

The Impact of a Proposal for Innovation Measurement in the Software Industry

Nauman bin Ali
Blekinge Institute of Technology
Sweden
nal@bth.se

Henry Edison
Lero, NUI Galway
Ireland
henry.edison@nuigalway.ie

Richard Torkar
Chalmers and University of
Gothenburg
Sweden
Stellenbosch Institute for Advanced
Study (STIAS)
South Africa
torkarr@chalmers.se

Abstract

Measuring an organization's capability to innovate and assessing its innovation output and performance on the market is a challenging task. We proposed a comprehensive model and a suite of measurements to support this task. In the current paper, we have reflected on the impact of the work. We have mainly relied on quantitative and qualitative analysis of the citations of the paper.

CCS Concepts: • **Computer systems organization** → **Embedded systems**; *Redundancy*; *Robotics*; • **Networks** → *Network reliability*.

Keywords: innovation, impact, relevance, measurement

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Richard 1 Introduction

Innovation measurement in SE was a challenge—we contributed with a measurement framework in *Towards innovation measurement in the software industry* [4].

The paper is structured as follows: Section 2 summarizes the contribution of *Towards innovation measurement in the software industry*. In Section 4, we describe a content analysis of the articles citing *Towards innovation measurement in the software industry*. Section 5 discusses the research identified

in Section 4 that has extended our work. In Section 6, we discuss the research which documents the use of our work in industrial settings. Section 7 concludes the paper with some suggested directions for future research.

2 Summary and main contributions of *Towards innovation measurement in the software industry*

Over the past, companies relied on cost and lead time reduction and quality improvement to strengthening their competitiveness. While quality is necessity, today it is not sufficient. Companies must continuously innovate; develop new processes and deliver new products to achieve and sustain a competitive advantage. Otherwise, they tend to lose their position to new and emerging startups that have innovative offerings. 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.

The important of innovation measurement is well emphasised in industry. The Boston Consulting Group's survey [1] revealed that most executives believe that their companies should measure innovation as rigorously as core business operation, but less than half of companies actually do so. There is little consensus on how innovation measurement should be carried out. Each definition of innovation that is used signify a different aspect of innovation, e.g. perspectives, levels and types etc. This in turn determines what is considered as elements of innovation and how these are measured.

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.

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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. A systematic literature review (SLR) [6] was conducted to establish the state of the art of innovation measurement, followed by a web-based questionnaire [5] and face-to-face interviews [3] to collect the opinions of software industry practitioners and academics. In total, we retrieved 13,401 articles from seven digital libraries (Compendex, Scopus, IEEEExplore, ACM Digital Library, ScienceDirect and Business Source Premiere). After applying inclusion/exclusion criteria, 204 papers were accepted as the primary studies. We had 145 respondents out of which 94 completed the questionnaire - thus the completion rate was 54.83%. Four industry practitioners (middle managers) and three academics with close relationship with industry were interviewed in this study.

Our review shows that there are 41 definitions of innovation found in the literature which highlight 4 important attributes to measure:

- Impact of innovation on the market and technology, e.g. incremental or radical innovation, market or technological breakthrough.
- Types of innovation, e.g. product (new or significantly improved products), process (new or significantly improved design, analysis, or development method), market (new or significantly improved marketing methods, strategies, and concept in product design or packaging, placement, promotion, or pricing), and organisation innovation (new or significantly improved organisation methods, e.g. business practices, workplace organisation or external relations).
- Degree of novelty, e.g. new to the firm, new to the market, new to the world, and new to the industry.
- Nature of process: iterative process.

While twenty-eight determinants of innovation have been reported in literature, but only seven of them are studied in the software industry: internal collaboration, customer orientation, champions, human resources, strategy, networking, and leadership. Two-hundred and thirty-two metrics have been used to measure innovation in firm (88%), industry (1%), regional level (11%). However, only 37% of them have been statistically validated and 58% have never been used in practice. Our review also identifies 13 innovation measurement frameworks. Most of these framework focus on technological breakthrough (8 frameworks). Out of these frameworks, only one framework have been studied in software companies.

