Product, Process and Organizational Innovations in Embedded Systems Engineering

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Abstract
Paper focuses on manufacturing industries providing complex embedded systems. Embedded systems are composed of mechanical, electronic, software and service components. Paper tackles the challenges that manufacturing companies are facing in the management of their product, process and organizational innovations. Research is based on the literature and a case study.

Keywords: Engineering, Embedded system, Innovations

Introduction

It is widely recognized that innovation is key to the economic performance of firms and innovative firms grow more quickly and make higher profits (Panne et al. 2003). According Olson et al. (2008) about 13% of company growth stalls are causing from innovation management break down. It means a company mismanages the processes for creating new offerings. Their study shows that 23% of growth stalls are caused by premium position captivity, which includes innovation captivity. Talent bench shortfall causes about 9% of growth stalls. That has a direct link to organization innovation capabilities, when organizations have had an internal skills gap, narrow experience base, or loss of key talent, for example. From the operation management perspective, the most important issue for management's control is to ensure innovation resources. Resources should be used effectively, organizations should regenerate themselves and they have to follow-up what is happening in markets.

The Oslo Manual (2005) defines four types of innovations: product, process, organizational and marketing innovations. The first three are the most relevant from an engineering perspective and we do not analyze marketing innovations in this study. Changes in the specific products and services offered to the customers correspond to product innovation (Hemilä and Airola, 2014). Product innovations involve significant changes in the capabilities of goods or services, where both entirely new goods and services, and significant improvements to existing products are included (ibid.). Process innovations represent significant changes in production and delivery methods, while organizational innovations refer to the implementation of new organizational methods (ibid.). Avoiding companies' growth stall, innovations should be implemented at all

levels, not only in product and service design, but also continuously innovating new practices, processes and engineering.

In this study we compare innovation and engineering perspectives collected from Stanford University Engineering Department, Silicon Valley start-ups and traditional SMEs. Our focus is on embedded systems, which is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints (Heath, 2003). Embedded systems development requires the integration of several disciplines: software, electronics, mechanics and services. As a result, embedded systems engineering is a great challenge for SMEs. Traditionally, product engineering and innovation activity is a long lasting and continuous process in manufacturing industries. In cases of start-ups, the innovation processes are much faster than traditional engineering processes in manufacturing companies.

Research design

The purpose of this paper is to increase the understanding of product, process and organizational innovations within the engineering of embedded systems. We have a case study which discovers the innovation and engineering challenges faced by manufacturing SMEs providing embedded systems. Additionally, we have collected data from Silicon Valley during the visiting research period at San Jose State University. In Silicon Valley are we had discussions with engineering experts in start-up pitching sessions. We also visited and had discussions with experts at Stanford University's Mechanical Engineering Department. The experience and insights of different engineering experts were considered to be essential in order to make in-depth sense of the phenomena (Eisenhardt, 1989). The qualitative case study research approach was chosen to gain empirical insight into this topic (Yin, 2003). To give more detail, we have analyzed how start-ups in Silicon Valley are undertaking product engineering and innovations, but also how Stanford University is teaching product design and engineering. We compare findings from the US to traditional manufacturing SMEs in Europe and particularly in Finland. We propose how traditional manufacturers providing embedded systems should improve their innovation processes by using lessons learned from Silicon Valley.

In this study, our case is a Finnish machine manufacturer SME called Oy M. Haloila Ab, which provides wrapping machines. An automatic wrapping machine is an example of embedded system as being a complex product with intelligent electronics, sensors and control technologies embedded in a highly innovative mechanical design. Typical customers are globally operating construction, tissue paper and food industry companies. The case company uses different-sized companies as tier-one suppliers of engineering, mechanical components, sub-systems, software and services.

