
Volume 86, issue 5, May 2013
ISSN 0164-1212
ELSEVIER
The Journal of
Systems and Software

The Journal of Systems and Software 86 (2013) 1390–1407

Contents lists available at SciVerse ScienceDirect

The Journal of Systems and Software

journal homepage: www.elsevier.com/locate/jss

Towards innovation measurement in the software industry

Henry Edison[a], Nauman bin Ali[a], Richard Torkar[a,b,*]

[a] Blekinge Institute of Technology, Karlskrona, Sweden
[b] Chalmers University of Technology and Gothenburg University, Gothenburg, Sweden

ARTICLE INFO

Article history:
Received 24 January 2012
Received in revised form
17 November 2012
Accepted 7 January 2013
Available online 8 February 2013

Keywords:
Innovation
Measurement
Systematic literature review
Metrics
Empirical study

ABSTRACT

In today's highly competitive business environments with shortened product and technology life cycle, it is critical for software industry to continuously innovate. This goal can be achieved by developing a better understanding and control of the activities and determinants of innovation. Innovation measurement initiatives assess innovation capability, output and performance to help develop such an understanding. This study explores various aspects relevant to innovation measurement ranging from definitions, measurement frameworks and metrics that have been proposed in literature and used in practice. A systematic literature review followed by an online questionnaire and interviews with practitioners and academics were employed to identify a comprehensive definition of innovation that can be used in software industry. The metrics for the evaluation of determinants, inputs, outputs and performance were also aggregated and categorised. Based on these findings, a conceptual model of the key measurable elements of innovation was constructed from the findings of the systematic review. The model was further refined after feedback from academia and industry through interviews.

1. Introduction

The modern business context is characterised by high competition driven by deregulation, empowered customers, emerging technology, globalisation of the economy, uncertain economic circumstances and rapid product development (Romijn and Albaladejo, 2002; Akman and Yilmaz, 2008; Gumusluoğlu and Ilsev, 2009). With shortened product and technology life-cycles, the software industry is particularly affected because of its knowledge-intensive and technology-driven nature (Romijn and Albaladejo, 2002). In this context, innovation is considered a key success factor, central to increasing economic output and productivity (Akman and Yilmaz, 2008). Innovation is the ability to dictate and modify the 'rules of the game' that enables organisations to gain entry to new markets and challenge established market leaders (Brown and Eisenhardt, 1995).

In the past, management has focused on cost, lead time reduction and quality improvement for competitiveness in the market (Rejeb et al., 2008). However, in today's competitive business environment, quality is a necessity but it is not sufficient (Romijn and Albaladejo, 2002; Rejeb et al., 2008). Organisations must continuously innovate, develop new processes and deliver novel products (in this study, we use the term 'products' for both goods and services), to achieve and sustain a competitive advantage (Muller et al., 2005; Rejeb et al., 2008).

Innovation helps organisations to gain large market share but if they fail to consistently innovate overtime they tend to loose their position to emerging firms that have innovative offerings (Muller et al., 2005). Such turnover signifies the importance of sustained innovation, thus the problem is not happen-stance innovation but rather doing it continuously on a regular basis. For sustained innovation to become a reality, a better understanding of innovation is required, which is possible only when innovation is measured (Kuczmarskl, 2001).

The importance of innovation measurement is well emphasised in industry. According to The Boston Consulting Group's survey (James et al., 2008), 74% of the executives believed that their company should track innovation as rigorously as core business operations, but only 43% of the companies actually measured innovation. Although, some companies think that innovation cannot and should not be measured, the real issue is a lack of metrics and measurements (James et al., 2008). This makes companies measure too little, measure the wrong things or not measure innovation at all (James et al., 2008).

There is little consensus on how innovation measurement should be carried out (Jensen and Webster, 2009). This lack of consensus is caused by the different definitions of innovation used. Each of these definitions signify a different aspect of innovation, e.g. perspectives, levels and types (Mathiassen and Pourkomeylian, 2003). This in turn determines what is considered as elements of innovation and how these are measured.

The perspective of innovation as adopted by an organisation would delineate the ideal measures of innovation (Jensen and

* Corresponding author. Tel.: +46 768653342.

0164-1212/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.jss.2013.01.013

Webster, 2009). For some problems a universal yardstick is enough but innovation encompasses creation of new opportunities, businesses, markets, environments, methods of working and operating (Shapiro, 2006). In essence no single measure can cover all these constituting aspects of innovation (Shapiro, 2006). The survey by The Boston Consulting Group revealed that only 35% of the executives were satisfied with their current innovation measurement practices. Part of the reason for this dissatisfaction could be that most of the companies (i.e. 58%) use less than five metrics, which is not enough for measuring the entire range of innovation activities (James et al., 2008).

Organisations require means not only to measure their innovative output but also to assess their ability and capacity to innovate. Measurement helps to better understand and evaluate the consequences of the initiatives geared towards innovation. Furthermore, like any other measurements, these will allow organisations to specify realistic targets of innovation in the future and to identify and resolve problems hindering progress towards goals, making decisions and continuously improve the abilities to innovate (Ebert and Dumke, 2007).

In this study, the area of innovation measurement was explored. The study attempts to contribute to the innovation measurement body of knowledge for the software industry. First, by performing a systematic literature review we establish the current state of art of innovation measurement. Second, the literature review is then complemented with a questionnaire and interviews to elicit the perception of innovation and the state of practice in the software industry. Finally, an innovation measurement model was developed for, amongst many things, identifying the aspects of innovation that are measurable and thus serving as a starting point for innovation measurement.

The remainder of this paper is structured as follows: Section 2 discusses the existing research related to this study and Section 3 presents the research methodology undertaken in this study. The results of this study are reported in Section 4 and discussed in Section 5. Section 6 presents the proposed model, which covers various dimension of innovation. Validity threats of the study are discussed in Section 7, while the conclusions and future work are covered in Section 8.

2. Related work

To the best of our knowledge, there is no systematic review on innovation measurement in the software industry. We have, however, identified several studies in other domains that attempt to address similar questions and issues as presented in this paper.

Becheikh et al. (2006) conducted a systematic review on technological innovation in the manufacturing sector from 1993 to 2003. The aim was to find what the main variables are and how they are used to measure the innovation behaviour and capacity of the organisation. The study was based on the empirical evidence reported in journals published in ABI/INFORM of Proquest, Business Source Premier (BSP) of EBSCO, and ScienceDirect of Elsevier. The study, however, only considered two areas, as suggested by the Oslo Manual (OECD, 2005): product and process innovation. Although the study identified 36 internal and 10 external determinants, no framework to measure innovation was proposed.

A systematic review by Crossan and Apaydin (2010) found the common definitions and determinants of innovation based on journals published in ISI Web of Knowledge's Social Sciences Citation Index (SSCI). The study also proposed a comprehensive framework of organisational innovation. However, the study did not focus on software industry and used only one database.

Several researchers have tried to develop a framework to measure innovation. Berg et al. (2008) proposed a model for measuring the front-end innovation activities based on three assessment areas: process, social, and physical environment. However, the model was developed for the manufacturing sector. Moreover, the proposed model is solely based on research and development data. Small and Medium Enterprises (SMEs) usually cannot afford to have dedicated R&D departments (Gorschek et al., 2010a). Therefore, we claim, that this model is not applicable in their particular context.

Misra et al. (2005) proposed a goal-driven measurement framework for measuring innovation activities in an organisation. The framework adopted the Goal-Question-Metric (GQM) approach to define the goals of an innovation program with accompanying metrics. Although they provided a set of metrics for measuring innovation, the study did not present a clear methodology on how they defined the goal, questions and metrics. The study also did not explain clearly the relationship between the suggested metrics and innovation.

Narayana (2005) proposed an innovation maturity framework to assess the maturity of the innovation process in a firm. The framework is modeled based on the Capability Maturity Model (CMM). However, the framework has not been validated and it does not provide any metrics to assess the process maturity. Moreover, it only considers R&D as the main factor to determine the maturity of a process.

3. Research methodology

The aims of this study were to establish the state of the art of innovation measurement and to capture the state of the practice of innovation measurement in the software industry. These aims were achieved by addressing the following objectives:

1. To identify the perception of innovation in software industry and the definitions of innovation in literature.
2. To identify the determinants or drivers of innovation in the software industry.
3. To identify the commonly used metrics to assess innovation.
4. To identify the existing innovation measurement models and major challenges in evaluating innovation.

A systematic literature review was conducted to establish the state of the art of innovation measurement. In this study, we conducted a systematic review as proposed by Kitchenham and Charters (2007) to accumulate primary studies aiming to improve the understanding and to ascertain the validity and reliability of claims and propositions. A defined review protocol, search strategy, explicit inclusion and exclusion criteria, and specified information that will be retrieved from primary studies differentiates a systematic review from a conventional literature review (Kitchenham and Charters, 2007).

To capture the state of the practice of innovation measurement, we used a questionnaire and face-to-face meetings to collect the opinions of software industry practitioners and academics. We followed the main steps in developing a questionnaire as suggested by Kasunic (2005). The results of the questionnaire were then used to confirm the findings of the systematic review.

Based on the findings from the systematic literature review and questionnaire, we conducted a conceptual analysis to develop an innovation measurement model. This model was evaluated through interviews with industry practitioners and academics. Interviews were also used to capture the perception of innovation and state of practice regarding innovation measurement in software industry, industrial interviews focused on evaluation of the usefulness and applicability of the proposed model for industry. Whereas the aim of the academic interviews was to assess the completeness and correctness of the proposed model. Both industrial

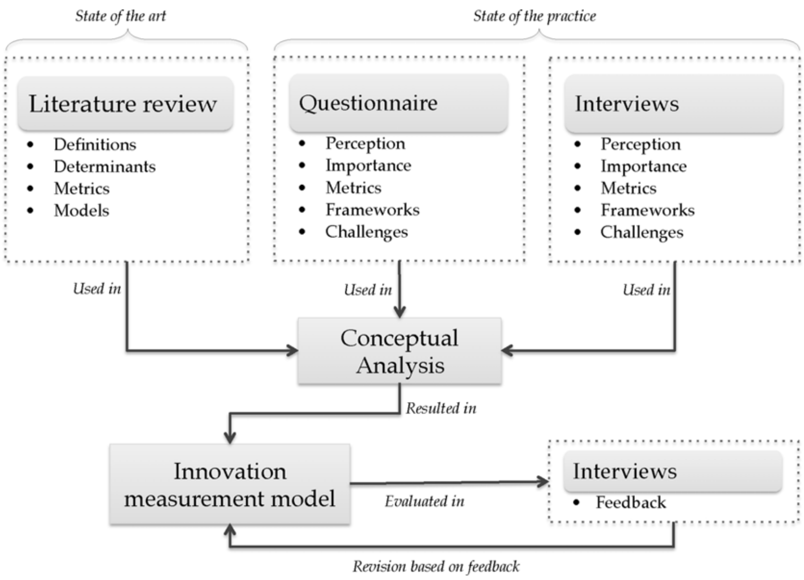

Fig. 1. Mapping of research aims and methodology as employed in this study.

and academic interviews in this study each lasted for 1 h. Overview of the research objectives and research methods used to achieve them are shown in Fig. 1.

3.1. Systematic literature review

3.1.1. Search strategy

We used seven online databases to perform the search: Inspec and Compendex (through Engineering Village), Scopus, IEEE Xplore, ACM Digital Library, ScienceDirect and Business Source Premier (BSP). The target for this review was journals published in the fields of engineering, economics, computer science, finance and management between 1949 and 2010. We choose this starting point even though the concept of innovation was first introduced by Schumpeter in 1911, the first English translation of his book, Theorie der wirtschaftlichen Entwicklung, was published in 1949 (Schumpeter, 1949). The search was conducted in early February 2010. We did not preselect the journals and relied on the journals included in the seven databases used.

To ensure that all the performed searches were consistent and comparable for each database, we used selected keywords and expressions. The generic search string with combination of keywords to answer the research questions was as follows:

(*"innovation" AND ("evaluat* *" OR "assess* *" OR "measur* *" OR "metric* *" OR "determinant" OR "driver" OR "key elements" OR "indicator* *" OR "attribute"*))

3.1.2. Study selection criteria

Three inclusion/exclusion criteria were defined to select the relevant articles for this study. The first criteria made sure that we only considered those primary studies, which are published in journals and are written in English. No duplicate studies were allowed. The second inclusion/exclusion criteria were based on the relevance of the primary studies to innovation and innovation measurement. The relevance of the studies was decided based on the title and abstract the criteria for this decision is listed in Table 1a. If a decision could not be made, the introduction and conclusion of the article were analysed. If there was still an uncertainty about the paper, it was classified as 'Doubtful' and submitted for discussion with the second reviewer.

The third inclusion/exclusion criteria (see Table 1b) were intended to check whether the relevant primary studies discussed the key concept of innovation and innovation measurement. To ensure that we had access to the selected key papers, we collaborated with a librarian to retrieve the papers in printed format. Any article available in full-text was included provided it met one of the remaining criterion in Table 1b.

