https://doi.org/10.1016/j.ijpe.2015.09.037

A. K. Jha, I. Bose and E. W. T. Ngai, (2016), "Platform based Innovation: the Case of Bosch India", International Journal of Production Economics, 171, 250 – 265

Platform based innovation: The case of Bosch India

Abstract:

A multitude of factors are leading to increase in demand in large varieties of any particular product. This rise in demand for variety is forcing firms to indulge in mass customization of products. Platform based innovation to produce a large variety of products from the same base is an offshoot of the product family based approach. While a plethora of frameworks exist in extant research for analyzing and implementing best innovation practices, most of them fail to take into account environmental regulations enforced by the governments of the land for planning and executing production plans. In our study we develop a new framework to analyze and plan the implementation of platform development under environmental regulatory constraints among other factors – Strategic Platform Innovation Star (SPINS). We validate the framework through a case study on Bosch India that developed a successful product platform to meet customer demands under regulatory considerations. We analyze the complete innovation effort at Bosch India using the various components of the proposed framework. We observe that a clear understanding of the requirements arising from consumer demand and regulatory aspects combined with the ability to implement the right solutions structure due to an ingrained innovation culture help a firm embrace the business challenges and emerge as a market leader.

Keywords: Framework for platform based innovation; Innovations in manufacturing; Product development; Value based innovation.

1. Introduction

For businesses across the sector innovation is not just another buzzword but an effort to differentiate themselves from their competitors and gain competitive advantage. Innovation, as a definition, is not just invention but consists of three overlapping stages of invention, implementation and diffusion (Dosi, 1988). The forces of industry dynamics, customer demand and regulations force firms to indulge in innovation. Demand for different varieties of products has grown very strong in past few decades. This is due to both changes in customer demand (Pirmoradi, Wang, & Simpson, 2014) as well as regulations brought in by governments (Fagre & Wells Jr., 1982) that have forced firms to maintain a vast portfolio of products. Attempts to maintain production efficiency while also targeting niche markets of customers forces firms to offer its customers a family of products (Chai et al., 2012; Pirmoradi et al., 2014). Bringing modularity in products is one of the initial steps that is adopted by firms to cater to a rising demand for product variety (Mikkola & Gassmann, 2003). As mass customization becomes the need of the hour innovative techniques need to be introduced to cater to the consumer demands. Platform based production makes it easier for firms to implement and manage mass customization (Fogliatto, da Silveria, & Borenstein, 2012). Managing the design of product families via a common platform enables the development of highly customizable products, thereby leading to larger varieties of the same product (Park & Simpson, 2008). Meyer and Lehnerd (1997) define product family as a set of products which share a number of parts and components with each other while at the same time having unique features that are customized for certain consumer segments (Meyer & Lehnerd, 1997). Several studies have attempted to demystify the factors and drivers for platform based innovation. Most of these research efforts focus on development of platform based products to cater to rising consumer demands for varieties and to gain competitive advantage (Krishnan & Gupta, 2001; Veenstra, Halman, & Voordijk, 2006; Berry & Pakes, 2007).

Mass customization is introduced first in consumer facing businesses and only adopted by business to business firms over time (Fogliatto, da Silveria, & Borenstein, 2012). Innovating For large manufacturing firms, innovation efforts to create platforms to cater to different business clients is a challenging proposition that requires careful planning and execution over a long time horizon (Sood & Tellis, 2005). Innovation in itself is not a one time activity but an effort that needs to thrive over time and throughout the firm to nurture innovative thinking and bring out something new. The long gestation period makes it a difficult proposition for large manufacturing firms.

