A Function Innovation Model for the Manufacturing Industry

John Lindström¹, Magnus Löfstrand², Vahid Kalhori³,
Martin Helgason³, Mattias Nyström⁴, Bengt Liljedahl⁵,
Rikard Mäki⁶, Lennart Karlsson²

¹*Luleå University of Technology, 971 87 Luleå, Sweden*

²*Uppsala University, UDBL, SE-75105 Uppsala, Sweden*

³*AB Sandvik Coromant, 811 81 Sandviken, Sweden*

⁴*Masticon AB, Talgoxevägen 37, 178 39 Ekerö, Sweden*

⁵*Bosch Rexroth Mellansel AB, 895 80 Mellansel, Sweden*

⁶*Volvo Construction Equipment, 631 85 Eskilstuna, Sweden*

E-mail: {magnus.lofstrand; lennart.a.karlsson}@it.uu.se;

{vahid.kalhori; martin.helgason}@sandvik.com;

john.lindstrom@ltu.se; mattiasenystrom@gmail.com;

bengt.liljedahl@boschrexroth.se; rikard.maki@volvo.com

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Abstract

The paper addresses the need for innovation in order to achieve sustainable growth and business development within the manufacturing industry, and further how that can be enabled by striving towards functions. Adopting an open perspective, the paper proposes a function innovation model involving academia, potential function providers and customers in order to create a long-term win-win situation between function providers and their customers.

Keywords: business value, function, Functional Product, Functional Sales, innovation model, Industrial Product-Service System, manufacturing industry, Product-Service System, sustainability.

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1 Introduction

This paper addresses the need for innovation in order to achieve sustainable growth as well as internal and external business development within the manufacturing industry and, further, how that can be enabled by striving towards offering and selling functions. A function is sold when a provider, instead of selling traditional products and services, offers customers a function with an agreed-upon level of availability. Other potential contract parameters to offer a function are with an agreed-upon productivity or result that should be met. Hereafter, the term ‘function’ will denote the concepts of Functional Sales (Stahel, 1997) and Functional Products (Alonso-Rasgado et al., 2004; Lindström et al., 2013 and 2015) as well as Product-Service Systems/Industrial Product-Service Systems (Meier et al., 2010) when sold as availability- or result-oriented.

Innovation, which is essential for the long-term survival of corporations, can be addressed using specific or general innovation models and, in addition, a closed or open innovation perspective can be applied. A specific innovation model targets a specific area and is tailored for the innovation challenges in such an area. A general innovation model may be applied for a wider area or many areas, providing support when addressing the innovation challenges encountered within one or more areas. However, a specific innovation model may provide a better support for a specific area’s innovation challenges compared to when using a general purpose innovation model. Numerous innovation models have been proposed, ranging from specific to general as well as the open and closed innovation perspectives. Examples of innovation models targeting a specific area are: user-centric innovation (von Hippel, 2009), business model innovation (Chesbrough, 2011a; Sawhney et al., 2011; Lee et al., 2012), technology/product innovation (Wheelwright and Clark, 1992; Edgett, 2013), service innovation (den Hertog, 2000; Fischer et al., 2012), or product-service systems innovation (Tukker and Tischner, 2006). Further, examples of general innovation models are: integrated innovation (Khilji et al., 2006; Zhang et al., 2010), use of networks (Nonaka and Takeuchi, 1995; Thorgren et al., 2009; Gnyawali and Srivastava, 2013), and open innovation (Lee et al., 2010; Chesbrough, 2011b). Currently, there is a dearth of literature regarding how a function innovation model for the manufacturing industry can be constructed, as well as what specifics need to be taken into account during such innovation.

Chesbrough (2010, p. 355) asserts that the choice of business model is crucial, as “a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model”. In addition, Casadesus-Masanell and Ricart (2010) underline the need to understand how to innovate business models in order to improve the creation and capture of value. Radical or disruptive innovation is not always necessary (Gallouj and Weinstein, 1997). Commonly, innovation is embodied in incremental development or refinement of e.g., business models, products or services, and may require organizational change, new skills or capabilities. Customers may also need to change in order to adapt to new offerings and possibilities to innovate, and thus gain competitive advantage. However, larger changes or innovations are sometimes necessary to stay competitive. *The required innovation will not happen by coincidence or via an organizational bottom-up initiated change. What is required is provider top-management direction and support for changes (Young and Jordan, 2008) combined with provider bottom-up adoption of new ideas (Daft, 1978) for design, development, business modelling and offerings, and that customers need to adapt accordingly.*