Before performing the actual selection procedure a pilot selection was performed where both reviewers applied selection criteria on same 30 papers, individually. Then the results were compared to see if the two reviewers had a shared understanding of the criteria. By discussing the conflicts a coherent understanding of the criteria and procedure was developed. After having the same understanding, reviewers performed the actual studies selection. The list of studies extracted from the resources was divided equally among the reviewers and each member did selection independently.

Before executing the data extraction, we performed a pilot extraction to ensure that each reviewer understood and had the same interpretation of the form and data to be extracted. The pilot extraction was performed in a manner similar to the studies selection procedure. After having the same understanding and interpretation of the data extraction strategy, the actual data extraction was performed. While reading the full-text of the studies, key concepts from each study were extracted according to the agreed upon form finalised after piloting.

3.1.3. Characteristics of primary studies

We retrieved a total of 13,401 articles from all seven databases. By applying the three inclusion/exclusion criteria sequentially, we accepted 204 articles as primary studies. In the preliminary selection, we rejected 2683 articles for not meeting the requirements of being written in English, being peer-reviewed article or being a duplicate. Applying the relevance criteria, we rejected 10,273 articles based on title and abstract. We applied the advanced criteria to the remaining articles and filtered out 75 of them, which were unavailable in full-text. We also rejected 166 articles since they did not discuss the key concepts that we were looking for and finally, as mentioned previously, we accepted 204 remaining articles as the selected primary studies.

Table 1
Selection criteria.

(a) Relevance criteria	
1.	Include the articles that focus on organisational level and exclude the ones that explore regional strategies and policies or other external entities for innovation.
2.	Include the articles from management, software engineering, economics and computer science and exclude the articles from chemical, mechanical, medical, education, etc.
3.	Include an article that discusses or potentially discusses any of the following: definition or determinants of innovation or metrics or frameworks for innovation measurement (we revisited these criteria when we performed advanced inclusion criteria as shown in (b). However, exclude an article that presents inventions or discusses the usage, application and evaluation of inventions.
(b) Advanced inclusion criteria	
1.	Full-text is available.
2.	The article discusses a definition of innovation.
3.	The article discusses the determinants of innovation.
4.	The article describes one or more metrics to measure innovation.
5.	The article gives an overview of a model or framework for innovation measurement.
6.	The article compares two or more existing frameworks for innovation measurement.
7.	The article analyses or evaluates an existing framework for innovation measurement.

As suggested by Kitchenham and Charters (2007), we developed a check-list to assess the quality of the selected primary studies. This assessment was not part of the data extraction form as it was assessed separately. The primary studies were evaluated based on the quality criteria presented in Table 2. The quality criteria were rated with 'Yes', 'No' and 'Partially' depending on the fulfilment of each criterion. The assessment criteria were not used to include or exclude the papers nor did it have any influence on data synthesis. It is just used to indicate the quality of current work. From Table 2, it can be seen that many studies are of good quality according to criteria 1, 2 and 5. We identified 87 studies as empirical studies, but not all of these discuss validity threats. Moreover, 42 studies were industry reports which did not clearly state the methodology used. This might explain why only a few studies discuss the validity threats (criteria 3). Only 41 studies formulated their own definitions of innovation or used existing definitions. Twelve studies did not clearly define innovation and 151 studies did not have a definition (criteria 4).

The goal of this identification was to analyse the trend of selected primary studies from the viewpoint of the used research methods. The primary studies were classified based on the research method mentioned in the article. Hence, the categories of the studies are:

- *Survey*: The study uses questionnaires, interviews or both to collect empirical data. We found 36 studies in this category.
- *Case study*: The study declares the use of case study to answer one or more research questions. There are 5 studies that use case study method.
- *Experiment*: The study uses an experiment to examine the hypothesis. The study also clearly describes the design of the experiment. Only one study included in this review performs an experiment.
- *Conceptual analysis*: The study presents a theoretical concept without empirical evaluation. 37 studies use conceptual analysis.
- *No research method specified*: All the studies that do not state explicitly the research method used are grouped in this category. It includes, many times, the studies that report sectorial or regional level studies, i.e. the experience of individual countries or groups of countries. 21 studies did not specifically mention the research method used in their research.

Based on these categories, we found that 37% of the studies used conceptual analysis as a basis for their study and 36% of the studies used a survey approach. Surveys are considered as the main instrument to collect quantitative and qualitative data followed by statistical analytical methods to validate the concept. 20% of the studies presented a theoretical concept but used existing or published data to evaluate the concept. In this study, such studies are not considered as categorical empirical studies since the researchers just took freely available data and did not collect the data by themselves. However, these studies are marked as 'conceptual analysis with empirical evaluation' and treated as a subset of this category. Only 17% of the studies are classified as pure conceptual analysis.

3.2. Interview

We used a semi-structured interview to grasp as much information as we could get from the interviewees. With the interviewee's permission the interviews were recorded. We followed the interview protocol as described in Creswell (2009) to conduct the interviews. Four industry practitioners and three academics were interviewed in this study. Both academics and industry practitioners were selected to ensure that we get balanced information from academia and industry point of view. We chose four industry practitioners in managerial level of the software firm who have roles and responsibilities related to innovation. For academics, we selected three key professors in software engineering and business who have experience and interest in innovation and also have close relationship with the industry. Due to geographical limitation, we only selected the interviewees who were based in Sweden. In this study, the interviewees have been anonymised for confidentiality and they are referred to with female pronoun regardless of their actual gender. The background information of interviewees

Table 2
Quality assessment results.

	Inclusion/exclusion criteria	Number of publications		
		Yes	Partially	No
1	Is the aim of the study clearly explained?	194	2	8
2	Is the presented methodology/approach clearly stated?	121	24	59
3	Are the threats to validity of the study analysed?	42	16	146
4	Is an appropriate definition of innovation provided?	41	12	151
5	Is there empirical evidence provided in the study?	91	9	104

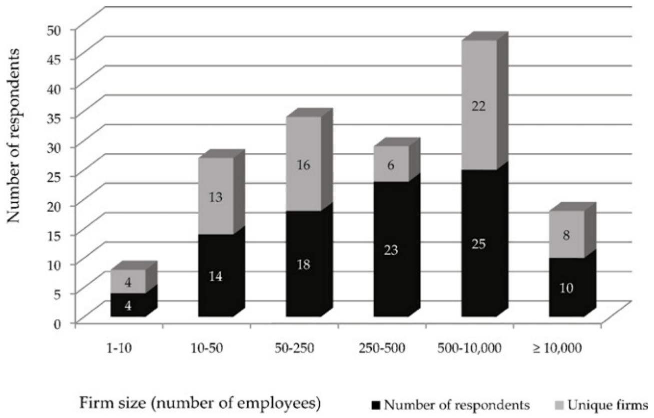

Fig. 2. Distribution of respondents according to organisation size.

including their experience, role, responsibilities and the size of their company are available online at (bin Ali et al., 2011).

3.3. Questionnaire

A web-based questionnaire served as an instrument to collect the opinions of those experts whom we could not interview face-to-face. The target respondents were software industry practitioners, i.e. software engineers, analysts, project managers, R&D managers, CTOs, CEOs, etc. To get a higher response rate, a personalised email was sent to industrial contacts inviting them to participate in the questionnaire. The request for participation was also posted on researchers' respective alumni mailing lists. Due to the limited time, we gave 7 days for respondents to complete the questionnaire. The data submitted by respondents was taken into consideration only if the respondents fully completed the questionnaire within the deadline. In the end, we had 145 respondents out of which 94 completed the questionnaire. This means that our completion rate was 64.83%. The responses with incorrect demographic information, incomplete or late responses were discarded.

We categorised the respondents into similar roles. Ten different roles were identified from the responses. Approximately a quarter (25.53%) of the respondents were software engineers, 20.21% were categorised as senior software engineers and 23.40% had management or executive responsibilities in their respective organisations. Out of the 94 respondents from 13 different countries, 42.55% were from Pakistan, 22.34% were from Indonesia, 12.76% were from the USA and 12.7% were from Europe. They came from 68 different organisations.

The respondents came from a variety of organisations of varying sizes (in terms of number of employees). For categorisation based on organisation size, the size definitions, according to EC (2005), were followed. Slightly more than a quarter of the respondents (26.59%) were from organisations with 500 to 10,000 employees, 24.46% from organisations with 250 to 500 employees and 19.14% from organisations with 50 to 250 employees. The distribution of respondents according to organisation size is shown in Fig. 2.

4. Results

We present major findings of the study in this section. Due to space limitations the detailed results and supplementary information[1] are available online at (bin Ali et al., 2011).

4.1. State of the art of innovation measurement

The following section describes the state of the art of innovation measurement based on systematic literature review.

4.1.1. Definitions of innovation as reported in literature

The 41 definitions found in the literature review were analysed and various aspects of innovation were identified. These aspects are considered important as these delineate what attributes will be measured when an organisation attempts to measure innovation. Some of these definitions are shown in Table 3.

Impact of innovation. Based on the impact on the market and the change in underlying technology, innovation is classified into four major categories:

- *Incremental innovation*: These are relatively minor changes in technology based on existing platforms that deliver relatively low incremental customer benefits (Chandy and Tellis, 1998; Cheng and Shiu, 2008).
- *Market breakthrough*: These are based on core technology that is similar to existing products but provides substantially higher customer benefits per dollar (Chandy and Tellis, 1998; McMillan, 2010).
- *Technological breakthroughs*: These innovations adopt a substantially different technology than existing products but do not provide superior customer benefits per dollar (Chandy and Tellis, 1998; McMillan, 2010).
- *Radical innovation*: They are referred to as disruptive innovations which introduce first time features or exceptional performance (Dibrell et al., 2008; Assink, 2006). They use a substantially different technology (Herrmann et al., 2006; Chandy and Tellis, 1998) at a cost that transforms existing or creates new markets (Assink, 2006) and deliver a novel utility experience to customer (Herrmann et al., 2006).

Types of innovation. There are four types of innovation according to our primary studies:

- *Product innovation*: This refers to creation and introduction of new (technologically new or significantly improved) products which are different from existing products (Hage, 1999; Geiger and Cashen, 2002; OECD, 2005; Herrmann et al., 2006; Singh and Singh, 2009; Amara et al., 2009; Jensen and Webster, 2009; Carmona-Lavado et al., 2010). It includes architecture structure (Schumpeter, 1949; Romijn and Albaladejo, 2002), technology (Hage, 1999), features (Romijn and Albaladejo, 2002; Assink, 2006; Dibrell et al., 2008), performance (Dibrell et al., 2008).
- *Process innovation*: This refers to implementation of a new design, analysis or development method that changes the way how products are created (Acs and Audretsch, 1988; OECD, 2005;

[1] The information online includes:

- The exact search strings used in respective databases along with the number of articles.
- Definitions of innovation found in this literature review with the references to the source publications.
- Classification of determinants and respective measures of innovation along with a reference to source publications.
- Mapping of determinants of innovation to innovation lifecycle.
- Metrics of innovation that have been studied in the context of software industry.
- Metrics with respect to innovation life-cycle activities.
- Metrics for innovation input, innovative output and its performance.
- Existing frameworks for evaluation of innovation.
- Primary studies used in this study from software context.
- The questions used in the interviews during this study.
- The questionnaire used for a web based survey in this study.
- List of the primary studies used for data extraction in this study.

Table 3
Definition of innovation.

Acs and Audretsch (1988)	'Innovation is a process that begins with an invention, proceeds with the development of the inventions, and results in the introduction of a new product, process or service to the market-place.'
Damanpour (1992)	'Innovation is defined as the adoption of an idea or behaviour whether a system, policy, program, device, process, product or service that is new to the adopting organisation.'
de Jong and Kemp (2003)	'Innovation behaviour can be defined as all individual actions directed at the generation, introduction and application of beneficial novelty at any organisation level.'
Fruhling and Keng (2007)	'Innovation is an idea, practice or object that is perceived as new to an individual or another unit of adoption.'
Geiger and Cashen (2002)	'Innovation refers to the creation of new product within the firm.'
Hage (1999)	'Organisational innovation has been consistently defined as the adoption of an idea of behaviour that is new to the organisation. The innovation can either be a new product, a new service, a new technology, or a new administrative practice.'
Palmberg (2004)	'Innovation is defined as "a technologically new or significantly enhanced product compared to the firm's previous product" which has been commercialised on the market.'
Dibrell et al. (2008)	'Innovations vary in complexity and can range from minor changes to existing products, processes, or services to breakthrough products, and processes or services that introduce first-time features or exceptional performance.'

Singh and Singh, 2009; Amara et al., 2009; Jensen and Webster, 2009).

- *Market innovation*: This refers to implementation of new or significantly modified marketing methods, strategies and concepts in product design or packaging, placement, promotion or pricing (OECD, 2005; Amara et al., 2009). It includes opening up new market opportunities, position innovations (including changes in the context in which the products are introduced) and the implementation of new or significantly modified marketing strategies (Singh and Singh, 2009; Jensen and Webster, 2009).
- *Organisation innovation*: This refers to the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations (OECD, 2005). It includes changes in the architecture of production and accounts for innovations in management structure, corporate governance, financial systems or employees remuneration system (Hage, 1999; Jensen and Webster, 2009; McMillan, 2010).