There exist numerous frameworks for managing and analyzing innovation in firms like Innovation radar (Atuahene-Gia, 1996; Atuahene-Gima, 2001; Atuahene-Gima, 2005; Sawhney, Wolcott & Arroniz, 2006). In our analysis of literature we observe that of these numerous frameworks that are available for analyzing and implementing innovation, none take delve deep into the complexity created by the interaction of the pressure of consumer demand as well as the force of environmental regulations imposed by governments. In this paper we bring these two varying strands of literature together and propose a scholarly framework for analyzing platform based product innovation. The framework is validated by the analysis of a rigorous in-depth case study on Bosch India. Bosch has been an innovation leader for long. Its innovation capability has helped sustain it as leader in many industries including the Fuel Injectors (FI) industry. Faced with the unique consumer demand of variety in an emerging economy as well as environmental regulations imposed by laws of the land, Bosch India embarked into innovating and developing a unique platform for various types of Fuel Injectors. This paper strives to understand how firms, particularly those in the B2B segment, react to changes in environmental regulations. It also addresses the issue whether development of a product platform is a suitable way to counter the challenges raised by environmental regulations and if so, what factors lead to successful product platform development in firms. The framework presented in this paper makes it possible to analyze innovation efforts of firms in the light of multiple theories. The analysis driven by the detailed case study on Bosch India led to two very interesting conclusions. First, in a B2B segment a product platform provides a much needed cushion against regulatory challenges and second, the presence of a strong innovation culture and collaborative development efforts are vital in quickly responding to the dynamic competitive landscape and launching new products.

The next section provides a summary of literature related to innovation in product platform development as well as the impact of environmental regulations on innovation. In section 3, we present our framework that aims to fill some of the gaps in extant research. This framework can be utilized by firms to evaluate their innovation efforts and also to plan a roadmap for product platform development. Section 4 explains the research method that is adopted in this paper. In section 5, we provide a description of the product platform development at Bosch India and its impact. In the next section we analyze critically the reasons for success of Bosch's approach and draw lessons from its approach for possible implementation at other firms. Section 7 identifies the limitations of this research and describes the ways to extend it in future. Section 8 concludes the article.

2. Literature review

Innovation is not a one-time effort but rather a continuous process by which firm attempts to gain competitive advantage over its competitors (Bessant & Caffyn, 1997). The need to innovate for a firm to stay competitive is a well proven fact (Acs, Audretsch, & Feldman, 1994). Eisdorfer and Hsu (2011) find that inability to innovate for a firm is a close precursor to its bankruptcy. Innovation is not invention rather it covers the whole spectrum of invention to diffusion (Dosi, 1988). A firm needs to invent new products and support its diffusion in the market to complete the cycle of innovation and gain competitive advantage.

Extant research on innovation identify various types of innovation such as product innovation (Ettlie & Bridges, 1982), process innovation (Gallouj & Weinstein, 1997), incremental innovation (Damanpour, 1991), radical innovation (Duchesneau, Cohn, & Dutton, 1979), among others. The decision of the firm to indulge in a particular strand of innovation depends on the returns and the expectations of the firm. Since innovation is usually long drawn, a large amount of effort and time needs to be put in by the firm to generate the culture of continuous innovation over long time spans (Škerlavaj, Štemberger, Škrinjar, & Dimovski, 2007). An innovation culture ensures that a firm continually innovates and this leads to better performance of the firm vis-à-vis its competitors (Gunday, Ulusoy, Kilic, & Alpkan, 2011). This implies that continual innovation and not one shot efforts are required to stand out from the competition.

All these innovation efforts are aimed at solving the primary need of the firm to cater to its primary consumers demand or to expand the market. The demand for a large variety of products by consumers in recent times has forced firms to innovate very differently in their attempt to create a large family of products (Pirmoradi, Wang, & Simpson, 2014). To cater to large product families firms have attempted to create modular products or product families as product families lead to shortening of lead times and reduces incremental cost per variety (Jiao, Simpson, & Siddique, 2007; Simpson, Siddique, & Jiao, 2006). We have defined a product platform as “a set of subsystems and interfaces developed to form a common structure from which a stream of derivative products can be efficiently created” (Meyer & Lehnerd, 1997, p.39). New products of the created product family are developed on the same product platform by adding, removing or substituting few modules (Farrell & Simpson, 2003). This is done to cater to a specific consumer demand of related products. A firm may create a product platform by intentionally investing in a platform from where allied products can be created (Sanderson & Uzumeri, 1997) (also known as top down product platform innovation) or by standardizing

the parts and modules of existing products to make them part of the product family (Pessina & Renner, 1998) (bottom up approach). Some examples of product platform development from industry are listed in Table 1.