If a function is offered, to manage the complexity, a consortium of corporations with complementary skills and capabilities may need to be formed and together act as a provider. To innovate within and as a consortium it is possible to use a general innovation model and adapt it, whereas another possibility is to use an innovation model developed for a function context. It is likely that, although adding additional complexity for an organization, a specific innovation model will render a better result than a general one. Thus, since there is no current function innovation model published, the research question of the paper can be formulated as: how can a function innovation model be constructed? Further, the purpose of this paper is to propose, from a largely open perspective, how a function innovation model can be constructed, involving academia, potential function providers and customers in order to create a long-term win-win situation between function providers and their customers. Teece (2010) raises the question as to how to build a sustainable competitive advantage with profit or super profit. The answer, according to Teece (2010), is to excel at innovation of both technology and business models, and to understand the customers and business design options. Having a function in mind, instead of a technology, Teece’s answer is interesting and will be used to analyze the proposed function innovation model.

2 Research Approach

The research has been based on a spiral process (Boehm, 1988) i.e., an iterative process with incremental further refinement over time in terms of evolving requirement analysis, planning, risk analysis, development, testing/evaluation and verification/validation. The spiral process was selected, as it supports additions, changes and refinements with following test and verification/validation over time – and it takes time and a number of iterations to reach a robust function innovation model. Another possible research approach would have been to use action research, which was discarded because the notion of function development processes was too ambiguous at the start and the spiral model offers a clear and straight-forward way of addressing the research question, as many parties were involved. The spiral process was adapted to an innovation model development context, as Boehm's process originally was intended for software development; however, it was later used as a general development/research process by many organizations. The starting point was an initial conceptual outline regarding a functional innovation model for the manufacturing industry, which has been further researched, developed and refined over almost 8 years and 3 iterations. Starting out with a conceptual outline, the testing/evaluation and verification/validation were limited during the first iterations due to lack of robustness and actual implementation. As more knowledge has been gained on function innovation, the function innovation model has become further sophisticated during the spiral iterations in terms of theoretical foundation, actor network and level of details. The first iteration model was exploratory and mainly used to guide the initial research activities, whereas the second iteration model involved academia and potential function providers. The third iteration model, which is outlined and explained in this paper, involves academia, function providers and customers, and targets different organizational levels in order to enable and facilitate change and uptake of new ideas where appropriate. Currently, the function innovation model has partly been implemented at a few corporate/industrial partners. Additional improvement, implementation, testing/evaluation and verification/validation activities are foreseen using action research and case study methodology.

The research process has been driven by the Swedish VINNOVA Excellence Centre the Faste Laboratory¹ at Luleå University of Technology, Sweden, which at the time of writing includes seven corporate/industrial

¹See acknowledgements.

partners as members. Six research subjects at Luleå University of Technology are involved. The corporate/industrial partners are all manufacturing corporations, spanning from small to large and global. The partners do not compete with each other, and may sometimes have business relations with one another. Although the corporate/industrial partners have different offerings, they are all interested in how to best develop, market and sell functions and/or similar concepts such as Product-Service Systems or Industrial Product-Service Systems, either as a provider in a partner consortium or as part of their own offerings. The corporate/industrial partners are all manufacturing corporations with roots in hardware development and additional components have been added to their customer offerings. What the additional components comprise and their weight or importance differs depending on industry and customer segments served. Some of the corporate/industrial partners aim to increase their revenue from soft parts i.e., services, knowledge or know-how, etc., as well as functions sold globally. The potential functions planned or currently being offered, by some of the corporate/industrial partners, differ and have differing emphasis on the composition of hardware, software, service support system and management of operation. Thus, all of the Faste Laboratory's corporate/industrial partners are not yet to be considered as potential function providers.

Currently, the Faste Laboratory is in the process of developing an innovation model to enable Functional Product Innovation (i.e., function innovation) involving academia, potential function providers and customers. The involvement of potential function providers and customers is crucial. The Faste Laboratory's nine current research projects, which are divided into three main streams, are further supported and complemented by three additional Swedish and internationally funded projects. The Faste Laboratory is the main vehicle and aggregator in the process and is supported by the other research projects.

The above research process is supported by an international Scientific Advisory Board and an international team of centre evaluators attached to the Faste Laboratory via VINNOVA. Confidentiality agreements in different research projects need to be honoured, and thus all results and ideas may not be aggregated and shared accordingly. However, aggregation of published results is always possible. Within the Faste Laboratory all results can be shared among the corporate/industrial partners. The outcome of using the described research approach is a proposed function innovation model, which will be further improved, verified and validated in future research together with potential function providers and customers.