The results of the interview and the questionnaire are consistent with the view of the impact, types and the dimension of novelty of innovation. The experts and respondents with management and executive roles perceive innovation at a much broader level and emphasise the market and organisation innovations by using abstract concepts like value

creation and need fulfilment. They looked at the purpose and goal to define what may be considered as innovation. While respondents with technical roles have a strong inclination on product innovation as they mainly involved in product development.

There is also an agreement on the importance of innovation measurement from the interviews and the questionnaire results but the practice is still lagging behind. Majority of respondents and experts reported the lack of explicit innovation strategy and measurement programme. Moreover, innovation measurement suffers from the following challenges:

- Lack of consistent definition of innovation. Definitions are fundamental as they affect the measurement program and help provide a common understanding.
- Lack of meaningful metrics. For example, R&D measures (e.g. percentage of sales spent on R&D, number of R&D staff, etc) only focus on input and may not be applicable in small and medium enterprises. Similarly, the IPR-based measures (e.g. patent counts, and citation-based data, etc) may no represent innovation at all - prevent competitor from exploiting opportunities.
- Lack of frameworks to guide innovation measurement. Measurement frameworks consist of a set of related metrics, data collection mechanism and data uses inside a company. However, as there is no clear understanding what innovation is, there is also no agreement on what metrics should be collected.

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. 1. This model was further refined after preliminary evaluation by academics and practitioners. From the 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 terms of implications, the paper makes three contributions to both research and practice. First, 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

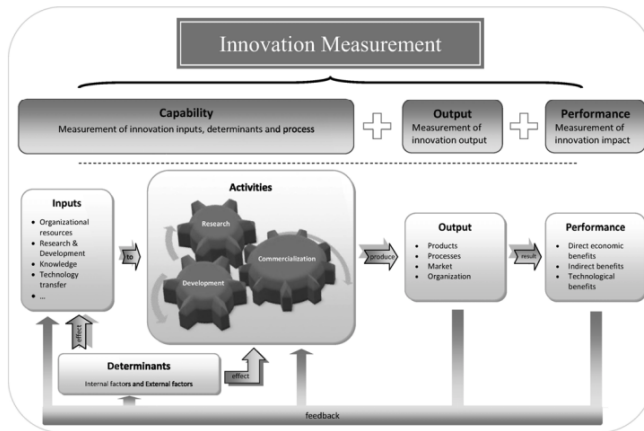


Figure 1. Innovation Measurement Model

metrics and their classification based on what aspect of innovation they are used to measure. The second contribution is to provide an innovation measurement model, which is founded in empirical research and has been evaluated by experts. The model captures various dimension of innovation. Industry practitioners could use our findings to reflect on their experience on innovation measurement in order to minimise the challenges in their contexts. Finally, the study provides future direction for innovation measurement research.

3 Methodology

For understanding the impact of *Towards innovation measurement in the software industry*, we have relied on the classification schema for academic citations proposed by Teufel et al. [9]. We also considered the taxonomy proposed by Bornmann and Daniel [2]. However, based on a pilot application we found Teufel et al. [9] more straight forward and sufficient for our analysis. The decision is further supported by prior experience of using Bornmann and Daniel's taxonomy in software engineering literature [8].

The categories in the schema we used are listed and briefly described in Table 1. To separate any industrial application of our work we added a separate category.

On February 24, 2020, the *Towards innovation measurement in the software industry* had over 72 citations in Science Direct and Scopus, 61 in Web of Science Core Collection, and 234 in Google Scholar. To get a relatively complete picture of how this work has impacted further research, we decided to analyse the 234 citations on Google Scholar.

In a pilot, the first two authors classified ten randomly selected articles and discussed the use of categories. Thereafter, they divided the 234 articles among them and independently classified them. The procedure followed is briefly summarized below:

- Exclude citations where the full-text is not available.