Table 1 Some examples of product platform development.

Company	Development approach	Reference
Sony Walkman	Top down	Sanderson & Uzumeri, 1997
Kodak Cameras	Top down	Wheelwright & Clark, 1992
Lutron	Bottom up	Pessina & Renner, 1998
Black and Decker	Bottom up	Lehnerd, 1987
John Deere	Bottom up	Shirley, 1990

Our analysis of the firms indulging in product platform development indicates that most firms that have successfully developed and used product platforms satisfy two criteria: (a) They cater to retail consumers and are in the competitive market space, and (b) they develop platforms to cater to rising demand for product variety.

We notice a gap in extant research that study product platform innovation driven by factors beyond consumer demand for variety. One of the important drivers for such innovation is regulations imposed by the law of land to become more environmentally sustainable (Nidumolu, Prahalad, & Rangaswami, 2009). Although many policy makers globally have used regulations as a policy tool to impact innovation in firms (Lundvall & Borrás, 2005), we are unable to locate scholarly research where the policy decision on regulations indirectly leads to innovation in firms. In other words, for such cases the policies are implemented with other concerns such as environmental or labor welfare but these in turn inspire innovations leading to new product platform development.

Carlin and Soskice (2006) have done an economic analysis of regulations on technological progress and have determined a steady state of technological progress based on the Solow growth model. How the regulations impact the process of technological advancement can be seen as a tradeoff between compliance cost and the resulting incentives (Crafts, 2006; Carlin and Soskice, 2006). Figure 1 explains the tradeoff between compliance cost and incentive. At point x1, the incentives are higher than compliance cost leading to positive net impact on innovation. The situation is opposite at point x2.

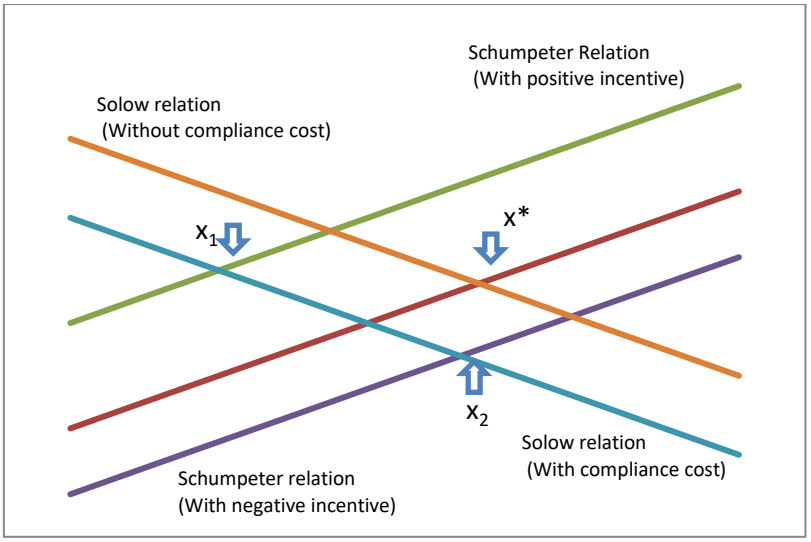

Figure 1 Influence of regulation on innovation (Adapted from Crafts, 2006).

Carlin and Soskice (2006) also postulate that regulations change the incentive structure and thus bring in new dynamics of investment which may lead to growth or decline in R&D intensity. Blind (2012) in his work establishes that, specifically in case of environmental regulations, the effect in short run may be ambivalent but is positive in long run as it provides an incentive for development of new eco-friendly products by creating temporary market entry barriers. Kemp (1998) has proposed that environmental regulations can be used as a modulator for technical change.

Most of the work done by various researchers establishes the fact that environmental laws create a social regulation that helps in promoting innovation in certain contexts. But the literature survey also shows that there is lack of a scholarly framework that can be used by business leaders to plan, analyze or execute innovation leading to development of product family catering not just to current regulations but also utilizing the opportunity to develop products by keeping in mind possible future regulations. In the next section we propose a framework for product platform innovation to fill this void.