3 From Products and Services towards Functions within the Manufacturing Industry

This section aims to give a foundation for understanding why functions are of interest and how functions can be embodied within the manufacturing industry. Increasing competition from industrial players with the advantage of lower labour and production costs forces many corporations to reconsider why/how/what they do. Corporations with a global presence often sense where the existing offers continue to work, and where new offers and ideas are required in order to stay in business. Thus, changing or adding new business models can be quite straightforward and business-as-usual. However, in some cases, it can be far from easy and may require a transformation of the corporation and its delivery process.

For corporations that are used to producing and selling products, services or services bundled with products, taking the step towards selling a function may seem attractive. To actually sell a function, with an agreed-upon availability level, where the customer pays for the delivered function only, requires additional thinking and preparation. It necessitates a lifecycle perspective that encompasses business modelling and development, risk management, finance, design and development, support and maintenance, and access to competencies and skills, for example (Lindström et al., 2012a). Today, many corporations and research groups strive to find the keys to new business models such as Industrial Product-Service Systems, Functional Sales or Functional Products. These business models are all related in the sense that they all enable a revenue increase from soft parts such as services, knowledge and know-how – often extending existing hardware product sales. These business models vary in terms of their sophistication and constituents although, compared with selling products combined with services, selling a function brings additional complexity. The additional sophistication allows for additional revenue and intimate long-term relationships between providers and customers, requiring the creation of a clear win-win situation where the provider needs to be able to charge for assuming increased risks and costs.

As providers of functions differ and many of them target different customer segments, the providers in most cases use business models with varying focal points and thus place different emphasis on the business model elements used (Lindström et al., 2013). Further, the providers may also use different measures to operate a function – in particular, depending on the level of availability and criticality – which may affect the innovation model applied (including the business model used).

3.1 What Is Required to Offer Functions and Manage Risks?

To be able to offer functions and manage the risks involved there is a need, during the design phase of the development, to model the level of availability versus cost to offer. This is necessary in order to determine if and how the function should be sold – i.e., to get a viable and sustainable business case. A function may comprise hardware, software, a service support system and management of operation (Lindström et al., 2012a). A function must be developed in such a way that its operation can be monitored, which requires the capacity to extract data regarding the status and usage of the function (Löfstrand et al., 2012). As a function is deployed at customers and put in operation, providers need to monitor the function in order to honour the level of availability agreed upon with the customer. The idea is not only to monitor the operation (and ensure that it is running within agreed parameters) but also to find and locate the root cause of any problem that arises, and not just merely manage the symptoms. Otherwise, such problems will commonly recur unless properly managed (Karlsson et al., 2012). A mind-set and ability to predict problems, and be able to act proactively instead of reactively is crucial (Löfstrand et al., 2011) if there is a challenging level of agreed-upon availability and penalties for non-conformity. Thus, continuous monitoring and optimization of the function and its operation is necessary.

During the operational part of a function's lifecycle, which can sometimes be 30 years or more, there is an opportunity for small and medium-sized enterprises to provide specialist services remotely and/or on site. Thus, the function provider may need to contract additional provider consortium partners. Adequate collaboration tools, skills and knowing who to put on a mitigation team and when becomes very important for a function provider in order to resolve any arising issues or problems in a timely fashion.

The monitoring of functions and collaboration, during servicing or fault mitigation, should be used to improve and refine the function and its constituents, as well as its operation throughout its lifecycle. In addition, new ideas from customer feedback and unexpected usage can open up for business development in untapped niches, segments or markets.

3.2 Transformation of Existing Products and Services – by Extension or New Development?

An application of the ideas outlined in Section 3 can be that traditional industrially manufactured goods are extended and sold as functions instead. However, it may sometimes be a lot easier to develop a function from the

start, rather than transforming existing products and services into a function (Karlsson et al., 2012). By adding features, during the development, required for a function from the start, it is easier and less expensive to add, for instance, data-extraction by means of interfaces or sensors inside an oil tank, gearbox or motor. Commonly, adding sensors later on is much harder and expensive, and may in many cases not even be possible without expensive re-designs of parts or sub-systems. However, undertaking such transformation activities and efforts may make providers market leaders instead of followers in the future (Karlsson et al., 2012).

The above applies the Internet-of-Things² approach in an industrial context involving machines, production equipment, humans, business models, complex computations on data streams, scalable computing power and sensor data in data streams.