Degree of novelty of innovations. This aspect of innovations has differential implications for organisation growth (De Jong and Vermeulen, 2006). This is also useful to identify developers and adaptors of innovation who can differentiate market leaders from followers (OECD, 2005). Based on the perspectives important to the firm, there are four types of innovation based on novelty:

- *New to the firm*: The minimum level of novelty of innovation is that it must be new to firm. It is defined as the adoption of an idea, practice or behaviour whether a system, policy, program, device, process, product, technology or administrative practice that is new to the adopting organisation (Damanpour, 1992; Hage, 1999; Parashar and Sunil Kumar, 2005; Berger and Revilla Diez, 2006; Fruhling and Keng, 2007; Linton, 2007; Carmona-Lavado et al., 2010).
- *New to the market*: When the firm is the first to introduce the innovation to its market (Acs and Audretsch, 1988; OECD, 2005).
- *New to the world*: These innovations imply a greater degree of novelty than new to the market and include innovations first introduced by the firm to all markets and industries, domestic and international (OECD, 2005; Berger and Revilla Diez, 2006).
- *New to the industry*: These innovations are new to the firm's industry sector (Garcia and Calantone, 2002; De Jong and Vermeulen, 2006; Beugelsdijk, 2008).

Innovation activities. Schumpeter's definition stresses the novelty in innovation (Schumpeter, 1949). While invention is the first occurrence of ideas, innovation refers to their first economic utilisation or commercialisation (Schumpeter, 1949; Haner, 2002) and successful launch to market as products (Banerjee, 1998). This idea still dominates the definitions and the necessity of commercialisation for innovation is emphasised. Innovation is described as the discovery of new ideas (with value in marketplace (Orlando and Verba, 2005)) and successful exploitation through commercialisation of these discoveries (Gaynor, 2001; Adams et al., 2006; Jensen and Webster, 2009; Oke et al., 2009). It is the tendency to not only implement products but also to introduce them to the market (Gumusluoğlu and Ilsev, 2009). In situations where the innovation relates to an internal activity like the improvement in a development process, the phrase commercialisation can be substituted with 'implementation' (Gaynor, 2001).

Nature of process. Innovation is an iterative process (Garcia and Calantone, 2002). In this process, idea generation or adoption, development of products (by using competencies inside and outside the organisation), and introduction of products to marketplace and implementation of processes in organisation are the major activities (Acs and Audretsch, 1988; Damanpor, 1996; Garcia and Calantone, 2002; Cormican and O'Sullivan, 2004; Aiman-Smith et al., 2005; Freeman and Engel, 2007). Other definitions focus on where the ideas for an innovation are generated; (Wakasugi and Koyata, 1997) suggest that innovations are generated as products moved through product life-cycle processes from a research laboratory to the factory. Yet others see innovation as creation of knowledge by application, recombination or extension of existing knowledge (Cho and Pucik, 2005; Parashar and Sunil Kumar, 2005). It can be understood as a process in which organisations' knowledgeable and creative people define and frame problems and then develop new knowledge to understand and solve them (Caloghirou et al., 2004; Adamides and Karacapilidis, 2006).

4.1.2. *Determinants of innovation*

We identified 244 determinants of innovation and classified them into two groups: external and internal determinants. This classification was created based on the sources of factors, whether from outside or inside the organisation. External determinants are factors outside an organisation, which affect innovation, and are beyond the control of the organisation, e.g. public policy that reduces the tax for start-up companies or R&D grants for small companies (Frenkel et al., 2003). Internal determinants are factors inside the organisation's influence that improve the innovation capability of the organisation, e.g. the availability of a strategy on innovation or a creative climate (Cormican and O'Sullivan, 2004) (confirmed also in (Gorschek et al., 2010b) which unfortunately was only published recently, thus falling out of the scope of the systematic literature review).

We also categorised the individual internal determinants into groups based on their meaning and purpose. For example, we grouped the determinants related to customers into customer-related determinants and the determinants associated with marketing into marketing-related determinants. Table 4 presents the taxonomy of internal determinants.

Table 4
Taxonomy of internal determinants.

Market	Knowledge &information	Technology	Empowerment
Tool-support	Planning	R&D	Acquisition &alliances
Champions	Intellectual property	Alignment	Size
External collaboration	Structure	Financial	Culture
Management	Commitment	Risk	Trust
Organisation resources	Individual	Customer-orientation	Strategy
Policy	Internal collaboration	Networking	Human resources

Out of 23 studies conducted in a software-related context, there were only six studies that identified determinants of innovation. However, this does not mean that determinants found in other contexts are not applicable to the software industry. The following discussion is based on the findings of determinants studied in a software industry context.

A study by Akman and Yilmaz (2008) found that customer-orientation is one of the important factors that significantly affects the innovation capability. They argue that by focusing on customers, software organisations will be able to improve their innovation capability since customers' needs and wants are the source of innovative ideas. To this end, Paladino (2007) and Voss (1985) suggested that managers should look for a new strategy to fulfil the market needs and, moreover, an organisation should not focus on current needs but also future needs, and this can be done when an organisation maintains a good relationship with its customers (Akman and Yilmaz, 2008).

Inter-functional co-ordination is another factor that has a significant effect on innovative capability (Akman and Yilmaz, 2008). Good and integrated co-ordination among all departments can promote an effective knowledge transfer inside the firm. Innovative ideas are shared among the employees and transformed into innovation outcome. However, according to Voss (1985) this happens only if the customers know the problems and the technology is available inside the organisation. Otherwise, an organisation needs to communicate with an external side to better identify a potential market and, ultimately, reach commercial success (Voss, 1985).

To support inter-functional co-ordination, a study by Romijn and Albaladejo (2002) found that in small hi-tech companies, specialised knowledge and experience in science and technology should be in place. This is more important than technical or general managerial skills. Hence, start-ups need at least two important things: access to universities or other research institutes to train the staffs and R&D funding to maintain innovation while learning to achieve technological excellence.

On the other hand, competitor-orientation does not significantly affect the innovation capability (Akman and Yilmaz, 2008). In the software industry, competitors are many times treated as partners rather than as rivals (Akman and Yilmaz, 2008). Software companies tend to collaborate in software development with competitors. This usually happens for SMEs in order to survive the competition from large enterprises. Therefore, being aggressive—by allocating more resources to improve the market position—will not improve innovation capability per default. The same effect can also be seen when companies become defensive, i.e. by making incremental innovation on current products (Akman and Yilmaz, 2008).

Different from other industries, technology-orientation has a negative impact on the software industry (Akman and Yilmaz, 2008). Software development highly depends on skilled and creative employees rather than technology. This result echoes Brooks' statement, that 'software construction is a creative process' (Brooks, 1987). Moreover, Brooks argued that no silver bullet can solve 'the essential difficulties in the nature of software' (Brooks, 1987). This creative work should be supported by a creative climate, e.g. challenging work, freedom and group support (Fagan, 2004).

In hardware technology focused areas, as in the manufacturing industry, technology breakthrough has improved the productivity and reliability of computer hardware. In the software industry, analysis and design has become the crucial phase in software development (Voss, 1985; Brooks, 1987). A good software design can be reused in other projects, will shorten the development period and, ultimately, the costs as well. Hence, this development aspect needs to be managed properly.

A study by Gumusluoğlu and Ilsev (2009) found that transformational leadership also has positive effects on a company's innovation capabilities. The study found that the positive influence is visible in incremental innovation in developmental work. When this pro-active behaviour is part of an innovation strategy, the organisations seem to be more flexible to facilitate innovations (Akman and Yilmaz, 2008).

The importance of a product champion (in the context of the software industry) was introduced by Voss (1985). Champions enthusiastically encourage and promote innovation during the project. They are the individuals with a strong reputation, knowledge of the business, possessing good facilitating skills and having the authority to bring change into the organisation (Voss, 1985; Andrew and Sirkin, 2008). They are responsible for the entire innovation process and play their role in the development stage to help initiate the project while staying involved in the commercialisation stage as well (Voss, 1985; Andrew and Sirkin, 2008).

Voss (1985), and then Akman and Yilmaz (2008), also found that innovation should be part of an organisation's strategy, plan and culture. Once innovation has become a daily habit inside the organisation, the innovation process will also become more effective (Voss, 1985).

4.1.3. Metrics for innovation measurement

A large number of metrics have been suggested in literature to measure innovation. In this study, 232 metrics were identified and classified into three levels based on measurement context in Firm, Industry and Region level metrics. We found that 88% of the studies focused on innovation in individual companies (Firm level) while 1% and 11% were used for measurement at Industry and regional level respectively. Moreover, only 48 out of the total 232 metrics were reported in studies related to the software industry.

37% of the metrics found in the literature have been statically validated, as opposed to dynamically validated research results that are evaluated in live industry settings (Gorschek et al., 2006). Most of these metrics are validated through statistical analysis applied on empirical data. The data may have been collected directly from industry, from published data or existing databases. The majority of the metrics, 58%, were mere suggestions and have not been subjected to any or use in practice. Only 5% of the metrics have been used in industry, but no information about the validation of these metrics was available.

Beside the measurement level, the 232 metrics were classified based on the innovation aspect they measure, as shown in Table 5.

4.1.4. Existing innovation measurement models

We identified 13 existing innovation measurement frameworks reported in literature. We only considered the measurement

Table 5
Classification of metrics based on key aspects of innovation.

Category	Number of metrics	Example
Determinants	84	The existence of a project champion (Dodgson and Hinze, 2000), knowledge sharing (Lin, 2007), government regulation effect (Kumar et al., 1996)
Inputs	21	R&D expenditure (Berger and Revilla Diez, 2006), R&D intensity (ratio of R&D expenditure to total assets) (Desyllas and Hughes, 2009), percentage of workforce time that is currently dedicated to innovation projects (Muller et al., 2005)
Outputs	35	Patent density (Kivimäki et al., 2000), new organisational programs (Russell, 1990), number of new processes and significant enhancement per year (Chiesa et al., 1998)
Performance	33	Percentage of sales that is generated by new products (Akman and Yilmaz, 2008), citation ratio (Banerjee, 1998), impact of brand (Sundström and Zika-Viktorsson, 2009)
Activities	59	Percentage of ideas funded (Baron and Tang, 2011), quality of adaptation (Buganza and Verganti, 2006), managers survey (Jensen and Webster, 2009)

frameworks that were proposed by the studies and rejected any other frameworks developed as a tool to prove their concepts.

Most of the existing frameworks found in this study were more focused on measuring the technological aspect of innovation. There are eight frameworks which are intended to measure technical capability, i.e. (Kumar et al., 1996; Chiesa et al., 1998; Furman et al., 2002; Capaldo et al., 2003; Cormican and O'Sullivan, 2004; Yam et al., 2004; Wang et al., 2008; Nirjar, 2008). However, according to the Oslo Manual (OECD, 2005), technology is only one aspect of innovation. Thus these frameworks cannot be used to measure overall innovation that includes non-technological aspect as well. For this reason, in the latest version of the manual, the Organisation for Economic Co-operation and Development (OECD) removed the term technology in the definition and introduced two new types of innovation: marketing and organisation.

One framework focuses on product innovation (Maravelakis et al., 2006), while the remaining frameworks do not clearly specify the measurement area. There is a lack of empirical validation since only the study by Byrne et al. (2007) reports the usage of six sigma in industry. (The study itself focuses on radical innovations.)

Out of 13 frameworks, index of innovativeness (Nirjar, 2008) is the only framework that focuses on software firms. The framework was based on six metrics adapted from the Oslo Manual. Using the data from these metrics, an index of innovativeness is calculated. Based on this number, the firms can be plotted into three dimensions to see the relative position of the firms in a particular geographic market. However, this framework does not take into consideration organisational and marketing innovations.

Surprisingly, there was only one framework that has been validated in industry: the technical audit framework by Chiesa et al. (1998). This might be the reason why other technical audit-based frameworks have cited this framework, e.g. (Capaldo et al., 2003; Cormican and O'Sullivan, 2004; Yam et al., 2004).

4.2. State of the practice in innovation measurement

4.2.1. Interview results regarding innovation measurement practice

The results from the five interview respondents with extensive industrial experience, related to the practice of innovation measurement in industry are summarised here. Two Interviewees defined innovation as "development of new processes and products". While each of the remaining defined it as, "improvements in existing processes and products", "value addition" and "surpassing user expectation". All five said that innovation was a strategic objective of their organisation. Two of three interviewees said they have a defined process for innovation, same was the result for innovation measurement in the organisation. All interviewees expressed dissatisfaction with the visibility and control they get from the current metrics (number of ideas and patents) used in the organisation. Finally all five industrial interviews said they do not use a framework for innovation measurement. The results of the interviews are further discussed in the light of the findings of the literature review and questionnaire in Section 5.

4.2.2. Perceptions of innovation

In general, all respondents agreed that idea generation is the most important activity of innovation and commercialisation is the least. However, when the data was analysed with different roles of the respondents' new trends appear (see Fig. 3).

Based on the respondents' roles, it can be seen that respondents in technical roles consider that innovation consist of idea generation and new development. This means that respondents in technical roles are more focused on technological breakthroughs. The main reason for this is most likely the nature of their responsibilities; as technical staff is more concerned about technical aspects rather than commercialisation.