3. Research framework

There is no dearth of generic innovation frameworks available in literature which attempt to provide a tool to plan and analyze firms' approach to innovation. Innovation radar proposed by Sawhney et al. (2006) identifies 12 dimensions of business innovation to provide a 360 degree view of the innovation landscape (Sawhney, Wolcott, & Arroniz, 2006). The innovation radar broadly classifies the 12 dimensions along various major factors but does not include either the investment or the regulations aspect. Some innovation frameworks for product development that have drawn from different theories are listed in Table 2.

Table 2 Various product innovation frameworks and underlying theories.

Salient aspect of framework	Base theory/concepts	Reference
Environmental turbulence and institutional support; Strategic alliances	Resource Dependency Theory	(Haiyang & Atuahene-Gima, 2001)
Link competency relating to technology and customers	Organizational learning theory; Dynamic capability	(Danneels, 2002)
Market orientation related to product innovation, marketing fit of innovation	Product-market fit; Market demand	(Atuahene-Gima, 1996)
Environment-strategy-performance defines product innovation	Firm competency; Market orientation	(Atuahene-Gima, 2005)
Innovation depending on firm's learning and evolving capacities	Absorptive capacity	(Cohen & Levinthal, 1990)

Table 2 represents the varied thought processes that have been prevalent in the academic community over the years about factors that influence product based innovation. Haiyang & Atuahene-Gima (2001) in their investigation on the links between innovation and performance for new technology ventures in China found that institutional support and alliances formed by these ventures play a crucial role in determining eventual success. Another perspective on innovation theory put that is forward by Cohen & Levinthal (1990) has suggested that absorptive capacity of a firm and its evolution, as well as learning capability of the firm were the primary drivers of innovation in a firm. Danneels (2002) also linked competencies of firm and its dynamic capabilities to a firm's innovation capabilities. Atuahene-Gima (1996) has used empirical analysis of Australian firms and has found a crucial link between product innovation characteristics and market orientation of the firm. Later the same author (Atuahene-Gima, 2005) has also found that product innovation has occurred through exploration and exploitation have different relationships with incremental and radical innovation. The analysis drew from firm competency theory and stated that market orientation provided insights into the managerial task of enhancing innovation in a firm. The papers discussed above reflect the various thought processes that have been prevalent in extant research about innovation in firms. These have drawn from various varied management theories. Many of these frameworks also have some commonalities in drivers and factors. The innovation radar proposed by Swahney

et al. (2011) drew from several of the above mentioned frameworks to develop the 12 strategic dimensions of innovation.

To bridge the gap between the various existing frameworks, there is a need to develop a framework which attempts to comprehensively cover the various aspects of product innovation of the firm including the impact of regulation. Any new framework proposed in this domain has to be concise, comprehensive, easily interpretable and easily usable by the people responsible for implementing it. Based on these criteria we develop the Strategic Platform Innovation Star (SPINS) as depicted in Figure 2. The framework represents the set of circumstances that are best suited for platform based innovation. It is composed of two overlapping set of conditions, one internal to the firm and other external.