4 Enabling Function Innovation on Strategic and Partly Tactical Levels: Business Modelling and Development, Development Processes and Risk Level Management

As part of crafting a function innovation model involving academia, potential function providers and customers, it is deemed necessary to involve large parts of the providers' organizations, as these may be largely affected. Thus, top-down and bottom-up perspectives are part of the proposed function innovation model. According to literature (Daft, 1978; Young and Jordan, 2008) as well as the authors' own experiences, to successfully implement major change required in organizations, initiative, continuous support and engagement from top-level management are needed (i.e., a top-down approach). Otherwise, the implementation will most likely fail. The initiative, support and engagement show that the change is on the top-management agenda and is important. Some of the following research project topics are mentioned in both Sections 4 and 5, depending on the tactical level overlap.

To address function innovation on strategic and partly tactical levels at potential function providers and customers, a number of research projects aimed at business modelling and development, development process and risk level management target the following:

- **business modelling and development;** e.g., the elements of a function business model (Lindström et al., 2013), how to create a win-win

²See <http://www.rfidjournal.com/article/view/4986> for Kevin Ashton's own explanation of the term.

situation (Parida et al., 2014), open operation, how to charge for functions (Lindström, 2014);

- **development process**; e.g., constituents of a function, managing collaboration in provider consortiums (issues related to intellectual property, information sharing/security), information sharing between provider consortium partners and customers during design/development/operation (Lindström et al., 2012b), and how a function development process can be devised (Lindström et al., 2012a);
- **risk level management**; e.g., risks related to providing functions (Reim, 2013), simulation of availability versus cost drivers, availability management (Löfstrand et al., 2011), building and maintaining trust, profitability and sustainability over time.

Getting closer to the business logic on strategic and partly tactical levels can be sensitive, and trust between the researchers and the potential function providers and, in some cases, their customers is essential to get access to data and adequate numbers of people/roles to interview. However, having credibility at tactical and operational levels opens many doors at the strategic (i.e., top-management) level. For purposes of e.g., problematization, data collection, verification/validation studies, implementation of results, and to provide feedback, one or more potential function providers is/are always involved. Further, the different potential function providers share and discuss ideas and experiences among themselves within the boundaries of the confidentiality agreement. The volume of research on strategic and tactical levels is being ramped up, since, owing to its holistic character, it potentially affects large parts of organizations and is thus important for the take-up and implementation on tactical and operational levels.

5 Enabling Function Innovation on Tactical and Operational Levels: Development of Processes, Frameworks, Approaches, Tools and Methods

A bottom-up perspective is necessary to engage and change behaviour of employees at different levels in provider organizations, mainly involved in the design and development of functions, to enable the organizational change and take-up of new ideas required.

To enable function innovation on tactical and operational levels at potential function providers and customers a number of research projects aimed at design and development of functions target the following:

- **processes**; e.g., development process for functions and what information to share before, during and after the development process (Lindström et al., 2012a and 2012b);
- **frameworks**; e.g., simulation of availability and optimization of cost drivers, constituents of a function, knowledge integration with learning capabilities (Helgason and Kalhori, 2012);
- **approaches**; e.g., data-driven design and simulation-driven design (Löfstrand et al., 2011);
- **tools**; e.g., monitoring of functions in operation using data streams from sensors, etc. and other product data (Löfstrand et al., 2012), collaboration tools;
- **methods**; e.g., requirement engineering involving customer testing, methods to analyze causal relationships in functions used to monitor and predict failures (Löfstrand et al., 2012).

Regarding frameworks, in a collaborative function development scenario addressing process planning activities, there is a need to efficiently share and process data, information and knowledge related to pre-process activities (e.g., modelling, design and operation planning), in-process activities (e.g., operation) and post-process activities (e.g., quality verification). In order to support efficient use and re-use of knowledge in such a scenario, a conceptual model and framework for knowledge integration with learning capability has been proposed by Helgason and Kalhori (2012).

The relations among the researchers and the potential function providers involved in the research projects are based on actual need, trust and cooperation. As is the case on strategic and tactical levels, there is always one or more potential function provider involved (e.g., for purposes of problematization, data collection, verification/validation studies, implementation of results, feedback), and the different partners share and discuss ideas and experiences among themselves. In the past a majority of the research projects have targeted tactical and operational levels. Subsequently, the relations between researchers and potential function providers on those levels are well developed.

6 Inspiring and Facilitating Function Innovation: Research in Academia

To drive the research and development of a function innovation model, a research project portfolio targeting problems on strategic, tactical and operational levels at function providers and customers is needed. The research problems for academia can be categorized on a high level according to:

- what and how to offer?
- what to develop?
- how to design and develop?

These problems are interrelated, which increases the complexity level further, and present a number of sub-problems. In addition, a project portfolio is necessary to reach a critical number of new ideas, methods, approaches, models, processes, etc., that inspire and facilitate necessary change at the function providers and customers.