Specialities in Silicon Valley

Silicon Valley is a nickname for the South Bay portion of the San Francisco Bay Area in Northern California, United States. Silicon Valley has the highest concentration of high-tech workers of any metropolitan area, with 285.9 out of every 1,000 private-sector workers. Thousands of high technology companies are headquartered in Silicon Valley as well as thousands of small start-ups. Statistically, only one out of a hundred start-ups

succeed in Silicon Valley, so competition is really high. Most of the best engineering and technology universities and graduate schools are located in the Silicon Valley area (see Table 1), so the world's best learning environment can be found in this area.

Table 1 –Engineering school rankings 2014

World Top 100 universities for engineering and technology 2013-2014 (Times Higher Education World University Rankings, 2014)	**The top graduate engineering schools for industrial and manufacturing engineering in US, 2014** (U.S. News Best Engineering Schools 2014)
#1 Massachusetts Institute of Technology (MIT), United States	#1 Georgia Institute of Technology Atlanta, GA
#2 Stanford University, United States	#2 University of Michigan, Ann Arbor, MI
#3 University of California, Berkeley, United States	#3 Northwestern University (McCormick) Evanston, IL
#4 California Institute of Technology (Caltech), United States	#4 University of California, Berkeley, Berkeley, CA
#5 Princeton University, United States	#5 Stanford University, Stanford, CA

Density of high tech and start-up companies, but also the level of engineering teaching and research were the main reasons for the visiting research period at San Jose.

Embedded system engineering and innovations

The car is a good example of an embedded system. The automotive industry is continuously innovating new features and functionalities to cars. A typical car today is full of embedded intelligence, sensors and software. A car is no longer just a mechanical or design challenge, but the challenge is more about how to ensure quality and interoperability of different parts. In the year 2014, General Motors recalled 2.6 million cars that were built with, or may contain, a faulty switch design. If the switch slipped out of the "run" position, airbags, power steering and power brake assist were all disabled. That case is an extremely sad story of how engineering can effect a product, but also an entire business. It is difficult to understand what may have driven engineer Ray DeGiorgio to undermine the standards and procedures of General Motors for more than a decade (Fortune, 2014). DeGiorgio was the design release engineer who first approved an ignition switch that didn't meet specifications and then secretly replaced it with an upgraded switch, with the full knowledge that he was violating long-established engineering standards, according to the report, all the while disclaiming any responsibility of the defects or the change (ibid.). The General Motors case is an example of bad attitude, decision making and engineering ethics. That kind of activity should not be learned at school, but somehow in practice similar cases can be seen. We see that in this case they made bad product innovation by selecting parts, without meeting specifications. They made bad process innovation by not following procedures and standards accepted by the company. Finally they made bad organizational innovation by changing the attitude of some employees and by accepting dangerous decisions. With better control, better management and better quality systems and finally better attitude by employees, this kind of crisis can be avoided.

Comprehensive embedded system engineering process development should be programmed with competent resources and the establishment of cross-functional development teams (Hemilä et al. 2014). The most challenging part of the development is ICT and the integration of tools within the supplier network, because information technology support in business development is crucial for success (ibid.). Because start-ups and SMEs have limited resources, the outsourcing of some engineering activities is almost crucial for success and should be managed well. The R&D function should ensure that a product can be installed, maintained and operated as planned (ibid.). New technologies, embedded intelligence, sensors, diagnostic tools and human-machine interaction are issues which even SME machine manufacturers should be aware of (ibid.). The key question is how to manage all these innovations with limited resources.

Start-ups compared to traditional manufacturing SMEs

Like the General Motors case, the Olson et al. (2008) study is based on large scale companies, but it can be said that reasons for growth stalls are quite similar for the smaller companies. But still, there are also huge differences between large and small companies, or even start-ups. The first issue is brand and status in the market. Start-ups do not yet have a name in the market and they have to show their value for stakeholders. The same is true for many SMEs, because of the lack of resources, especially in marketing and sales. Locally small companies can be well known, but in global business it's hard to make your business visible and known. On the other hand, small companies with a unique knowledge and an innovative product or offering, can rapidly make themselves well known.