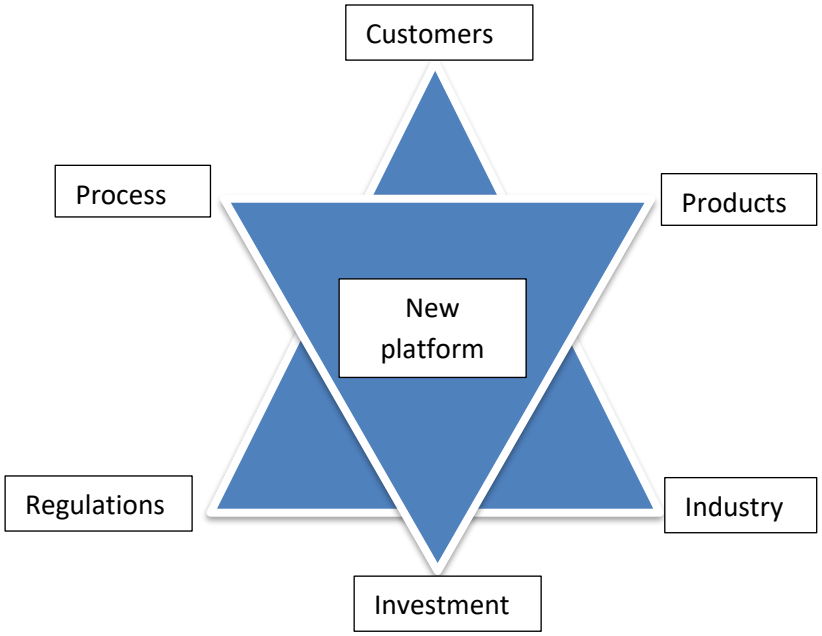

Figure 2 Strategic Platform Innovation Star (SPINS).

The internal star represents the three factors directly under the control of the firm that it can easily influence. These are:

Products - The basket of products that the firm offers or is about to introduce. The decision of the firm of what products it wants to introduce in the market has a bearing on whether or not new platform development is suitable for it or not. The product corner of the internal star is composed of three sub-factors

(a) **Brand**: The brand position of the firm's product is an important determinant of both its capability to innovate and the success of its innovation. The brand of a firm gives it an ability to introduce new products more successfully than its competitors (Chandy & Tellis, 1998). The corporate brand can be used to position the new product and it also provides impetus for

innovation (Aaker, 2004). Another aspect is that higher the brand value of the firm for the given products, higher is the demand for its variety of products in each segment and higher is the requirement for a platform based solution (Berger, Draganska, & Simonson, 2007).

(b) **Solutions**: Sawheny et al. define solutions as "customized, integrated combination of products, services and information that solves a customer problem" (Sawhney, Wolcott, & Arroniz, 2006) (p. 31). The integrated solutions that a firm provides or aims to provide to its consumers are an important determinant for the innovation drive within the firm.

Processes - The processes that the firm employs depict how the firm indulges in business innovation

(a) Innovation culture: Since innovation is not a product of sustained effort over time, innovation culture of a firm is an important driver for all kinds of innovation including product platforms. It is due to lack of culture of innovation that large firms with all other factors on their side fail to innovate (Henderson & Clark, 1990). Organizational culture for taking risks has always been an important driver for new product development (Cooper & Kleinschmidt, 1995)

(b) Standardisation: The efforts and organisation processes that attempt to get standardization in the products promotes modularity of design. This in turn provides a conducive environment for product family design (Chen & Liu, 2005).

(c) Organization: The kind of organizational structure that exists also holds a lot of importance. A firm which is itself very modular and loosely coupled as an organization is more attuned to create new products than a tightly coupled and rigid firm (Sanchez & Mahoney, 1996).

Investment - The investments made by the firm in various aspects of the business are an important determinant of the innovation outcome as well as innovation processes of the firm. The two different aspects of investment are explained below:

(a) **Supply chain**: Integrating the supplier into any product design process is an important part of the product development process (Lee, 2002). Improved investment in designing the right supply chain for the targeted products is an important determinant of new product innovation (Petersen, Handfield, & Ragatz, 2005).

(b) **Research and development**: Over the decades a lot has been said about R&D investment and its impact on product innovation. Almost all existing frameworks on innovation invariably have R&D investment as an important determinant of product innovation capability.

The external star represents the externalities which impact how the firm indulges in innovation and its three factors are:

Industry - Factors internal to the industry. These factors are driven by the industry dynamics and include the following:

(a) **Competition**: Intra-industry competition and innovation has an intricate relationship. In general higher competition leads to a regime of one-upmanship leading to higher innovation (Leiponen & Drejer, 2007). But, very high degree of competition reduces the capability of a firm to take risk and promotes imitation rather than innovation. This implies competition and innovation has an 'inverted U' relationship with highest innovation potential at average to high competition (Aghion, Bloom, Blundell, Griffith, & Howitt, 2002).