A strong reason for academia to be part of the function innovation model is that developing and selling functions are complex, emerging and require new knowledge in many areas. Developing, selling and operating functions are multi-disciplinary problems and may thus require input from multi-disciplinary research ranging from business and financial modelling, contract and IPR management to development, maintenance, availability management and long-term operations planning, etc. Currently, without involvement from academia, the function innovation model would most likely work out; however, probably a lot more slowly than with academic involvement and input. In the future, when more research on functions is available, there will be less need for academic involvement and input.

Aggregation, combination and integration of the results from a project portfolio comprising two sets of projects described below is conducted, and the intent is to make the total aggregated output from the projects larger than the sum of the individual components, and pass that on as input to function providers and customers.

The main academic contribution to the function innovation model proposed in this paper originates from the strategic and tactical-level projects described below:

- research projects funded on a national level involving international cooperation³ with top-class universities and research institutes addressing overarching function innovation topics including: business modelling and development, development process and availability issues. These research projects are necessary for the **top-down initiated innovation** i.e., targeting potential function providers and customers on mainly a **strategic level** but also partly on a **tactical level**.
- research projects funded on national and international levels² addressing: processes, frameworks, approaches, tools and methods, also required to design and develop functions. These research projects are needed for the

³See acknowledgements.

implementation of **bottom-up innovation** i.e., targeting the potential function providers and customers on **tactical and operational levels**.

7 A Function Innovation Model

Figure 1 shows a proposed **function innovation model** spanning academia, potential function providers and customers. The innovation model has intentionally been kept limited to what can be directly influenced by any of the actors taking part in the innovation model. The innovation model is driven by academia and academic research projects, but also aggregates public results from other research projects in which project participants have participated. Thus, the results from research projects on national and international levels are aggregated, combined, integrated and made available for usage by the potential function providers.

On the far right are **academic activities** which include the research projects addressing problems and topics on strategic, tactical and operational levels at the potential function providers and customers. The problems are all real and actual problems, formulated together by mainly potential function providers

Figure 1 Proposed function innovation model.

and researchers. However, function customers provide input to the providers. The results from a number of research projects are aggregated, combined, integrated and disseminated to the potential function providers and, where appropriate, function customers as well. When appropriate, initial results with large potential are verified, validated and implemented at the potential function providers. Reaching the validation and implementation state is the ultimate objective for the researchers. The industrial objective is that the results should be put into context to provide input and ideas in order to create value for the potential function providers. Thus, the dissemination of research results needs to be carefully planned, targeting adequate roles on appropriate levels at potential function providers.

In addition, targeted and/or public dissemination activities are part of all individual research projects under the umbrella of academia. The **value created for academia** is, besides publications and funding for doctoral students and senior researchers, the industrial network and additional academic contacts built up in combination with having the opportunity to “go all the way” and take research results from academia to validation and implementation in the manufacturing industry.

In the middle, potential **function providers** are divided into strategic and partly tactical levels (top) as well as tactical and operational levels (bottom). The different levels address different topics needed to design, develop, market, offer, sell and subsequently operate a function at customers, **creating a long-term win-win situation**. A win-win situation implies that business value is created and captured for both providers and customers. Examples of possible **business value for function providers** are: increased revenue (by taking a greater responsibility, and managing additional complexity and risk) and improved competitiveness and sustainability. However, a function also poses additional risk and complexity that must be managed throughout the lifecycle of the function. The long-term economic and technical lifecycle considerations differ significantly from when selling, for instance, products and services, and must necessarily be taken into consideration as early as possible in the development of the business case, the function itself as well as the operation of the function (Lindström et al., 2014). The long-term, or through-lifecycle, aspects involve a number of both challenging as well as costly activities and management issues. Examples of such aspects include lifecycle engineering and management, knowledge management, asset management (involving obsolescence/change/configuration management), availability management, monitoring, diagnostics, predictive/proactive maintenance, etc. (Lindström, 2015). The longer the expected lifecycle is,

the more emphasis needs to be put on the long-term aspects to not make mistakes that may cause severe economic/financial impact at a later stage of the operation of the function. Below are further details describing what is dealt with at the top and bottom in Figure 1 at function providers:

- The strategic and partly tactical levels are mostly concerned with: business strategy and planning, business model development, technology strategizing and development, long-term aspects, intellectual property management, development processes, quality, organizational management, human resource management (e.g., skills and competences required), outsourcing, supply chain management, and management of potential function provider consortiums, etc. A provider consortium can have great use for specialized and innovative SMEs. Thus, many aspects must be addressed, many of which are of a holistic character and affect whole or large parts of organizations. A close relation with the customers allows for proactivity, joint strategic and tactical development, discussion on emerging strategic customer needs, and ideas and proper feedback from customers to learn how the function and its surrounding business and technical frameworks can be improved.
- The tactical and operational levels are initially mainly concerned with design and development of functions. During design consideration must also be given to how to manage the operation of the function at customer sites (which can be globally dispersed) over time. To reach a long-term win-win situation, close cooperation between function providers and customers is foreseen as necessary, requiring joint tactical and operational development and discussions on emerging tactical and operational customer needs. Further, a close relation also opens up for bi-directional feedback and ideas to improve the function and its operation for providers, as well as how it is applied and operated at customers.

On the far left are potential **function customers** who should work closely with the function providers to get the most out of the function procured. As procurement of functions is foreseen to lead to long-term relationships between customers and providers, it is necessary to facilitate a win-win situation from both ends. To achieve this requires dedication, effort and resources (including top-management attention and involvement). The customers should interact with the providers on both strategic and partly tactical as well as on tactical and operational levels, and address/manage the necessary topics on an adequate level. If the win-win situation between a function provider and customer is

skewed, the win-win situation needs to be restored. This is considered as paramount, as the win-win situation can be considered to govern the economic lifecycle (Lindström et al., 2014). Further, trust between the function provider and customer is considered as the most important long-term aspect, and thus the trust needs to be nurtured and invested in (Lindström, 2015). The **business value** created and captured at customers can be embodied in various forms ranging from: (increasing) revenue, (improved) efficiency/competitiveness and sustainability, and less risk as well as complexity by procurement of a function.

7.1 Scope

Outside of the proposed function innovation model there are a number of aspects and factors affecting the attainment of a win-win situation involving functions; these need to be considered by both function providers and customers. Examples of such aspects and factors are (Lindström et al., 2013):

- **Internal:** corporate history/age/organization/size
- **External:** target markets and geographical coverage

Further, depending on the function and its complexity, provider consortiums (including specialist SMEs) which, together, are able to design, develop, market, offer and sell functions may need to be formed. The customer types, customer offerings and cultures need to be encompassed as well.

The above aspects and factors should be used to build a larger innovation perspective (or system) by the function providers and customers, but are not further addressed in this paper, even though they encircle the proposed innovation model. The reason for limiting the scope in this way is that it would otherwise be too large and complicated.

7.2 Analysis of Outcome

The outcome (see Figure 1) is a proposed function innovation model, currently being developed, which relies on a systemic approach bringing in research results aimed at either strategic and partly tactical levels or tactical and operational levels. However, there is some necessary overlap on the tactical level to provide “organizational glue” which enables any changes required to be initiated both from the top and the bottom (see Figure 1 and function providers). The innovation model creates business value for potential function providers and customers as well as for academia, though in different forms.

Thus, the innovation model creates a systemic win-win situation for the involved actors, and this win-win situation needs to be continuously maintained and developed to yield business value in the future as well. In addition, feedback, ideas and innovations can be input from any of the participating actors.

The proposed function innovation model can be affected by the different properties of function providers and the functions provided. The general framework of the model will most likely remain intact in the future. However, what is researched and its weight/importance, as well as what constitutes the relation's properties (i.e., bi-directional arrows in Figure 1) depends on whether the function customer and application are situated in e.g., the manufacturing, process (pulp and paper, chemicals, pharmaceuticals, etc.) or mining industry. Although the proposed innovation model is intended for the manufacturing industry, that does not rule out application of the model and function innovation in other types of industries.

Various forms of innovation (e.g., radical, improvement, incremental, ad hoc, re-combinative and formalization as suggested by Gallouj and Weinstein (1997)) are envisaged to be supported in the proposed function innovation model. This is due to the continuous development and improvement of a function during its lifecycle using feedback and new ideas from all actors involved.

Comparing the function innovation model with, for instance, a stage-gate model, in which what is developed is commonly moved from one stage to the next in a gradual refinement, reveals that within the function innovation model the "innovation activities" can take place in many places simultaneously. Thus, there are no stages limiting when and where the innovation may take place.

Analyzing the proposed function innovation model towards Teece's (2010) raised question on how to build sustainable competitive advantage with profit or super profit, the model does not per se guarantee profit or super profit. However, it matches well Teece's (2010) answer that what is needed is to excel at both technology and business model innovation, and to understand the customers and business design options. This is accomplished on strategic and partly tactical as well as tactical and operational levels. The model indicates a need for close collaboration and input of new ideas in all directions (i.e., bi-directional relations between the parties). Further, if the customers are able, by using functions, to successfully create and capture business value, the model will most likely add sustainable competitive advantage and create business value for all the involved parties.