On the other hand, 66.67% of senior management and 75% of executives consider commercialisation an important constituent of innovation in contrast with only 18.30% of the more technically oriented respondents. This is an expected trend as higher management is more concerned about business objectives and the financial success of the company. This is also in line with the importance of commercialisation found in the systematic literature review.

Respondents in higher management roles also recognised the presence of incremental innovation. This was also understandable since radical innovation has higher financial risk than incremental. Hence, showing, once again, that focusing on current customers is required when wanting to sustain a long-term business relationship.

Types of innovation. The respondents with technical roles have a strong inclination on product innovation followed by process, market and organisation (see Fig. 4). The main reason for this is that practitioners with technical perspectives are mainly involved with product and process development so they consider

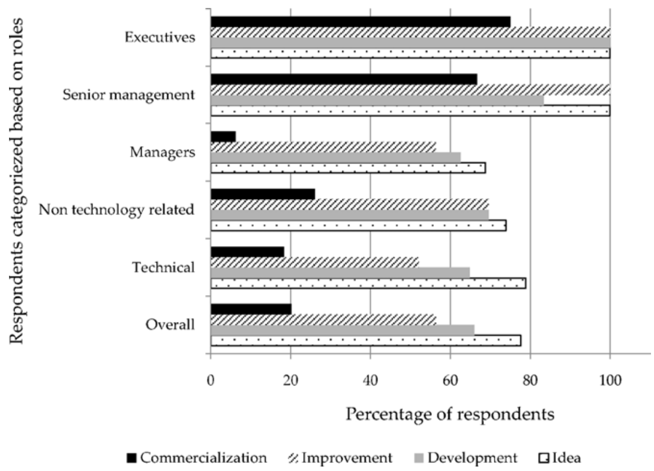

Fig. 3. What constitutes innovation?

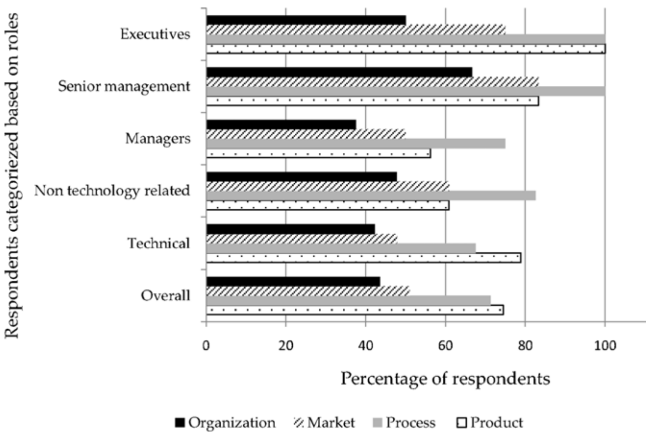

Fig. 4. Types of innovation.

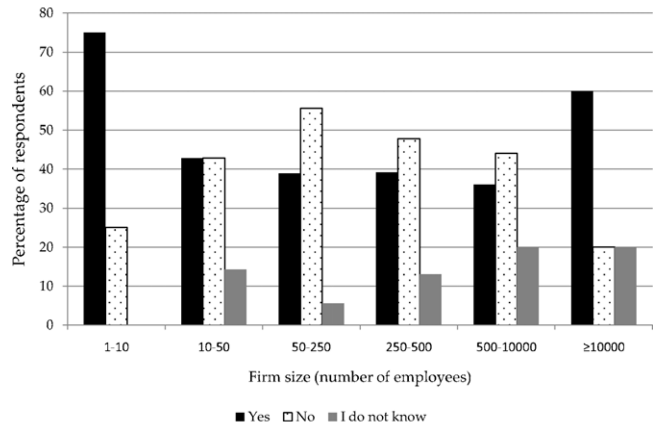

Fig. 5. Innovation strategy and firm size.

innovations only in this, limited, perspective. On the other hand, the respondents with management and executive roles prefer process innovation to product innovation. Furthermore, as they have a business perspective, they considerably emphasise the 'Market' followed by 'Organisational' innovations.

4.2.3. Importance of innovation measurement

The respondents were almost unanimous in considering the importance of innovation measurement. This is inline with the findings by the BCG survey (James et al., 2008) and validates the findings of the systematic review, where innovation measurement has been extensively emphasised.

Innovation strategy and measurement. Only 40 respondents (42.55%) said that they were aware of an explicit innovation strategy for the organisation while 41 respondents (43.61%) were sure of no explicit strategy for innovation in their organisations. Similarly, only 33 respondents (35.10%) said that their organisation measured innovation while 38 respondents (40.42 %) were sure of no innovation measurements being performed in their organisations. Remaining, 13 respondents (13.82%) and 23 respondents (24.46%) expressed unawareness of an explicit strategy or measurement program in the organisation, respectively. One reason for such high unawareness is the challenge of knowledge sharing, the strategies are often not spread throughout the organisation. Therefore, in the case of technical resources, such unawareness can be expected concerning strategies and measurement programs. Out of the 13 respondents unaware of such a strategy in their organisations, 12 were technically oriented respondents. Similarly, out of 23 respondents who were unsure about innovation measurement practices, 19 were technically oriented and 4 were managers.

The 24 respondents who were aware of an explicit strategy on innovation also reported an innovation measurement program in their organisation. Similarly, the 27 respondents who claimed there was no explicit strategy reported that they do not engage in innovation measurement. This would be expected, as an organisation with explicit emphasis on innovation is more likely to use measurements for innovation management and vice versa. It was interesting to see there were six respondents who said their organisations do not have an innovation strategy but claimed they do innovation measurement. One possible explanation is the fact that employees are unaware of the strategies in the organisation, while measurement programs affect everyone when it is operational. Another possible explanation for this result is that the organisation measures aspects related to innovation but not under a defined strategy.

Organisation size, innovation strategy and measurement. The respondents from firms with 10 to 10,000 employees showed a lack of having an innovation strategy (Fig. 5). However, the results are interesting at both extremes considering employee size. The smaller firms, with less than 10 employees, are most likely not to have an explicit strategy but 75% of respondents in this range reported having a strategy. Since, we had only four participants from organisations with less than ten employees the result is, of course, inconclusive. On the other hand, as expected, 60% of employees with a firm size over 10,000 employees reported having an explicit innovation strategy.

The trend in responses regarding innovation measurement is very similar to the responses concerning innovation strategy (see Fig. 6). From the questionnaire results (shown in Fig. 5) we can see that the practice of innovation measurement is driven by the existence of an innovation strategy.

4.2.4. Metrics used in measuring innovation

A subset of metrics from the findings of the systematic literature review, covering key aspects of innovation measurement, was put in the questionnaire. The respondents were grouped on the basis of the company they belonged to. We had a total of 28 unique companies that measured innovation. One response was ignored since eight other respondents from the same company in the same and different roles reported that there was no innovation measurement in their organisation. These metrics are examples for the six groups of metrics based on key aspect of innovation, as described in Table 5.

The most widely used metrics were "Number of improvements in existing products" (63%) followed by "Number of ideas converted successfully to products" (59%), "Percentage of sales spent on new projects" (56%) and "Improvement in product quality as a result of innovation" (56%), whereas, "Creative environment (Subjective

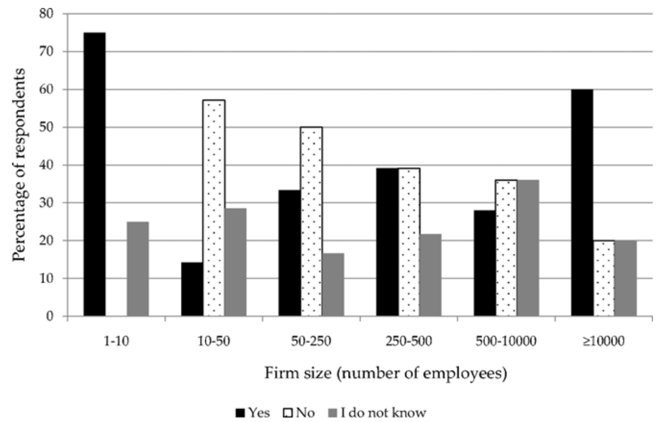

Fig. 6. Innovation measurement and firm size.

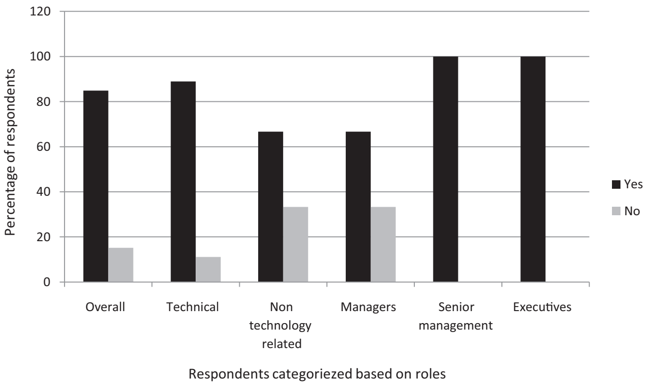

Fig. 7. Satisfaction with used innovation measurements.

assessment)" (19%) preceded by "Presence of innovation champions" (26%) and "Time taken in converting an idea to a product or process" (33%) were the least used metrics. This shows an emphasis on measuring inputs and outputs of innovation in terms of resources spent on innovation and results in the form of improvements in processes and products (with regards to the last, especially improved product quality). This result was expected as factors like environment and commitment, which are necessary to create an environment conducive to innovation, are often ignored.

Satisfaction from metrics used. Unlike the results from existing surveys, e.g. the BCG survey (James et al., 2008), the questionnaire respondents expressed satisfaction with the metrics that they currently use to measure innovation (see Fig. 7). It seems that these metrics give them enough control and visibility to manage innovation. However, since there were only six non-technical respondents who said that their organisations measure innovation we do not have enough of a sample size to conclude anything here. One of the respondents, who expressed dissatisfaction, said that the metrics are currently calculated in 'Silos' without a defined governing process. This hinders organisation-wide sharing of metrics about innovation, which may otherwise prove very useful for business teams. Another dissatisfied respondent mentioned that the cycle time (time taken to convert an idea to a product/process) could be a useful metric to identify a 'bloat in the process'. However, these metrics were not currently collected in the organisation.

4.2.5. Frameworks used for innovation measurement

The importance of an innovation measurement initiative has been recognised in the software industry. For example, 32 respondents from 27 unique firms said that their organisation does measure innovation. However, of these firms, 74.07% do not use any measurement frameworks. One respondent mentioned using a survey for evaluating innovation in the company. Another respondent mentioned the use of a framework but did not share any details because it was confidential.

4.2.6. Challenges of innovation measurement

Based on the systematic literature review, we identified five common challenges of innovation measurement. We asked the respondents whether the same challenges also existed in their context. The following section discusses the results of the questionnaire from this perspective:

- *Lack of recognition of the importance of innovation measurement*: Respondents from firms smaller than 10,000 employees generally agreed to the statement that innovation measurement importance is not recognised. On the contrary, larger organisations do not consider that there is a lack of acknowledgement of innovation measurement importance. These organisations are already undertaking innovation measurements (as found in the systematic literature review and the questionnaire; see Fig. 8).

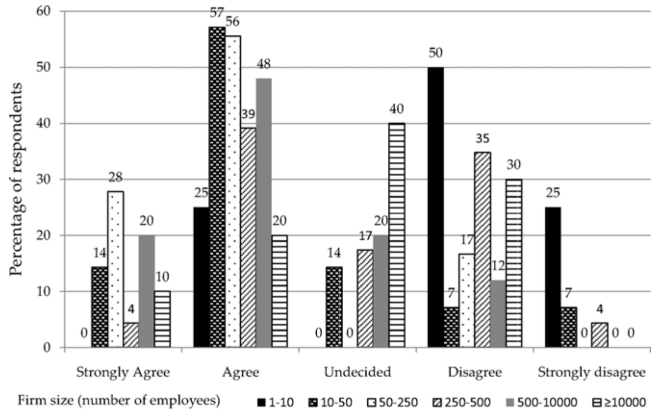

Fig. 8. Lack of recognition of importance of innovation measurement.

- *Lack of consistent definition of innovation*: With the exception of firms with 1–10 employees (see Fig. 9), there seems to be a consensus that there is a lack of consistent definitions and that it hinders innovation measurement. This result is consistent with the findings of the systematic literature review where 41 definitions were found. For larger organisations the issue is a lack of consistent definitions of innovation, metrics and guidelines. Whereas for smaller firms the issues also include a lack of recognition that innovation measurement is useful.
- *Lack of metrics for innovation measurement*: All respondents tend to agree that there is a lack of metrics that is hindering organisations to pursue innovation measurement (see Fig. 10).
- *Lack of guidelines and frameworks*: Except for respondents from 1 to 10 employee firms, the majority of the respondents agree that the lack of guidelines and frameworks is a main challenge for innovation measurement in their firm (see Fig. 11).
- *Cost associated with innovation measurement*: Like any measurement program, innovation measurement would also require an undertaking from the company in terms of financial, time and human resources. The respondents were asked to express their opinion if the cost associated with a measurement program is hindering their firm from adopting it. However, looking at the graph in Fig. 12 we can draw no conclusion, as respondents from all firm sizes tend to be unsure whether the cost associated with the innovation measurement program is a challenge. (That in itself is worrying since it most likely affects the willingness to implement measurement programs.)