(b) **Maturity**: Innovation in any industry is a function of the life cycle of the industry itself (Audretsch & Feldman, 1996). The maturity of the industry thus becomes an important determinant of the innovation potential of the firms in that industry (Klepper, 1996).

Customers - The requirements and the expectations of the target customer of the firm include the following factors that may influence innovation:

(a) Perceived value: Any innovation process cannot succeed without there being enough realization of perceived values by the most important stakeholders, i.e., its customers. For all types of innovation each sample of consumer has a different perceived value from the product (Flint, Larsson, Gammelgaard, & Mentzer, 2005). The product innovation is expected to fulfil the value perceptions of the target consumer segments.

(b) Service: Customer service orientation can be considered to be a cultural phenomenon of the firm itself. However, the perception of consumers of the service obtained from the firm directly or via its products differs according to the target consumer segments. Often this decides the success or failure of the innovations introduced by the firm (Atuahene-Gima, 1996).

Regulations - The regulations controlled and introduced by the government. These include regulatory measures for the industry as well as environmental regulations.

(a) **Institutional regulations**: Institutional regulation like protection of intellectual property or product liability has a mixed effect on innovation. For example, high liability in case of product safety rules has been found to be negatively related to innovation (Viscusi & Moore, 1993).

(b) **Social regulations**: These are the most important regulations enforced by laws of the land. These include regulations for environment protection, labour protection etc. Environmental regulations can be used to modulate what kind of innovations to bring in (Kemp, 1998). Environmental regulations may be challenging to industry in the beginning but in the long run it has a positive impact on the industry as a whole (Porter & van der Linde, 1995). There are however instances where some regulations have negatively impacted the innovation

ecosystem. Hence, regulations need to be analysed from a complete institutional perspective rather than on an individual basis (Blind, 2012).

(c) **Economic regulations**: It includes regulations like market entry regulations, price regulations etc. Economic regulations have a mixed impact on innovation (Blind, 2012). Competition enhancing policies have a positive impact but market entry regulation decreases competition thereby reducing the incentive to innovate.

The framework that is presented above provides a novel perspective by allowing researchers to analyse the innovation activities at a firm under different dimensions that are broadly categorized into internal and external. The framework builds on the work done by Cohen et al. (1990) on innovation due to organizational learning by including factors internal to the organization like innovation culture as well as the theory of market orientation that has been proposed by Atuahene-Gima (1996, 2005) by considering factors that are external to the organization. A major contribution of the SPINS is the categorization of factors that are crucial for innovation into internal and external in order to provide a more organized analysis of the firm's actions through multiple lens simultaneously. Also, the framework combines the important theories available in extant research for analyzing innovation with the important and emergent stream of government regulations that can enable a more holistic analysis of product based innovation.

4. Case method

Case study has been considered as an important method useful for theory development and building (Eisenhardt, 1989). Exploratory cases, even with their limited breadth, provide a depth of understanding which very few methods provide (Berg & Lune, 2004). This makes it a very powerful method to analyze any social phenomenon and associated open ended questions which are otherwise difficult to understand or study. An in-depth study of a single case with high access to crucial information has a very high internal validity which may lead to creation of more complicated theories (Eisenhardt & Garebner, 2007). An in-depth case study is a widely used business research method and has been used by many researchers as a powerful field validation method for proposed frameworks (Lee 1989; Dubé & Paré, 2003). Recent research in diverse fields that analyze regulations and their impacts have chosen case study as an appropriate tool. Some examples include the study by Faulkner (2009) on tissue engineering, Abraham and Davis (2007) on pharmaceutical sector and Chataway et al. on agro-biotechnology (Chataway, Tait, & Wield, 2006).

We have used an in-depth case study to validate the proposed SPINS framework. Since the aim of this work is to analyze the impact of regulatory framework on innovations in a given market context, an in-depth case study is considered to be a preferable method. The design of the study is based on the principles of design for in-depth case studies as detailed in Yin (2014) and Yin (2011). This method involves an in-depth analysis and study of a single focus firm aimed at gathering maximum firsthand information about the phenomenon occurring at the firm. The method involves:

- Choosing a relevant target firm for case study
- Getting a champion in the firm for providing deep insights into the firm's activities
- Unstructured interviews and close analysis of the firm's activities

One of the factors involved in the choice of the method is the fact that platform innovation has few success stories. The dearth of such success stories combined with the aim of the research to gather detailed data about the implementation has shaped the choice of the research method for this article.