8 Discussion

Some features of the proposed function innovation model are discernible in other innovation models e.g., ideas can emerge from within/outside as well as the creation/capturing of value at different actors (open innovation – Chesbrough 2011a, 2011b) from an early stage until the end of a function's lifecycle. Further, using a consortium to develop and provide a function (use of networks – Thorgren et al., 2009; Gnyawali and Srivastava, 2013) and use of specialized SMEs (Lee et al., 2010) are other features needed in the required integration spanning from research activities to the creation/capturing of value at the function customers.

To develop and subsequently implement a function innovation model, in parts or in its full extent, in a corporation is hard and sometimes not even possible due to internal strategic considerations or other challenges. One of the lessons learnt during the research is that it is easier and faster for corporations to change and take up new ideas such as an innovation model when the risks introduced are comparably small and foreseeable. A further lesson learnt is that the uptake commonly is in parts and not all at once. However, the uptake is necessary for verification and validation of the research to not get stuck at the test and evaluation stage in the spiral process. Future research on the model will focus on further improving and stabilizing it and, finally, verifying and validating it.

The use of a spiral process as a research approach can be discussed if it is more appropriate than using, for instance, an action-research or possibly even a case-study approach. The strength of a spiral model is its simplicity when many people and organizations are involved on several organizational levels. Further, as the majority of the participants in the function provider and customer corporations were not researchers and commonly accustomed with various development processes, using an iterative spiral process was a choice that would create few problems, little resistance and also bring the research to its objective i.e., a function innovation model. Regarding future research, a further validation of the function innovation model may be conducted using action research or a case-study approach. The use of another research approach, enabling method triangulation, to further validate the model would benefit the further development and robustness of the model.

An interesting question is which way/ways of innovation is/are best to reach sustainable growth as well as internal and external business development in the manufacturing industry? Innovation models addressing both technology and business development will likely be more successful, on a long-term

basis, than innovation models addressing only one of them. As innovation can occur in many forms; an innovation model can be embodied in many shapes and there is probably no definitive innovation model. These models are merely adequate or appropriate, as long as sustainable growth and business development occur, leading to creation of business value and a competitive edge. Finally, Karlsson et al. (2012) point out that being able to offer a function can make the difference in closing a deal, and separate market leaders from followers. Consequently, striving towards functions may be essential for future success within the manufacturing industry.

9 Conclusions

The proposed function innovation model contributes to innovation management theory by adding specifics on how function innovation can be set up, involving academia, potential function providers and customers. The three research problem categories (see Section 6) may seem trivial. However, when placed in relation with each other, the level of complexity is raised significantly. Further, the relations in between the involved actors and the respective business value created are described. The business value foreseen differs for each actor, and this is important to understand to be able to create sustainable competitive advantage as well as strong relationships among the involved actors.

The practical impacts of the function innovation model are manifold. It demonstrates that innovation requires contributions from all involved and that different topics need to be dealt with on the adequate levels in organizations. The research activities part of the innovation model must address the needs from the different levels and assist in the creation of an innovation-friendly climate, particularly on the strategic and tactical levels at function providers, to facilitate the uptake of new ideas. The innovation-friendly climate should facilitate the transformation of those ideas into actual business value. Thus, mere technology innovation or business model innovation are not enough. Both are required for function innovation contexts (cf. Teece, 2010) in addition to understanding and closely collaborating with customers.

The proposed function innovation model has a framework that can be generalized and partly transferred to other contexts such as products or services produced by the manufacturing industry. What needs to be altered is mainly what the relations comprise and what needs to be dealt with on the providers' strategic and tactical levels as well as the respective tactical and operational

levels. What to market, offer and sell is, of course, a key topic to decide on as well.

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Biographies

J. Lindström Associate Professor EMBA CISSP, received his PhD in Information Systems Science at Luleå University of Technology, Sweden. Currently, John is CEO for the Process IT Innovations R&D Centre spanning Luleå University of Technology and Umeå University, Sweden. John's research interests include business modelling, development processes, availability matters on system and organizational level, as well as modelling and simulation applied in industrial development processes. One of his main research interests lies in the area of product development for function provision, i.e. Functional Product development. Prior to joining academy in 2009, he worked for 15 years in different industries in both management and specialist positions with product-, service-, process-, and business development.