Both start-ups and SMEs should pay special attention to their product, process, and organizational and marketing innovations. Start-ups in the early phase of their business lifecycle and their innovation processes are typically very fast and agile. Stakeholders require business plans, value chain analysis, and other methodology-based reports, which start-ups are typically doing as learned at school. However, traditional manufacturing companies are slow movers and engineers are producing continuous, long lasting work to innovate new products and features or to fulfil customer requirements.

Engineering and innovation practices include many models and approaches, which can be learned in school. Stanford University Mechanical Engineering Department is teaching different engineering methods by using Method Cards (see Figure 1). There are many examples of cards used to assist or provide structure to the design process, yet there has not yet been a thorough articulation of the strengths and weaknesses of the various examples (Wölfel and Merritt, 2013). Cards have been used widely by designers to make the design process visible and less abstract and to serve as communication tools between members of the design team and users (ibid.).

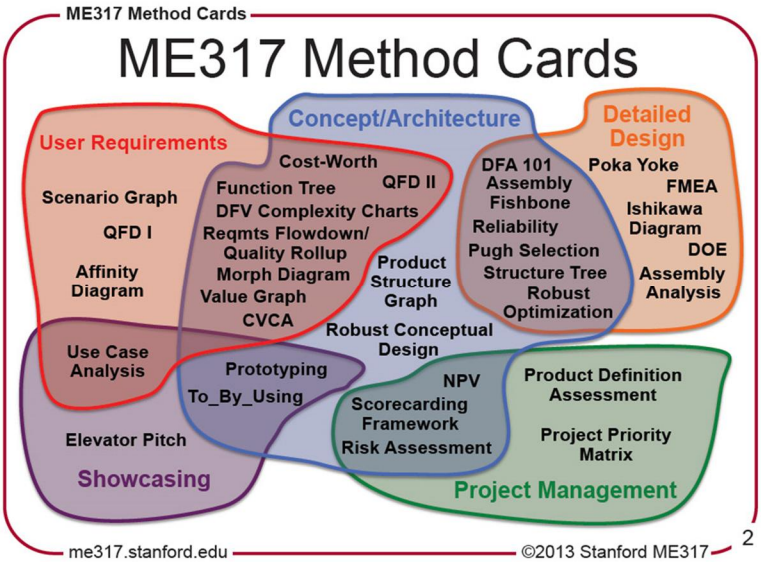

Figure 1 – Collection of Stanford University engineering methods.

According our findings from Silicon Valley, the majority of start-ups are telling their story and convincing financiers and other stakeholders with the kind of methods Stanford University teaches. SME manufacturers are still producing a lot of design and engineering without drawings or planning, but just in “piece of paper”.. One can often hear “we have always done this way”, and it is evident that new methods are not in use or implemented in practice.

Conclusion

Manufacturing SMEs providing embedded systems should have a wide range of knowledge, resources and experience during the innovation process. It has been argued that finance can be a determining factor for innovation in SMEs, which often lack internal funds to conduct innovation projects and have much more difficulty obtaining external funding than larger firms (Hemilä and Airola, 2014). Start-ups are in an even worse situation in that sense, than SMEs.

Companies should understand their innovation, engineering and business processes. In the case of SMEs, processes are not typically well documented (Hemilä and Airola, 2014). In a small company, all employees should have responsibility for all tasks, and should not focus on one specific area of responsibility. In that way, everyone has an overview of each other’s work, but on the other hand it is hard to innovate world class solutions without specific focus. Traditional SMEs should turn their activities to a more specified and structured way of conducting business. Focusing on core issues and then following the rules and lessons learned from school makes life easier and ensures better quality and effective collaboration. The Stanford methodology for product development is a comprehensive approach, not just focusing on processes improvement or quality. Traditional SMEs should have a wider perspective on product development by taking care of customer value and economical aspects. Product development and engineering should be faster, and feedback should be collected from markets with the use of prototypes. Traditional engineers are more focused nowadays on fixing the details on

their product before entering the market. In the future, successful manufacturing SMEs will act as fast as start-ups, have clear responsibilities for employees and avoid growth stalls with continuous innovations and management.

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