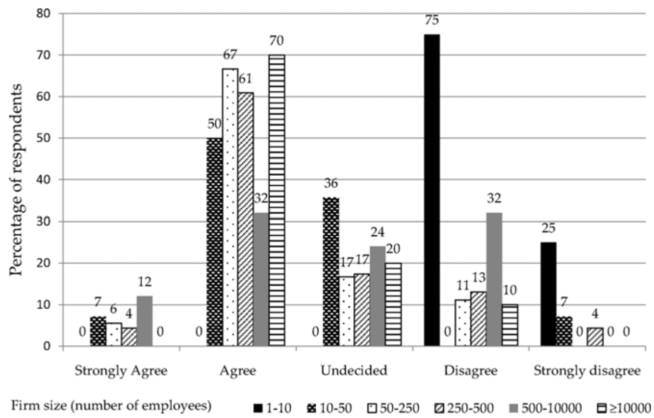

Fig. 9. Lack of consistent definition for innovation.

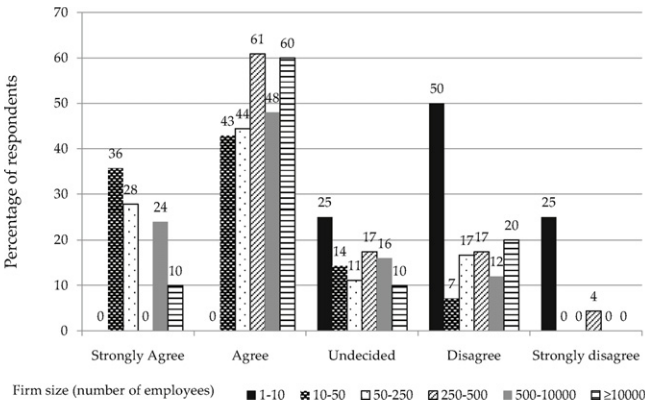

Fig. 10. Lack of metrics for innovation measurement.

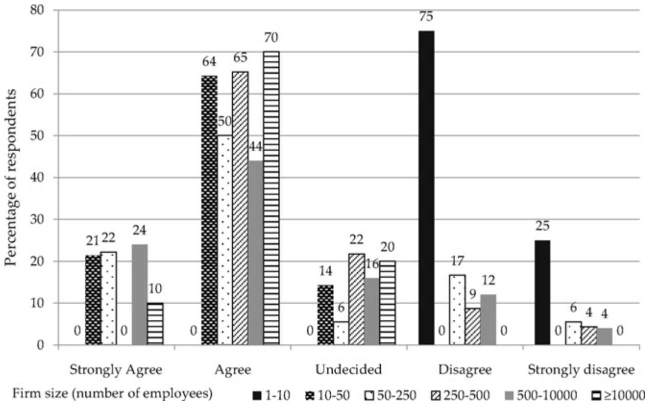

Fig. 11. Lack of guidelines and framework for innovation measurement.

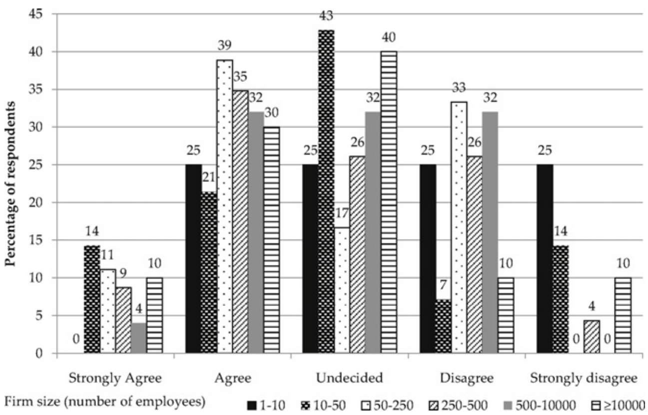

Fig. 12. Cost of innovation measurement program.

5. Discussions

In this section we compare the state of the art and the state of the practice of innovation measurement in the software industry based on a systematic literature review, a questionnaire and interview results.

5.1. Definition of innovation for the software industry

While defining innovation, one interviewee, emphasised the purposefulness of innovation. It must be targeted towards 'identifying and understanding existing and unfulfilled needs and fulfilling them in new ways with time, cost or usage advantage'. She also mentioned that commercialisation is an important requirement for something to qualify as innovation.

Another interviewee, described innovation as 'First thing that comes to mind is invention and new products but innovation has broader meanings. It means changing something or making something in a better way'. She further stressed the tangible and intangible nature of innovations (in this case process and product innovations) when she said 'It can be both something you can touch and a better way of doing things.' She did not mention the importance of commercialisation as a criteria to define innovation as she said, 'Sure if you are working in a company you want to make money.'

One academic, also emphasised that 'Innovation is adding value, and value could be customer value, user experience, internal value, etc.' According to her, innovation meant 'delivering something that creates new value, the value could be perceived by customer, user or producer.' She highlighted the importance of commercialisation for innovation. It can be noted here that there is some congruence between all of these definitions. The results of the systematic literature review and the interviews are also consistent with the view of the dimension of novelty in innovation. Basically, anything that is new to the firm qualifies as innovation.

The academics and practitioners (with higher management experience) perceive innovation at a much broader level by using abstract concepts like value creation and need fulfilment. They look at the purpose and goal to define what may be considered as innovation. While the practitioner with R&D management experience talked about concrete innovation types and mostly stressed new and improved processes and products, generally there was a consensus that for something to be considered an innovation, commercialisation is very important. This is also consistent with the view of innovation as found in the systematic literature review. Commercialisation that means introduction of products to markets and the implementation of processes, organisational and marketing methods in actual use is an important feature of innovation (OECD, 2005).

We noticed in the questionnaire results that only 18% of technical resources considered commercialisation an important determinant of innovation (refers to Fig. 3). According to one of the interviewees, there are many confounding factors that may affect the successful commercialisation of new products. She argued that with a strong brand, extensive marketing and large market share an organisation might manage to sell a 'bad innovation'. On the contrary, without these resources, an organisation might fail to sell a 'good innovation'. However, we think that by differentiating between commercialisation (introduction or implementation) and the performance of innovation one can resolve this disagreement.

Identifying a comprehensive innovation definition is important as in the questionnaire we found that the lack of a consistent innovation definition was considered a challenge (Fig. 9). This is also consistent with the findings of the survey where respondents gave different definitions focusing on different aspects. One practitioner mentioned how the perception of innovation differs across the departments of the same organisation.

Therefore, among the definitions given or used by the primary studies in this literature review, we analysed each definition for coverage against the identified aspects of innovation. Two definitions of innovation by Crossan and Apaydin (2010) and the Organisation for Economic Co-operation and Development (OECD) Oslo Manual (OECD, 2005) stood out. According to OECD (2005) 'An innovation is the implementation of a new or significantly improved product (goods or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.' Crossan and Apaydin (2010) modified the definition given by European Commission's Green Paper of Innovation to: 'Innovation is: production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems. It is both a process and an outcome.' This paper suggests use of this definition of innovation from Crossan and Apaydin (2010) for its comprehensive coverage of the identified aspects of innovation as found in literature and through the interviews.

5.2. Importance of innovation measurement

Although there was disagreement on what is currently measured by the organisations and what the interviewees thought should be measured, there was still an agreement on the importance of innovation measurement. Similarly, the respondents of the questionnaire, regardless of their roles in the company, agreed that innovation measurement is important. The increasing number of publications every year on the subject and the emphasis in literature also indicates that it is considered equally important in academia. However, when we look at the presence of an explicit strategy for innovation, actual measurement programs and innovation processes (these aspects indirectly indicate the importance given to the innovation measurement in practice), the reality is very different. Many respondents indicated a lack of an explicit strategy (44%) and measurement program (40%) in their organisations. The same scenario was found in the interviews where all four industry practitioners reported either a lack of innovation strategy and measurement program or expressed dissatisfaction with the current practice. Similarly, one firm had no innovation process and the practitioners from the other firms expressed dissatisfaction regarding the process being followed in their organisations. Thus, we can conclude that although there is a growing consensus on the importance of innovation measurement in both industry and academia, the practice is still lagging behind. We will next discuss some of the determinants of innovation in the software industry and then focus on the challenges inhibiting the innovation measurement practice in Section 5.4.

5.3. Determinants of innovation in the software industry

Most of our literature review results suggest that the existence of an innovation strategy will help organisations in promoting innovation culture. However, our findings from the interviews and the questionnaire suggest that the importance of having an innovation strategy in software industry is not significant. Only 42.55% of respondents are aware of an explicit strategy on innovation in their organisation. This is in line with what one of the interviewee said about her department that all employees have to be innovative to solve the problem, not because of the strategy, but for the sake of the project. In short, she knew that her company had a strategy related to innovation, but does not consider it as the main driver for innovation.

The importance of having an innovation strategy to create a creative climate is also not recognised in the software industry. One of the interviewee argued that organisational behaviour is not necessarily determined by the top-down approach but also bottom-up, where the employees actively change their day-to-day behaviour.

5.4. Challenges in measurement of innovation in the software industry

The following subsections discuss the challenges of innovation measurement in the software industry and the extent to which this study alleviates them.

5.4.1. Lack of a consistent definition of innovation

The lack of a consistent definition of innovation has been identified in the systematic review, during the interviews and in the results from the questionnaire. Definitions are fundamental as they affect the measurement program and help provide a common understanding. This improves communication and understanding between different stake-holders involved in innovation measurement. With the comprehensive definition we propose to be used in the software industry (as it covers all the aspects identified in the literature review and the interviews), we hope this will address this issue (see Section 5.1).

5.4.2. Lack of metrics

This issue was identified in the questionnaire executed as part of this study. However, looking at the large number of metrics found in the systematic literature review we think that there could be three explanations for this difference between state of art and state of practice:

- *Lack of awareness of appropriate metrics*: There were no studies, which have aggregated the existing metrics. This could explain the ignorance about the existence of, quite possibly, appropriate metrics.
- *Lack of validation of metrics*: Only 37% of the metrics found in literature (as shown in Table 5) have been subjected to some static validation and there have been no industry trials, i.e. dynamic validation (Gorschek et al., 2006). This lack of empirical validation may also be a reason why industry is hesitant in adopting the suggested metrics.
- *Interpretation*: As innovation is not fully understood, it is hard to interpret the values of the metrics. Therefore organisations often resort to only measuring the performance of innovation (e.g. revenue generated). For example, measuring the number of training opportunities that employees have had during the past years, provides an indication of whether you are investing to promote innovation. However, it does not give information about the innovation capability by itself.

By conducting a systematic literature review and aggregating the existing measures we attempted to facilitate tackling this issue. Furthermore, this study investigated and identified a lack of validation and thus identified a direction for future research.

5.4.3. Lack of frameworks for innovation measurement

According to Mendonça et al. (1998), measurement frameworks consist of 'a set of related metrics, data collection mechanism and data uses inside a software organisation.' Moreover, measurement should be based on goals and models (Basili et al., 1994). Since there is no agreement on what innovation is, there is also no agreement on what metrics should be collected. One interviewee mentioned that there is no consensus as to what constitutes innovation within the same organisation. Moreover, innovation is a broader term and some aspects might be difficult to measure. Even if metrics have been defined, the next issue is whether the metrics are reliable and give information about the innovativeness of the organisation.

Although we found only one innovation measurement model proposed for the software context (Section 4.1.4), the existence of such frameworks has been recognised in industry. Based on the questionnaire results, we found that some innovation measurement frameworks have been used in 25.93% of the companies (Section 4.2.5). However, it seems that there is no standard framework to measure innovation, it is subject to the company and often confidential. We think that any measurement framework like, e.g. GQM, Practical Software Measurement and Balanced Scorecards, can be used. Some of the aspects missing are a comprehensive innovation definition, a model and metrics for innovation measurement.

5.4.4. Challenges in existing innovation metrics

There are a number of different metrics that were found during the systematic literature review. These metrics can be classified into following major categories: R&D-based measures, revenue-based measures, IPR-based measures, innovation counts-based measures, process measures, survey measures, investment-based measures. Each of these proxies of innovation has their relative strengths and weaknesses in terms of coverage of the type of innovation they measure (Jensen and Webster, 2009). For example, R&D is just one of the inputs to the innovation process and thus these metrics do not cover the non-R&D inputs like, e.g. market analysis and training of employees (Kleinknecht et al., 2002).

R&D-based measures. There is a great deal of focus in traditional industries on R&D as an input and driver for innovation. However, dedicated research units is a luxury that is not available to SMEs in particular (Gorschek et al., 2010a). This was also noticed during the interviews, e.g. the 'scouting teams responsible for looking out for new technologies and ideas did this as an additional task in their job role'. This is also consistent when one interviewee related to her experience in a small firm 'back there we did not think about measurements, whatever it took, we just got the job done. For us innovation is in day-to-day activities in everything we do'.