- Exclude articles which are not written in English.
- Exclude articles that do not cite *Towards innovation measurement in the software industry* in the full-text.
- From the title, abstract and the publication venue judge the discipline of the publication (e.g. software industry, manufacturing, farming or automotive).
- Only for conference papers and journal article, search for the citation to *Towards innovation measurement in the software industry* in the full text, for each citation in the paper read the entire paragraph containing it to understand the context, then classify the citation based on categories in Table 1.

4 Overview of the papers citing *Towards innovation measurement in the software industry*

The 234 citations to *Towards innovation measurement in the software industry* were analysed using the process described in the Section 3. Figure 2 provides the results of the selection steps. In total 118 citations were excluded from further analysis. 54 were considered grey-literature i.e. books, technical reports and theses. A majority i.e. 42 of the 54 citations in the grey-literature were masters or doctoral theses. Similarly the remaining 64 of the 118 citations were excluded for other reasons (language of the publication, inaccessible full-text, incorrect citation and duplicate citations). A clear majority 52 of the 64 citations excluded in this group were not read in full-text as they were not written in English.

Two interesting results emerge from this data: (1) that a significant number of publications not written in English have cited *Towards innovation measurement in the software industry*, and (2) almost an equal number of citations are from grey literature. This indicates that systematic literature reviews in software engineering, like in medicine, should also develop a strategy to consider such literature or at the least consider the impact of not including such literature in SLRs.

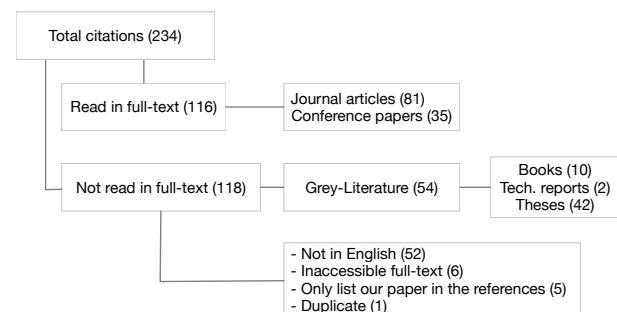


Figure 2. Results of applying selection criteria on the citations

Table 1. Categories of citing papers from Teufel et al. [9]

Category	Sub-category	Description
Weakness	Weak	Weakness of the approach pursued in <i>Towards innovation measurement in the software industry</i> , Weakness in the definition, model, entities, attributes, or measurements of innovation as proposed in <i>Towards innovation measurement in the software industry</i>
Contrast/Comparison	CoCoGM	Contrast/Comparison in Goals or Methods (neutral)
	CoCoR0	Contrast/Comparison in Results (neutral)
	CoCo-	Unfavourable Contrast/Comparison (current work is better than the work in <i>Towards innovation measurement in the software industry</i>)
	CoCoXY	Contrast between a cited method and the method in <i>Towards innovation measurement in the software industry</i>
Positive sentiment	PBas	author uses the work in <i>Towards innovation measurement in the software industry</i> as a starting point
	PUse	author uses definitions/models/measures
	PIUse ¹	author uses the work in <i>Towards innovation measurement in the software industry</i> in industrial settings
	PModi	author adapts or modifies definition/model/measurements presented in <i>Towards innovation measurement in the software industry</i>
	PMot	this citation is positive about approach or problem addressed in <i>Towards innovation measurement in the software industry</i> (used to motivate work in current paper)
	PSim	author's work and the work in <i>Towards innovation measurement in the software industry</i> are similar
	PSup	author's work and the work in <i>Towards innovation measurement in the software industry</i> are compatible/provide support for each other
Neutral	Neut	Neutral description of cited work, or not enough textual evidence for above categories.