The objectives for our case study in this research are the following:

- Gathering insights on the process of innovation
- Identifying factors leading to platform innovation
- Identifying steps leading to success of such an effort
- Figuring out the challenges involved in such an effort
- Analysing the benefits to the firm from such an effort

For the case study that we describe hereafter, the following three pronged approach is adopted:

- Field visits to the users and distributors of the new technologies to develop domain knowledge and prepare the background of the research
- Detailed interviews with members of the R&D team
- Corroboration of the collected information with secondary research

This three pronged approach has helped us in triangulation of data and has enabled us to collect a holistic view of all parties involved, thereby increasing the richness of the study. This has helped us gather evidences to recreate the logical chain of events (Benbasat, Goldstein, & Mead, 1987). As the first step we have conducted field visits to various users of the new technologies developed by the target firm in one Indian city (not the same city as the R&D office of the firm). We have also gathered information on various aspects of the impact of new products through interaction with re-sellers and distributors of the products. These visits preceded the several long and in depth face-to-face interviews with members of the R&D team

of the firm. The interviewees included the managing director and two vice presidents of the firm and several team members involved in the project. The interviews were semi-structured in nature and are conducted in several rounds of many hours over the span of a full day. The interviews are supplemented by demonstration of the innovative products and visits to the production centers where such products are manufactured at present.

Finally, we conduct secondary research to collect more information on the implications of the product innovation. These include detailed study of the company's website, related websites of regulatory bodies, and market analyst reports.

5. Case of product platform innovation at Bosch India

5.1. Overview of the company

Bosch India Ltd. is a subsidiary of Robert Bosch GmbH, a global leader in engineering and electronics manufacturing. Robert Bosch GmbH is a majority shareholder of Bosch India Ltd. with about 71% shares owned by Robert Bosch GmbH. It has a revenue turnover of over 46 billion euros in 2013 with approximately 1.2 billion euros in net profit. It is headquartered in Gerlingen near Stuttgart, Germany and has entered the Indian market in 1922 through its sales office. However, Bosch has begun its manufacturing operations in India about 30 years later in 1953. Currently it has over 0.2 million employees globally out of which over 26,000 work for its subsidiary units in India.