M. Löfstrand Associate Professor (Docent) in Product and production development at Chalmers University since 2015, was awarded his PhD in Computer Aided Design at Luleå University of Technology in 2007. The research concerned *methods and tools for process modelling and simulation*, with applications in industrial development processes. Löfstrand has also published research concerning industrial *distributed collaborative work* through various methods and tools communicating over IP-networks.

His main research since July 2007 has been focused on *simulation of industrial system availability* and using analytics based on data stream management systems and data stream mining to support development of availability based business offers, including functional products, mainly in the process and production industry. Löfstrand is currently employed as senior researcher at Uppsala University, Uppsala Data Base Laboratory.

M. Helgöson is a Ph.D. from Linköping University, Institute of Technology. His main fields of interest are related to technical product models, metrology, CAD/CAM, knowledge integration, closed loop systems and functional products. He came to Sandvik Coromant 1998 and has had different positions e.g. as project leader within R&D, manager of CAD/CAM/CAE-development and integration, and Process-CIO within product development and production. He has been engaged in several internal research and development activities related to method development, process development and functional products, as well as in external national and European research projects. He is currently senior project leader and technology leader at the department of R&D intelligent machining.

M. Nyström Management Consultant holds a Master of Science in Electrical Engineering from the Royal Institute of Technology in Stockholm, Sweden.

Currently Mattias is working for the Swedish company Handicare, owned by the Swedish venture capital company Investor AB, in the care sector. Handicare is a global company developing, manufacturing and selling products for safe handling of patients. Mattias is engaged to develop the organisation and the business processes to improve operational performance. Mattias started his career as one of the co-founders of the Swedish company LGP AB in the telecommunication sector, that grew its business to 100 MEUR in 8 years on a product developed, manufactured and sold on a global basis. Following this organical growth period Mattias continued to work for the company during its consolidation period, that included the acquisition of another Swedish company Allgon and the integration with the American company Powerwave. Following the integration with Powerwave Mattias was engaged in a few more acquisition and integration activities with Powerwave. Mattias has also been working in the Power Industry for a few years.

Mattias' interest and focus areas lie in organisational and business process development as well as business model development for creating future growth and profitability.

B. Liljedahl has a B.Sc. in Mech. Eng. from 1973, also a diploma at University level in Mech. Eng. from 1978. Bengt has totally 41 years of experience from working in Swedish Industry mainly within R&D with 23 years as a Manager for new development. Current position as a Technical Product Manager. Since 1989 co-ordinate and built up a network of close cooperation with Swedish Universities to increase competence in 3 main areas, Tribology, Product Development and Material Science. For that Bengt was awarded an Honorary Doctorate at Luleå University of Technology in June 2009. Bengt has also been a member in the management team for a Swedish Research School named Pro Viking which is a Swedish research program for 35 PhD-students in product development at 9 Universities. He has also been industrial

supervisor for 2 PhD-students doing research in Tribology at Luleå University of Technology.

R. Mäki Director Technology Planning & Public Funding at Volvo Construction Equipment, Eskilstuna, Sweden.

Dr. Rikard Mäki holds a PhD from Luleå University of Technology. Rikard is currently a member of the Volvo Construction Equipment Advanced Engineering Management Team. In his position as Director for the Technology Planning and Public Funding department he have responsibility for the Volvo CE Technology Plan, the Advanced Engineering project portfolio and Public Funded research activities at Volvo CE and partner universities and institutes. Rikard is actively driving pre-development process activities and strengthening the innovation in R&D. His interest covers Driveline Technologies including Hybrid Technologies, Vehicle Automation, ITS and new Business Models such as Functional Products.

L. Karlsson Professor received his PhD at Chalmers University of Technology 1976. He got a position at Luleå University of Technology (LTU) as Associate Professor 1976 to 1988 and was chaired Professor of Computer Aided Design from 1988 to 2013. He was centre director of two consecutive

excellence centres at LTU, The Polhem Laboratory for integrated product development and the Faste Laboratory for Functional Product Innovation, both financed by VINNOVA, Luleå University of Technology and several industrial partners.

Professor Karlsson was Vice Dean of the Faculty of Engineering during 1991–1997 and was Vice President of the university during 2001–2006, with responsibility for industry collaboration. He has published some 100 papers and books in the fields of Modelling and Simulation in Product Development, Engineering Information Systems and Distributed Engineering.

He has supervised 50 PhD students to their PhDs and an additional 20 to their licentiate degrees. Six of his former PhD students have become chaired professors. He has examined some 1000 MSc students in the areas of product development and applied mechanics. Professor Karlsson has in competition gained some 500 MSEK for LTU. Professor Karlsson is currently employed at Uppsala University, Uppsala Data Base Laboratory and working as a consultant.