The remaining 116 of the 234 citing papers were read in full-text. Of these 81 are journal articles and 35 are conference papers citing *Towards innovation measurement in the software industry*. This is an interesting result in itself as *Towards innovation measurement in the software industry* is getting significantly more citations from journal articles and grey-literature than conference papers. When looking at the publication forums from software engineering and other fields we see a different pattern. In SE, 24 of the 44 (55%) citing papers are journal articles and remaining 20 (i.e. 45%) are conference papers. Whereas in the 72 citing articles from other fields 57 (i.e. 80%) are journal articles and 15 (i.e. 20%) are conference papers. We speculate that this may be an artifact of different traditions of publications in different fields i.e. other fields may not have similar tradition of conference proceedings or even a similar frequency of conferences.

The analysis of the use of *Towards innovation measurement in the software industry* in 116 conference papers and journal articles is summarized in Table 2. Only eight self citations were identified.

In *Towards innovation measurement in the software industry*, we proposed a model and metrics based on a consolidation of research from other fields for software development field. However, it is interesting to observe that the article

has been cited frequently in literature from outside software engineering. Only 44 of the 116 (i.e. 38%) of the publications are on topics related to software development. A majority, 67 of the 116 (i.e. 62%) of the citing articles have no stated connection to the context of the software industry. These articles encompass several diverse fields including the following: automotive, banking, economics, farming, forestry, health sector, human resources, logistics, manufacturing, mechatronics, NGOs, oil industry, politics, restaurants and transportation. A more detailed analysis of the reasons for the citations will help speculate the reason for this disparity.

Overall, in terms of the categories of the citing article (please see Table 1 for a listing and the definitions of the categories) 75 of 116 (i.e. 65%) are neutral, 38 of 116 (i.e. 32%) are neutral, and only 2 of 116 (i.e. less than 1%) present a comparison/contrast. Surprisingly, we did not find any papers identifying or discussing a weakness of the research documented in *Towards innovation measurement in the software industry*.

We expected that the number of citing articles in different categories will be different for literature from software engineering research and other fields. As we expected more citations identifying weaknesses, presenting comparisons

and building on our work from within our discipline. However, similar patterns of citation appear both in and outside software engineering. In software engineering literature, of the 44 citing papers, 17 (i.e. 39%) are positive, 27 (i.e. 61%) are neutral while no comparison/contrast or weaknesses of *Towards innovation measurement in the software industry* are presented. Among the 72 citing papers from other fields, 21 (i.e. 29%) are positive, 48 (i.e. 67%) are neutral while 2 citing papers present a comparison/contrast and no citing papers present any weaknesses of *Towards innovation measurement in the software industry*. Therefore, no discernible difference in citing categories are observed.

A majority i.e. in 21 of the 38 (55%) citing articles with in the "positive" category, use the definition, metrics or the model proposed in *Towards innovation measurement in the software industry*. The next most frequent (12 of the 38 cases in the category i.e. 32%) positive use of *Towards innovation measurement in the software industry* as a starting point or motivation for their work. A few articles also describe that they adapted the definitions presented in *Towards innovation measurement in the software industry* or considered their work similar or supporting the work presented in *Towards innovation measurement in the software industry*.

However, we found no documented evidence of applying the model or metrics given in *Towards innovation measurement in the software industry* in industry in the citing papers. Perhaps they grey literature not considered for the detailed analysis in this study may have reported such a case as an experience report or technical report.

While discussing the citations the following reference will be useful [7] We can use this to also articulate why we have relied on citations as a way to reflect on the paper.

5 Positioning in consideration of the recent state of the art and practice

Our reading from the 44 citing papers indicate various research areas within SE context, e.g. software measurement, requirement engineering, software ecosystem and agile. Open innovation seems to gain more interest from scholars (6 papers). Open innovation is based on outside-in and inside-out knowledge flows that leverages both product and process innovation. Innovation stimulus, innovation measurement, and corporate innovation are the second most topics which are reported in 4 papers each. Innovation stimulus focuses on the key factors or determinant of innovation, while corporate innovation deals with leveraging innovation in the large companies. In addition, three papers focus on innovation process model.