R&D has important implications on the measurements that may be used to assess the inputs to innovation. However, this measure has not necessarily a relation to innovation output (Evangelista et al., 1998). Since most of the software firms are SMEs, which as discussed above do not have dedicated research departments, the percentage of sales spent on R&D, number of employees dedicated to R&D, etc. may not be useful in their context.

Revenue-based measures. Innovation measurement is often restricted to revenues generated by new offerings to the market (James et al., 2008). Apparently, this is a straightforward measure and organisations often tend to use it. Although it provides a good measure of the market success of a particular innovation, solely relying on this metric can have negative effects on innovation. If innovation is assessed by generated sales, organisations will develop a risk-averse culture with a negative effect on creativity. Over time organisations will start emphasising on incremental innovations and overlook the importance of radical and breakthrough innovations as they have an increased risk of not bringing monetary returns.

One interviewee called it the worst innovation metric, as there are confounding factors in the success of an innovation brought to the market. She emphasised the importance of measuring how well an innovation fulfils the intended purpose. Another interviewee criticised the sales-based measure, as 'it is so after the fact'; that is, it provides no transparency in the internal working of the organisation. Other interviewees called sales a tricky measure and that it is difficult to track sales to individual innovations. One of the interviewees mentioned that her organisation does not trace which patents are in which products. Another interviewee added that even if patents are tracked, the life-cycle of the products and that of innovations makes it extremely complex to track sales. Moreover, an interviewee, questioned how to define a time period for the return on investment since an innovation may be embedded in a suite of applications which, in combination with other components, delivers a combined value.

IPR-based measures. A large number of selected primary studies use IPR-based metrics for measuring innovation output, especially patent counts and citations-based data. However, there are a number of limitations in using patent-based measures for innovation measurement, e.g. patents only cover a certain type of innovation, patents may not represent innovation at all (preventing competitors from exploiting the opportunity) and the inclination to patent innovations may vary across size of firms and industry (Kleinknecht et al., 2002; Evangelista et al., 1998).

Furthermore, the use of patent-based measures is controversial in the software industry because of the ongoing debate about the patentability of software, process of patent protection and cost associated with it. Software giants (Juden, 2005; Chatterjee, 2004; Aharonian, 1999), however, are in favour of making software patentable for a number of reasons, while small companies and the open source community (Juden, 2005; McLaughlin, 2004) are against patent protection for exactly the opposite reasons.

Counts-based measures. It is perhaps the most trivial measure and includes number of ideas generated, number of ideas financed, number of new products introduced in the market, etc. The issue with this measurement is that it does not say much about the quality of the attribute measured. For example a couple of interviewees in this study identified that when counting ideas, the important and challenging thing is assessing the quality of the ideas. Similarly, another interviewee pointed out that when counting number of features, the issue is that not all features are equal or comparable since the size of features, development effort or delivered value are important aspects as well.

Process, investment-based and survey measures. When talking about innovation measurement, it is important to measure the output and performance. It is also equally important to assess the environment for innovation and capability of an organisation to innovate. One interviewee, said that measuring the innovation climate is more important and useful than measuring the innovation output itself since that is where the organisation is picking the ideas; however, her organisation currently did not measure those factors. Innovation is not just about bringing something new to the market it is also about winning the 'mind share' and being perceived as innovative said one interviewee. Hence, it is important to measure the social capital and image of the company, which is not captured by sales of the products alone and, furthermore, measure the creativity of the employees and then analyse if there are avenues and outlets for creativity in the company.

During the interviews and in the systematic literature review we found that the importance of these factors is well acknowledged but the results from both the interviews and the questionnaire suggest that it is not currently practised in industry. The reasons may include that such data is often more subjective, hard to gather, evaluate and analyse. As one interviewee said: 'innovation measurement is about assessment of innovation capability.' However, by measuring resources and other necessary factors we cannot guarantee that we will be innovative. Perhaps this is the reason why organisations often fail to undertake this type of measurements.

6. Proposed model

Undoubtedly, innovation is hard to measure (Anon, 2006). A model with various dimensions of innovation is required to provide a meaningful foundation for measurements (Mairesse and Mohnen, 2002). This study is one such attempt to develop a generic model that covers the various dimensions of innovation. Since innovation is not fully understood, this cannot be an exact model that gives the absolute measures of innovation. However, in the absence of the exact measures, this model will assist organisations to use the available measures to develop insights into their innovation program.

Using the different perspectives of innovation and the key aspects for innovation measurement as identified by the systematic literature review, we developed an innovation measurement model, as shown in Fig. 13. This model was further refined after preliminary evaluation by academics and practitioners. From the

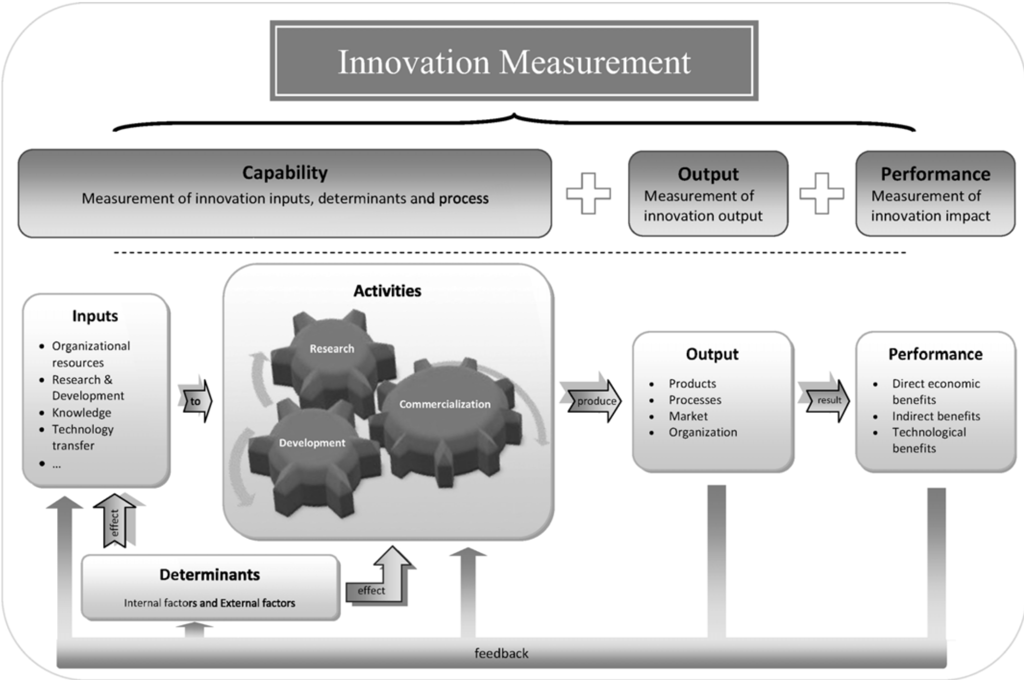

Fig. 13. A model for innovation measurement.

outset, the model identifies three main elements of measurement: innovation capability, innovation output and impact of innovation. Unlike the current strict reliance on sales as the sole measure for innovation, which may produce negative effects on the innovation climate of the organisation, this model highlights the opportunity of a more comprehensive approach towards innovation measurement. Each of these aspects identified in the model can be measured quantitatively (using both objective and subjective metrics). Metrics for each of these aspects identified from literature have been aggregated and categorised in this study.

In the following sections, the aspects of innovation that lead to the creation of this model, are discussed.

6.1. Innovation process model

Innovation is a non-linear evolving process that needs to be managed and guided (Kuczmarskl, 2001; Pires et al., 2008). It is how a firm produces innovation output from innovation inputs under contextual determinants (Mairesse and Mohnen, 2002; Pires et al., 2008; Atrostic, 2008). In this study, we do not propose a new innovation process model; instead we focus on identifying the key elements for innovation measurement. Hence, our model does not depict a flow of innovation stages.

The innovation process is divided into three main phases:

- Research phase (Jensen and Webster, 2009) including concept generation, evaluation and feasibility (Nambisan, 2002; Andrew and Sirkin, 2008). The goal of this phase is identification of new opportunities (Kuczmarskl, 2001).
- Development phase (Andrew and Sirkin, 2008; Jensen and Webster, 2009) including project planning, design, coding and testing (Nambisan, 2002). This phase involves product development based on the innovative concept (Kuczmarskl, 2001).
- Use in production (Jensen and Webster, 2009) or commercialisation (Nambisan, 2002). This phase includes activities that ensure introduction of products to the market or implementation of processes within the organisation.

Having these gates, or benchmarking points, help in measurements and do not in anyway suggest or dictate that the innovation process is as simplistic as to have three sequential steps.

6.2. Key aspects of innovation

From the systematic literature review, we found three dimensions of innovation that can be measured: capability (some studies exchange the term capability and capacity to address the potential ability of the organisation to innovate), output and success. The determinants and metrics reported in literature were classified according to this dimension. The classification was done based on the description of the determinants and metrics as provided by the selected primary studies.

The innovation capability is the willingness and ability to create, adopt and imitate new ideas to implement and commercialise them in order to satisfy current and future needs (Akman and Yilmaz, 2008; Tajeddini et al., 2006). It means mobilising organisational knowledge and other competencies necessary for improving existing processes/products, developing new processes/products and the capacity to respond to accidental technology shifts and unexpected opportunities created by the competitors (Akman and Yilmaz, 2008). Innovation capability includes assessment of innovation inputs, availability and quality of positive influencing factors and innovation process assessment.

Innovation is conceptualised as a change in the input and output of innovation function (Jensen and Webster, 2009; Aranda and Molina-Fernández, 2002). When viewed as a process like any other business process, innovation cannot be solely characterised and captured by the input and output metrics (Banerjee, 1998). Organisations need a range of measures to evaluate key aspects of innovation process (Andrew and Sirkin, 2008). The key aspects of innovation processes, which have been identified as important for measurement, are the following:

- Inputs are resources like capital, labour, knowledge and time (Muller et al., 2005; Andrew and Sirkin, 2008; Acs et al., 2002).

- Innovation process performance means tracking the people and processes acting upon these inputs (Andrew and Sirkin, 2008).
- Intermediate output as a proxy for economic output using patents acquired (Acs et al., 2002). Patents are good indicators of new technology creation however they do not measure the economic value of these technologies (Acs et al., 2002).
- Output is the measure of commercialised ideas resulting from innovation inputs (Acs et al., 2002; Tang and Le, 2007).
- Cash pay back (Andrew and Sirkin, 2008) or innovation performance refers to economic returns of innovation (Wang and Kafouros, 2009).
- Indirect benefits are not easily quantifiable often involving survey measures, third party rankings and benchmarking to evaluate organisation impact, brand image (Andrew and Sirkin, 2008) and competitiveness in market (Chiesa et al., 1998).

There is a general consensus that for changes to be considered as innovation, it must be commercialised (introduced to the market or implemented in the organisation). This confirms the business goals of the company and draws the line between anything that is new and something a company considers has a value. However, development of such products, processes and methodologies does provide the organisations a learning opportunity and adds to the capability of the organisation. This aspect is covered through the feedback loop in the model.

6.3. Purpose of the model

This model has benefits for both academia and industry. However it is important to identify its purpose and utility. The model has the following characteristics:

- This model identifies the aspects of innovation that are measurable and thus serves as a starting point for innovation measurement.
- The model serves as a generic map that covers the entire range of activities and aspects putting them all in perspective.
- It serves as the basis for future research, e.g. to study the effect of various determinants on innovation.
- Contrary to the current practice, this model emphasises the need of comprehensive measurements covering a range of activities (unlike the sole focus by some models on sales-based metrics).
- This model can help different stakeholders to communicate when talking about innovation. It will provide a common perspective to everyone involved in innovation measurement.

To understand the use of this model and to put it in the perspective of the overall innovation measurement program, consider the following example of an innovation measurement program implemented using Goal Question Metric (GQM) (Basili et al., 1994). We take GQM as an example as it provides a well structured and directed approach for measurements. Below, we argue how the proposed model and the contributions in the paper of aggregated determinants and metrcs will be useful at each level of applying GQM for innovation measurement:

- Step *A* (Conceptual level (Basili et al., 1994)): based on the analysis of organisation policy statements, strategic plans and interviews of relevant stakeholders the purpose of the goals is derived (Basili et al., 1994). The goals are defined for objects relative to the quality models, measurement perspectives and particular environment. These objects include processes, products and resources (Basili et al., 1994). The proposed model will be useful for identifying the objects of goals through its conceptual categorisation of capability (inputs, processes and determinants), output (product, process, organisation and market) and performance (direct economic, indirect and technological benefits).
- Step *B* (Operational level (Basili et al., 1994)): derive questions that try to characterise the objects of measurement identified in Step *A* (using the proposed innovation measurement model) with respect to a selected quality issue and to determine its quality from the selected (Basili et al., 1994).
- Step *C* (Quantitative level): the model, through the categorisation of metrics as found in literature, assists in choosing appropriate metrics for answering the questions in Step *B*. The objective and subjective metrics available helps in quantitatively answering these questions, which in turn helps to attain the goals of measurement.

