest_u_1" modItemIid = "mid201" type="Radio1"/>
<assessment_line lineId = "line_u_1_02" questionnaireId =
"quest_u_1" modItemIid = "mid202" type="Radio1" />

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<assessment_line lineId = "line_u_1_03" questionnaireId =
    "quest_u_1" modItemId = "mid203" type="Radio1" />
<assessment_line lineId = "line_u_1_04" questionnaireId =
    "quest_u_1" modItemId = "mid204" type="Radio1" />
<assessment_line lineId = "line_u_1_05" questionnaireId =
    "quest_u_1" modItemId = "mid205" type="Radio1" />
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        "quest_u_1" modItemId = "mid206" type="Radio1" />
<assessment_line lineId = "line_u_1_07" questionnaireId =
    "quest_u_1" modItemId = "mid207" type="Radio1" />
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    "quest_u_1" modItemId = "mid208" type="Radio1" />
<assessment_line lineId = "line_u_1_09" questionnaireId =
    "quest_u_1" modItemId = "mid209" type="Radio1" />
<assessment_line lineId = "line_u_1_10" questionnaireId =
    "quest_u_1" modItemId = "mid210" type="Radio1" />
<assessment_line lineId = "line_u_1_11" questionnaireId =
    "quest_u_1" modItemId = "mid211" type="Radio1" />
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    "quest_u_1" modItemId = "mid212" type="Radio1" />
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    "quest_u_1" modItemId = "mid213" type="Radio1" />
<assessment_line lineId = "line_u_1_14" questionnaireId =
    "quest_u_1" modItemId = "mid214" type="Radio1" />
<assessment_line lineId = "line_u_1_15" questionnaireId =
    "quest_u_1" modItemId = "mid215" type="Radio1" />
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<assessment_line lineId = "line_u_1_19" questionnaireId =
    "quest_u_1" modItemId = "mid219" type="Radio1" />
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<assessment_line lineId = "line_u_1_21" questionnaireId =
    "quest_u_1" modItemId = "mid221" type="Radio1" />
<assessment_line lineId = "line_u_1_22" questionnaireId =
    "quest_u_1" modItemId = "mid222" type="Radio1" />
<assessment_line lineId = "line_u_1_23" questionnaireId =
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<assessment_line lineId = "line_u_1_24" questionnaireId =
  "quest_u_1" modItemIid = "mid224" type="Radio1" />
<assessment_line lineId = "line_u_1_25" questionnaireId =
  "quest_u_1" modItemIid = "mid225" type="Radio1" />
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  "quest_u_1" modItemIid = "mid226" type="Radio1" />
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  "quest_u_1" modItemIid = "mid227" type="Radio1" />
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  "quest_u_1" modItemIid = "mid228" type="Radio1" />
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  "quest_u_1" modItemIid = "mid229" type="Radio1" />
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  "quest_u_1" modItemIid = "mid230" type="Radio1" />
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  "quest_u_1" modItemIid = "mid231" type="Radio1" />
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  "quest_u_1" modItemIid = "mid232" type="Radio1" />
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  "quest_u_1" modItemIid = "mid233" type="Radio1" />
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  "quest_u_1" modItemIid = "mid235" type="Radio2" />
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  "quest_u_1" modItemIid = "mid236" type="Radio1" />
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  "quest_u_1" modItemIid = "mid237" type="Radio2" />
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  "quest_u_1" modItemIid = "mid238" type="Radio1" />
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  "quest_u_1" modItemIid = "mid239" type="Radio1" />
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  "quest_u_1" modItemIid = "mid240" type="Radio1" />
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  "quest_u_1" modItemIid = "mid241" type="Radio1" />
<assessment_line lineId = "line_u_1_42" questionnaireId =
  "quest_u_1" modItemIid = "mid242" type="Radio1" />
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  "quest_u_1" modItemIid = "mid243" type="Radio2" />
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  "quest_u_1" modItemId = "mid246" type="Radio1" />
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  "quest_u_1" modItemId = "mid247" type="Radio2" />
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  "quest_u_1" modItemId = "mid248" type="Radio1" />
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  "quest_u_1" modItemId = "mid251" type="Radio1" />
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  "quest_u_1" modItemId = "mid252" type="Radio1" />
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  "quest_u_1" modItemId = "mid260" type="Radio2" />
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  "quest_u_1" modItemId = "mid261" type="Radio2" />
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  "quest_u_1" modItemId = "mid262" type="Radio2" />
<assessment_line lineId = "line_u_1_63" questionnaireId =
  "quest_u_1" modItemId = "mid263" type="Radio1" />
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        "quest_u_1" modItemIid = "mid267" type="Radio1" />
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        "quest_u_1" modItemIid = "mid272" type="Radio1" />
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        "quest_u_1" modItemIid = "mid274" type="Radio1" />
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## ANNEXES

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<assessment_line lineId = "line_u_2_29" questionnaireId =
  "quest_u_2" modItemId = "mid229" type="Radio1" />
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  "quest_u_2" modItemId = "mid232" type="Radio1" />
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  "quest_u_2" modItemId = "mid202" type="Radio1" />
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  "quest_u_2" modItemId = "mid205" type="Radio1" />
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  "quest_u_2" modItemId = "mid209" type="Radio1" />
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  "quest_u_2" modItemId = "mid214" type="Radio1" />
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  "quest_u_2" modItemId = "mid236" type="Radio1" />
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  "quest_u_2" modItemId = "mid246" type="Radio1" />
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  "quest_u_2" modItemId = "mid242" type="Radio1" />
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<assessment_line lineId = "line_u_2_50" questionnaireId =
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<assessment_line lineId = "line_u_2_51" questionnaireId =
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    "quest_u_2" modItemId = "mid253" type="Radio1" />
<assessment_line lineId = "line_u_2_55" questionnaireId =
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<assessment_line lineId = "line_u_2_58" questionnaireId =
    "quest_u_2" modItemId = "mid258" type="Radio1" />
<assessment_line lineId = "line_u_2_61" questionnaireId =
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<assessment_line lineId = "line_u_2_64" questionnaireId =
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<assessment_line lineId = "line_u_2_63" questionnaireId =
    "quest_u_2" modItemId = "mid263" type="Radio1" />
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    "quest_u_2" modItemId = "mid272" type="Radio1" />
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</assessment_questionnaires>
</innovation_assessment_model>
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