In terms of research type, 13 citing studies were theoretical papers (including literature review papers), while 28 were empirical research. All of the empirical research employed qualitative method. Case study was the predominant research method (21 studies), followed by Grounded Theory

(2 studies), survey (2 studies), Design Science, experiment and interview (1 study each). The summary of citing papers in SE and research method is shown in Table 3.

6 Expected impact

Here it would be nice to show cases in industry not counting Ericsson. Perhaps we can get it from Section 4?

Figure 3 shows the trend of citations to *Towards innovation measurement in the software industry* as indexed on Google Scholar. According to PlumX Metrics², in terms of the number of citations provided by Scopus, *Towards innovation measurement in the software industry* is getting more citations than 97% of the articles published in 2013 in the journal of systems and software. The article had an advantage since it was available online already in February 2013. However, *Towards innovation measurement in the software industry* is also doing better than 95% of the articles published in the journal of systems and software in the years 2013, 2012, and 2011.

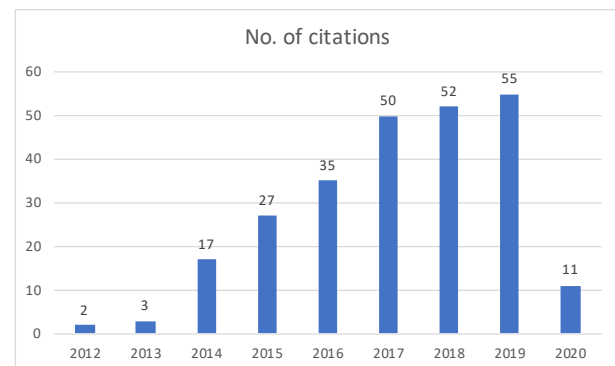


Figure 3. Trend of citations to *Towards innovation measurement in the software industry* on Google Scholar over the years

A thorough analysis of the citing papers showed no direct industrial impact of *Towards innovation measurement in the software industry* however the paper has had significant theoretical impact. A reasonable percentage of the citations (38 papers or 32%) have made use of the theoretical contributions (in terms of the proposed definitions, models and metrics) of *Towards innovation measurement in the software industry*.

Also significant is the impact of the paper outside SE, even though the title of the paper and the publication venue are both very explicitly focused on SE.

In this paper we have only analysed the citing papers from conferences and journals that are written in English. But, it is interesting to see that *Towards innovation measurement in the*

²Please see the following URL for latest statistics for *Towards innovation measurement in the software industry* <https://plu.mx/plum/a/?doi=10.1016/j.jss.2013.01.013&theme=plum-sciencedirect-theme&hideUsage=true>

Table 2. Results of an analysis of the citing papers

	Total	Weak	Comparison / Contrast	Positive	Neutral	Jrnl.	Conf.
Self citations	8	0	0	2 (PBas:1, PMot:1, PModi:1)	6	5	1
From software re- lated fields	44	0	0	17 (PBas:4, PModi:2,PUse:7,PMoti:4, PSup:1)	27	24	20
Others	72	0	2	21 (PBas:2, PModi:2,PUse:14,PMoti:2,PSim:1, PSup:2)	48	57	15
Total	116	0	2	38 (PBas:6, PModi:2,PUse:21,PMoti:6,PSim:1, PSup:3)	75	81	35

Table 3. Citing Papers and Research Method

Theme	Type of Studies				
	Theoretical	Empirical			
		Case Study	Grounded Theory	Survey	Others
Open Innovation	4	1		1	
Innovation Stimulus	1	2			1
Corporate Innovation	1	3			
Innovation Measurement		4			
Innovation Process Model		2	1		
Others	7	9	1	1	2

software industry has almost as many citations in non-English and non-peer reviewed literature as it does in conference proceedings and journals.

Possibly Richard? New emerging ideas and current vision

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