6.4. Evaluation results

All of the interviewees expressed positive feedback for the model (Fig. 13). However, there were some critical issues and concerns raised which are discussed below.

One interviewee expressed concerns about how ‘value’ is aligned with the innovation measurement programs undertaken by a company. She also mentioned the problems with relying too much on sales-based measures. This was alarming, as one of the purposes of this model was to emphasise the importance of non-sales and output-based measures. Hence, we redrew the model focusing on capability, output and performance. We emphasised more the capability aspects of innovation measurement and made it explicit that performance measurement does not solely comprise of sales measurement. It was shown in the model that performance measurement itself has three aspects of which direct economic benefits (based on sales data) is one dimension.

One interviewee from academia, found the term ‘front end of innovation’ misleading as it gives impression of a linear innovation process. Thus, we substituted the term with ‘research’ as suggested by Jensen and Webster (2009). Furthermore, the model was modified to give a more neutral perspective of the process of innovation and just emphasise the three interacting, and mutually constituting, activities of research, development and commercialisation.

One interviewee found separate feedback and learning loops from output and performance confusing. She suggested having only one feedback loop. Therefore, to make it clearer, the model was modified to have feedback from output and performance to inputs, determinants and activities.

Two industry interviewees expressed a need for customisation of this generic model to their company-specific practices and process models for further validation and use. The purpose of this model is to give a high-level overview of the key aspects of innovation measurement and it can be used with existing measurement frameworks to measure innovation. This validation, however, was beyond the scope of this study.

One interviewee raised an issue that some organisations are not into product development and just build IPRs and look for potential buyers. Therefore, she argued that the commercialisation step might not be applicable for such businesses. We think that this business approach can also be accommodated in the proposed model, where the commercialisation would mean putting the patents to the market (meaning to find a potential buyer for the IPR or to hunt for any infringements).

7. Validity threats

Threats to validity related to the results from this study have been identified and are discussed below.

7.1. Identification of primary studies

The keyword 'innovation' is a very generic term and the concept has been discussed almost in all domains (Subramanian, 1996), including software engineering. We found that studies of innovation in the software industry were not restricted to software engineering journals. To minimise the probability of missing relevant studies, we took the following steps:

- To cover literature from other important fields like management, economics and finance, etc., we did not restrict the literature review to software related databases.
- Only journal publications were included in the study, since publishing in a journal is one, indirect, sign of quality. This decision was also motivated by the observation that the best papers presented in a conference were subsequently published in a journal as well.

7.2. Primary studies selection and data extraction

Since this study involves many fields and hence a large number of potential primary studies, we required an effective and efficient strategy to minimise researchers' bias during the studies selection (Kitchenham and Charters, 2007). Therefore, we defined three levels of inclusion/exclusion criteria, which were applied on the results of the search strings.

The criteria were formulated explicitly and as clearly as possible to avoid misunderstanding between the reviewers. Based on these criteria, each reviewer selected the relevant studies individually. If one of the reviewers could not decide whether to accept or reject an article, the decision was made based on mutual agreement. To minimise the threat of misunderstanding, as suggested by Brereton et al. (2007), we piloted the selection criteria to reach an agreement among the reviewers on the criteria. This piloting was aimed to assess whether the reviewers had the same understanding about the criteria and to check whether the criteria were too strict or too loose. A defined data extraction strategy was also used after piloting, in order to conduct a structured data extraction.

7.3. Questionnaire

Several threats to the validity of the questionnaire were identified. The instrumentation threat is caused by bad design that leads to misunderstanding of the topic under discussion (Wohlin et al., 2000). This threat was minimised by piloting the questionnaire with eight students of a Master in Software Engineering programme and two researchers from industry with a master's degree in software engineering. The aim of this pilot was to see whether the questions were clear and understandable and to measure the time it took to fill out the questionnaire. We noticed that some of the respondents were reluctant to fill in the questionnaire or left it incomplete. Hence, the layout was refined and made simpler. Furthermore, depending on the answers of respondents they were only shown relevant questions on subsequent pages.

Another threat to validity was the threat of not having a representative sample of the target population (Wohlin et al., 2000). To minimise this threat we contacted respondents with different roles, from software engineers to executives, working in micro to large organisations. To help the respondents in filling in the questionnaire and to help us in managing the completed responses, we developed a web-based questionnaire and gave 1 week for respondents to fill in. The invitations were sent through personalised individual emails and postings on alumni mailing lists.

The maturation threat caused by the participants' change in behaviour, with the progression of time, can distort the results (Wohlin et al., 2000). This happens if subjects acquire new knowledge during the process or become detached. However, with a short questionnaire which was open only for a week we think we were able to minimise this threat. As the respondents may develop their understanding, while filling in the questionnaire, different type of questions, e.g. multiple choices, Likert scale (1–5) and open-ended questions were used.

Exposing the hypothesis may affect the way the survey respondents answer the questions (Juristo and Moreno, 2001). Therefore only general information about the intent of the study was given. The questions were also phrased in a neutral manner and using indirect statements rather than using the keywords to hide the findings of the systematic review.

7.4. Interviews

Although using interviews are useful to collect historical information, there are threats to validity. The interviewees may not be articulate and may have different perceptions and hence bias the results (Creswell, 2009). Therefore, for each organisation, we interviewed two individuals with different roles. Most of the interviewees were at managerial level. Each interview lasted between 45 and 60 min in their offices. A short interview also minimised the interviewee maturation threat and boredom effect (Juristo and Moreno, 2001).

To evaluate the framework and gain valuable feedback we conducted face-to-face meetings. This enabled a better and more effective presentation of ideas and arguments. To reduce the threat to generalisation of results (Wohlin et al., 2000), we tried to get a mix of representatives from different domains within the software industry in Sweden (ranging from software solutions and embedded software in manufacturing, software intensive product development in telecommunication and representatives from firms with pure software product development). Furthermore, the academics interviewed in this study also came from both management and computing schools.

8. Conclusions

The purpose of this study was to establish the current practices, mechanisms and challenges of innovation measurement in the software industry. A systematic literature review was performed to establish the state of the art of innovation measurement. Interviews and an online questionnaire were employed to examine the state of practice of innovation measurement.

The study found that among major challenges is a lack of a consistent perspective of innovation. This difference in views affects how innovation measurement initiatives are conceived (what is considered key aspect of innovation) and executed (which metrics are required to capture a particular aspect). A comprehensive definition of innovation was identified that addresses various aspects and stakeholders' concerns that may otherwise lead to above mentioned problems.

Consistent with the established perspective, this study found that innovation measurement is considered equally important in both academia and industry. However, there are several shortcomings in the state of practice. In the software industry, there is a lack of defined innovation process and measurement programs. Similarly, none of the well-known measurement frameworks are used to measure innovation. To address this deficit, this study identified metrics and frameworks used in domains other than software development to understand how those fields manage innovation measurement. To achieve this objective, this study aggregated the available empirical evidence reported in literature to establish the state of the art in innovation measurement through an extensive literature review. The outcome of this review contributed to the existing body of knowledge in the form of an innovation measurement model, enumeration of metrics and their classification based on what aspect of innovation they are used to measure.

Lastly, the issues found in the state of the art can explain the shortcoming of industrial practice with regard to innovation measurement. This also identifies the future direction for innovation measurement research. These issues are:

- A lack of comprehensive innovation measurement models covering all the aspects of innovation. Furthermore, the existing frameworks do not relate which innovation metrics can be used to measure which aspects. This may well be a reason why measurement frameworks are not being used, as without models and concrete metrics, launching a measurement program is not possible.
- Availability of little information about the collection, processing and interpretation of metrics proposed in literature. This limits the uses of metrics in practice.
- While a number of metrics have been proposed in literature, only a few of them have been dynamically validated in industry trials. Most of the metrics are only validated through statistical analysis. This lack of reliable metrics could be the other main reason why industry claims that they do not have enough metrics. Hence, industrial trials are imperative to establish the reliability and usability of the metrics.

References

Acs, Z.J., Anselin, L., Varga, A., 2002]. Patents and innovation counts as measures of regional production of new knowledge. Research Policy 31 (7), 1069–1085.
Acs, Z.J., Audretsch, D.B., 1988]. Innovation in large and small firms: an empirical analysis. American Economic Review 78 (4), 678.
Adamides, E.D., Karacapilidis, N., 2006]. Information technology support for the knowledge and social processes of innovation management. Technovation 26 (1), 50–59.
Adams, R., Bessant, J., Phelps, R., 2006]. Innovation management measurement: a review. International Journal of Management Reviews 8 (1), 21–47.
Aharonian, G., 1999]. Does the patent office respect the software community? IEEE Software 16 (4), 87–89.
Aiman-Smith, L., Goodrich, N., Roberts, D., Scinta, J., 2005]. Assessing your organization's potential for value innovation. Research Technology Management 48 (2), 37–42.
Akman, G., Yilmaz, C., 2008]. Innovative capability, innovation strategy and market orientation: an empirical analysis in Turkish software industry. International Journal of Innovation Management 12 (1), 69–111.
Amara, N., Landry, R., Doloreux, D., 2009]. Patterns of innovation in knowledge-intensive business services. Service Industries Journal 29 (4), 407–430.
Andrew, J.P., Sirkin, H.L., 2008]. Aligning for innovation. Global Business and Organizational Excellence 27 (6), 21–39.
Anon, 2006]. Organizing for innovation: consistent innovation message. Strategic Direction 22, 34–36.
Aranda, D.A., Molina-Fernández, L.M., 2002]. Determinants of innovation through a knowledge-based theory lens. Industrial Management and Data Systems 102 (5), 289–296.
Assink, M., 2006]. Inhibitors of disruptive innovation capability: a conceptual model. European Journal of Innovation Management 9 (2), 215–233.
Atrostic, B.K., 2008]. Measuring U.S. innovative activity: business data at the U.S. Census Bureau. Journal of Technology Transfer 33 (2), 153–171.
Banerjee, P., 1998]. Indicators of 'innovation as a process'. Scientometrics 43 (3), 331–357.
Baron, R.A., Tang, J., 2011]. The role of entrepreneurs in firm-level innovation: Joint effects of positive affect, creativity, and environmental dynamism. Journal of Business Venturing 26 (1), 49–60.
Basili, V., Caldiera, G., Rombach, H., 1994]. The goal question metric approach. Encyclopedia of Software Engineering 1, 528–532.
Becheikh, N., Landry, R., Amara, N., 2006]. Lessons from innovation empirical studies in the manufacturing sector: a systematic review of the literature from 1993–2003. Technovation 26 (5–6), 644–664.
Berg, P., Pihlajamaa, J., Poskela, J., Lempiala, T., Haner, U., Mabogunje, A., 2008]. Measurement of the innovation front end: viewpoint of process, social environment and physical environment. In: PICMET'08—2008 Portland International Conference on Management of Engineering Technology, IEEE, Piscataway, NJ, pp. 1112–1120.
Berger, M., Revilla Diez, J., 2006]. Technological capabilities and innovation in Southeast Asia: results from innovation surveys in S ingapore, Penang and Bangkok. Science, Technology and Society 11 (1), 109–148.
Beugelsdijk, S., 2008]. Strategic human resource practices and product innovation. Organization Studies 29 (6), 821–847.
bin Ali, N., Edison, H., Torkar, R., 2011]. Supplementary Material for the Publication. http://www.bth.se/com/nal.nsf/pages/supplements
Brereton, P., Kitchenham, B.A., Budgen, D., Turner, M., Khalil, M., 2007]. Lessons from applying the systematic literature review process within the software engineering domain. Journal of Systems and Software 80 (4), 571–583.
Brooks, F.P., 1987]. No silver bullet: essence and accidents of software engineering. Computer 20 (April (4)), 10–19.
Brown, S., Eisenhardt, K., 1995]. Product development: past research, present findings, and future directions. The Academy of Management Review 20 (2), 343–378.
Buganza, T., Verganti, R., 2006]. Life-cycle flexibility: how to measure and improve the innovative capability in turbulent environments. Journal of Product Innovation Management 23 (5), 393–407.
Byrne, G., Lubowe, D., Blitz, A., 2007]. Using a lean Six Sigma approach to drive innovation. Strategy and Leadership 35 (2), 5–10.
Caloghirou, Y., Kastelli, I., Tsakanikas, A., 2004]. Internal capabilities and external knowledge sources: complements or substitutes for innovative performance? Technovation 24 (1), 29–39.
Capaldo, G., Iandoli, I., Raffa, M., Zollo, G., 2003]. The evaluation of innovation capabilities in small software firms: a methodological approach. Small Business Economics 21 (4), 343–354.
Carmona-Lavado, A., Cuevas-Rodríguez, G., Cabello-Medina, C., 2010]. Social and organizational capital: building the context for innovation. Industrial Marketing Management 39 (4), 681–690.
Chandy, R.K., Tellis, G.J., 1998]. Organizing for radical product innovation: the overlooked role of willingness to cannibalize. Journal of Marketing Research 35 (4), 474–487.
Chatterjee, A.C., 2004]. Europe struggles over software patents. IEEE Spectrum 41 (9), 61–63.
Cheng, C.J., Shiu, E.C.C., 2008]. Re-innovation: the construct, measurement, and validation. Technovation 28 (10), 658–666.
Chiesa, V., Coughlan, P., Voss, C.A., 1998]. Development of a technical innovation audit. IEEE Engineering Management Review 26 (2), 64–91.
Cho, H.J., Pucik, V., 2005]. Relationship between innovativeness, quality, growth, profitability, and market value. Strategic Management Journal 26 (6), 555–575.
Cormican, K., O'Sullivan, D., 2004]. Auditing best practice for effective product innovation management. Technovation 24 (10), 819–829.
Creswell, J.W., 2009]. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 3rd edition. Sage Publication, Inc.
Crossan, M.M., Apaydin, M., 2010]. A multi-dimensional framework of organizational innovation: A systematic review of the literature. Journal of Management Studies 47 (6), 1467–6486.
Damanpor, F., 1996]. Bureaucracy and innovation revisited: effects of contingency factors, industrial sectors, and innovation characteristics. The Journal of High Technology Management Research 7 (2), 149–173.
Damanpour, F., 1992]. Organizational size and innovation. Organization Studies 13 (3), 375–402.
de Jong, J.P.J., Kemp, R., 2003]. Determinants of co-workers' innovative behaviour: an investigation into knowledge intensive services. International Journal of Innovation Management 7 (2), 189.
De Jong, P.J., Vermeulen, P.A.M., 2006]. Determinants of product innovation in small firms: a comparison across industries. International Small Business Journal 24 (6), 587–609.
Desyllas, P., Hughes, A., 2009]. The revealed preferences of high technology acquirers: an analysis of the innovation characteristics of their targets. Cambridge Journal of Economics 33 (6), 1089–1111.
Dibrell, C., Davis, P.S., Craig, J., 2008]. Fueling innovation through information technology in SMEs. Journal of Small Business Management 46 (2), 203–218.
Dodgson, M., Hinze, S., 2000]. Indicators used to measure the innovation process: defects and possible remedies. Research Evaluation 9 (2), 101–114.
Ebert, C., Dumke, R., 2007]. Software Measurement: Establish, Extract, Evaluate, Execute. Springer-Verlag, Berlin/Heidelberg.
EC, 2005]. The New SME Definition—User Guide and Model Declaration, Also available as http://ec.europa.eu/enterprise/policies/sme/files/sme_definition/sme_user_guide_en.pdf
Evangelista, R., Sandven, T., Sirilli, G., Smith, K., 1998]. Measuring innovation in European industry. International Journal of the Economics of Business 5 (3), 311–333.
Fagan, M.H., 2004]. The influence of creative style and climate on software development team creativity: an exporatory study. Journal of Computer Information Systems 44 (3), 73–80.
Freeman, J., Engel, J.S., 2007]. Models of innovation: startups and mature corporations. California Management Review 50 (1), 94–119.
Frenkel, A., Shefer, D., Roper, S., 2003]. Public policy, locational choice and the innovation capability of high-tech firms: a comparison between Israel and Ireland. Papers in Regional Science 82, 203–221.
Fruhling, A.L., Keng, S., 2007]. Assessing organizational innovation capability and its effect on e-commerce initiatives. Journal of Computer Information Systems 48 (1), 133–145.
Furman, J.L., Porter, M.E., Stern, S., 2002]. The determinants of national innovative capacity. Research Policy 31 (6), 899–933.
Garcia, R., Calantone, R., 2002]. A critical look at technological innovation typology and innovativeness terminology: a literature review. Journal of Product Innovation Management 19 (2), 110–132.

Gaynor, G.H., 2001]. Innovator: what does it take to be one? IEEE Antennas and Propagation Magazine 43 (3), 126–130.

Geiger, S.W., Cashen, L., 2002]. A multidimensional examination of slack and its impact on innovation. Journal of Managerial Issues 14 (1), 68.

Gorschek, T., Fricker, S., Palm, K., Kunsman, S., 2010a]. A lightweight innovation process for software-intensive product development. IEEE Software 27 (1), 37–45.

Gorschek, T., Fricker, S., Palm, K., Kunsman, S., 2010b]. A lightweight innovation process for software-intensive product development. IEEE Software 27, 37–45.

Gorschek, T., Garre, P., Larsson, S., Wohlin, C., 2006]. A model for technology transfer in practice. IEEE Software 23 (6), 88–95.

Gumusluoğlu, L., Ilsev, A., 2009]. Transformational leadership and organizational innovation: the roles of internal and external support for innovation. Journal of Product Innovation Management 26 (3), 264–277.

Hage, J.T., 1999]. Organizational innovation and organizational change. Annual Review of Sociology 25 (1), 597.

Haner, U.E., 2002]. Innovation quality—a conceptual framework. International Journal of Production Economics 80 (1), 31–37.

Herrmann, A., Tomczak, T., Befurt, R., 2006]. Determinants of radical product innovations. European Journal of Innovation Management 9 (1), 20–43.

James, P.A., Knut, H., David, C.M., Harold, L.S., Andrew, T., August 2008. A BCG Senior Management Survey—Measuring Innovation 2008: Squandered Opportunities.

Jensen, P.H., Webster, E., 2009]. Another look at the relationship between innovation proxies. Australian Economic Papers 48 (3), 252–269.

Juden, S., 2005]. Can software be patented? Computing & Control Engineering Journal 16 (4), 16–17.

Juristo, N., Moreno, A., 2001]. Basics of Software Engineering Experimentation. Kluwer.

Kasunic, M., 2005. Designing an effective survey. Tech. rep., Carnegie Mellon, Software Engineering Institute.

Kitchenham, B., Charters, S., 2007. Guidelines for performing systematic literature reviews in software engineering. Tech. Rep. EBSE 2007-001, Keele University and Durham University Joint Report.

Kivimäki, M., Länsisalmi, H., Elovainio, M., Heikkilä, A., Lindström, K., Harisalo, R., Sipilä, K., Puolimatka, L., 2000]. Communication as a determinant of organizational innovation. R&D Management 30 (1), 33–42.

Kleinknecht, A., Van Montfort, K., Brouwer, E., 2002]. The non-trivial choice between innovation indicators. Economics of Innovation & New Technology 11 (2), 109.

Kuczmarskl, T.D., 2001]. Five fatal flaws of innovation metrics. Marketing Management 10 (1), 34.

Kumar, V., Persaud, A.N.S., Kumar, U., 1996]. To terminate or not an ongoing R&D project: a managerial dilemma. IEEE Transactions on Engineering Management 43 (3), 273–284.

Lin, H.F., 2007]. Knowledge sharing and firm innovation capability: an empirical study. International Journal of Manpower 28 (3–4), 315–332.

Linton, J., 2007]. What is innovation, anyway? Circuits Assembly 18 (4), 18–20.

Mairesse, J., Mohnen, P., 2002]. Accounting for innovation and measuring innovativeness: an illustrative framework and an application. American Economic Review 92 (2), 226–230.

Maravelakis, E., Bilalis, N., Antoniadis, A., Jones, K.A., Moustakis, V., 2006]. Measuring and benchmarking the innovativeness of SMEs: a three-dimensional fuzzy logic approach. Production Planning & Control 17 (3), 283–292.

Mathiassen, L., Pourkomeylian, P., 2003]. Managing knowledge in a software organization. Journal of Knowledge Management 7 (2), 63–80.

McLaughlin, L., 2004]. European Union struggles with new rules for software patents. IEEE Software 21 (5), 101–104.

McMillan, C., 2010]. Five competitive forces of effective leadership and innovation. Journal of Business Strategy 31 (1), 11–22.

Mendonça, M.G., Basili, V.R., Bhandari, I.S., Dawson, J., 1998]. An approach to improving existing measurement frameworks. IBM Systems Journal 37 (4), 484–501.

Misra, S.C., Kumar, V., Kumar, U.,2005]. Goal-driven measurement framework for software innovation processes. In: Proceedings of the 2005 International Conference on Software Engineering Research and Practice, SERP'05, vol. 2. CSREA Press, Las Vegas, NV, pp. 710–716.

Muller, A., Välikangas, L., Merlyn, P., 2005]. Metrics for innovation: guidelines for developing a customized suite of innovation metrics. IEEE Engineering Management Review 33 (4), 66–72.

Nambisan, S., 2002]. Software firm evolution and innovation-orientation. Journal of Engineering and Technology Management 19 (2), 141–165.

Narayana, M.G.P.L., 2005]. A framework approach to measure innovation maturity. Proceedings of Engineering Management Conference 2, 765–769.

Nirjar, A., 2008]. Innovations and evolution of software SMEs: exploring the trajectories for sustainable growth. Vision 12 (2), 47–57.

OECD, 2005]. Oslo Manual—Guidelines for Collecting and Interpreting Innovation Data, 3rd edition. OECD Publishing.

Oke, A., Munshi, N., Walumbwa, F.O., 2009]. The influence of leadership on innovation processes and activities. Organizational Dynamics 38 (1), 64–72.

Orlando, M.J., Verba, M., 2005]. Do only big cities innovate? Technological maturity and the location of innovation. Economic Review) 90 (2), 31–57.

Paladino, A., 2007]. Investigating the drivers of innovation and new product success: a comparison of strategic orientations. Journal of Product Innovation Management 24 (6), 534–553.

Palmberg, C., 2004]. The sources of innovations—looking beyond technological opportunities. Economics of Innovation & New Technology 13 (2), 1.

Parashar, M., Sunil Kumar, S., 2005]. Innovation capability. IIMB Management Review 17 (4), 115–123.

Pires, C.P., Sarkar, S., Carvalho, L., 2008]. Innovation in services—how different from manufacturing? Service Industries Journal 28 (10), 1339–1356.

Rejeb, H.B., Morel-Guimar aes, L., Boly, V., Assiélou, N.G., 2008]. Measuring innovation best practices: improvement of an innovation index integrating threshold and synergy effects. Technovation 28 (12), 838–854.

Romijn, H., Albaladejo, M., 2002]. Determinants of innovation capability in small electronics and software firms in Southeast England. Journal of Research Policy 31 (7), 1053–1067.

Russell, R.D., 1990]. Innovation in organizations: toward an integrated model. Review of Business 12, 19.

Schumpeter, J.A., 1949]. The theory of economic development: an inquiry into profits, capital, credit, interest and the business cycle; translated from the German by Redvers Opie. Harvard University Press, Cambridge, MA.

Shapiro, A.R., 2006]. Measuring innovation: beyond revenue from new products. Research Technology Management 49 (6), 42–51.

Singh, A., Singh, V., 2009]. Innovation in services: design and management. African Journal of Business Management 3 (12), 871–878.

Subramanian, A., 1996]. Innovativeness: redefining the concept. Journal of Engineering and Technology Management 13 (3–4), 223–243.

Sundström, P., Zika-Viktorsson, A., 2009]. Organizing for innovation in a product development project: combining innovative and result oriented ways of working—a case study. International Journal of Project Management 27 (8), 745–753.

Tajeddini, K., Trueman, M., Larsen, G., 2006]. Examining the effect of market orientation on innovativeness. Journal of Marketing Management 22 (5–6), 529–551.

Tang, J., Le, C.D., 2007]. Multidimensional innovation and productivity. Economics of Innovation & New Technology 16 (7), 501–516.

Voss, C.A., 1985]. Determinants of success in the development of applications software. Journal of Product Innovation Management 2 (2), 122–129.

Wakasugi, R., Koyata, F., 1997]. R&d, firm size and innovation outputs: are Japanese firms efficient in product development? Journal of Product Innovation Management 14 (5), 383–392 (a Special Issue on Product Development in Japanese Companies).

Wang, C., Kafouros, M.I., 2009]. What factors determine innovation performance in emerging economies? Evidence from China. International Business Review 18 (6), 606–616.

Wang, C.-H., Lu, I.-Y., Chen, C.-B., 2008]. Evaluating firm technological innovation capability under uncertainty. Technovation 28 (6), 349–363.

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M.C., Regnel, B., Wesslen, A., 2000]. Experimentation in Software Engineering: An Introduction. Kluwer Academic Publisher, Massachusetts, USA.

Yam, R.C.M., Guan, J.C., Pun, K.F., Tang, E.P.Y., 2004]. An audit of technological innovation capabilities in Chinese firms: some empirical findings in Beijing, China. Research Policy 33 (8), 1123–1140.

Henry Edison received his BEng in Informatics from Bandung Institute of Technology, Indonesia in 2004 and his MSc in Software Engineering from Blekinge Institute of Technology, Sweden in 2010. He is currently a senior software engineer at Flight Focus Pte. Ltd., Indonesia.

Nauman bin Ali is a PhD student at Blekinge Institute of Technology. He is involved in empirical research in the field of software engineering. He received his MSc in software engineering from Blekinge Institute of Technology, Sweden in 2010 and the BSc in computer science from National University of Computers and Emerging Sciences, Pakistan in 2004.

Richard Torkar is an associate professor at Chalmers and Gothenburg University, and Blekinge Institute of Technology. His focus is on quantitative research methods in the field of software engineering. He received his PhD in software engineering from Blekinge Institute of Technology, Sweden in 2006.