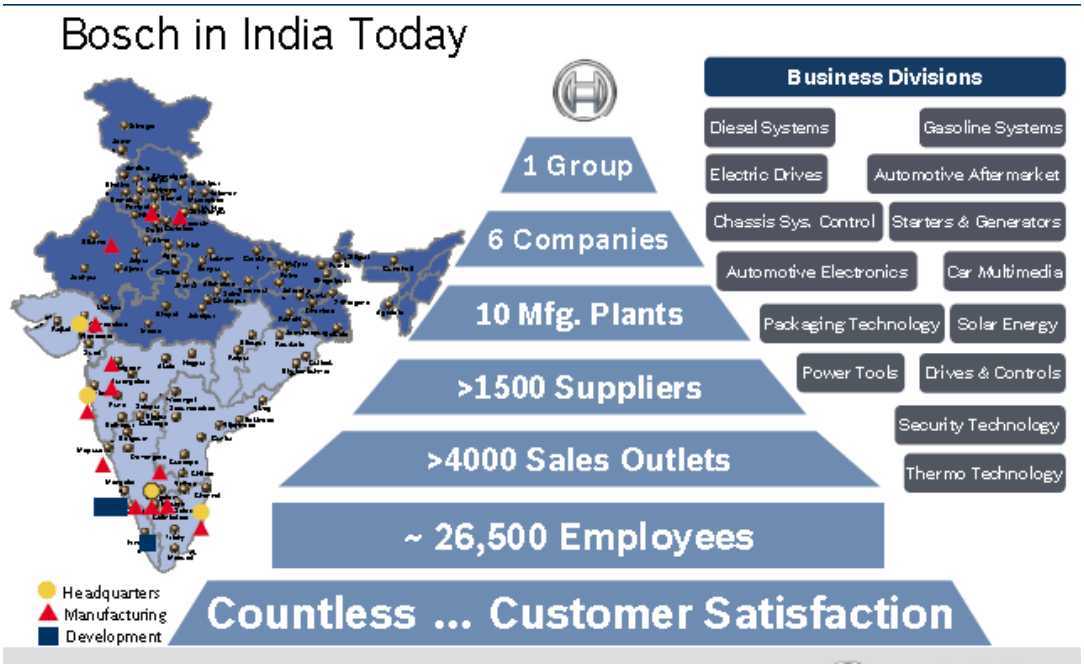

Figure 3 The presence of Bosch in India.

Bosch operates in seventeen divisions across four business sectors, i.e., Automotive Technology, Industrial Technology, Energy and Building Technology and Consumer Goods. Bosch India has 10 manufacturing centers in India and 7 development and application centers. Robert Bosch India Ltd. headquartered at Bangalore, India is the parent firm for 6 operating firms of Bosch in India. These are: Bosch Ltd., Bosch Chassis Systems India Ltd., Bosch Rexroth India Ltd., Robert Bosch Engineering and Business Solutions Ltd., Bosch Automotive Electronics India Private Ltd. and Bosch Electrical Drives India Private Ltd.

The case that we are studying is related to Bosch's diesel line Fuel Injection (FI) technology and innovation in the same line of products. Bosch's products account for 81% share of the global FI market and Bosch is well-known as one of the leading global players for it. Other major players in the FI market include Denso, Delphi and Continental AG with Delphi being a major competitor for Bosch.

5.2. History of fuel emission norms in India

To understand the context of the case it is essential to know the emission norms which are a defining externality in the automobile industry. The emission standards define and sometimes force new technology in automobiles. Fuel emission norms have come to prominence in India in 1992 for diesel fuels and this has led to the introduction of Ultra Low Sulphur Diesel. However, these emission norms have not been too stringent till the Supreme Court intervened in 1999 and introduced Euro 1 equivalent norms in India from 1999 and Euro II norms from 2000 in the National Capital Region. This has been referred to as the India 2000 norms. (Central Pollution Control Board, 2000) This has led to the Government of India forming an expert committee and introducing a plan for time bound introduction of various stages of fuel emission norms in the country, often referred to as the Euro norms, as part of the National Auto Fuel Policy 2003.(Ministry of Petroleum & Natural Gas, 2003)

Table 3 Timeline for introduction of fuel emission norms in India for diesel vehicles.

Year	Standard	Region
2000	India 2000	Nationally
2001	BS II/Euro II	Indian metros
2003	BS II/Euro II	13 major cities of India
2005	BS III/Euro III	13 major cities of India
2005	BS II/Euro II	Nationally
2010	BS IV/Euro IV	13 major cities of India
2010	BS III/Euro III	Nationally

Table 3 shows the schedule for introduction of fuel emission norms in India. The introduction of the more stringent BS IV and BS V/Euro V norms nationally has been a matter of debate due to the increased cost of its implementation. This has led to delay in its introduction from the earlier proposed deadline of 2014. This delay has had some serious repercussion for firms that have invested in getting ready for BS stage IV and V.

The tighter fuel emission norms have resulted in demand for higher pressure in FI systems. Higher pressure in FI is needed to meet the stringent requirements for cleaner emissions. Figure 4 shows the average requirement for pressure in FI as mandated by different fuel emission norms over the years. It is to be noted that one bar of pressure is created by a column of one metre of water at its bottom in a 1 cubic meter container. As can be seen the requirement of more than 1600 bar pressure has necessitated tremendous innovation from the manufacturers of FI systems. This has become even more challenging for small light commercial vehicles which are prevalent in India. The increased cost of such a change has significantly impacted the highly price sensitive small vehicle market in India.

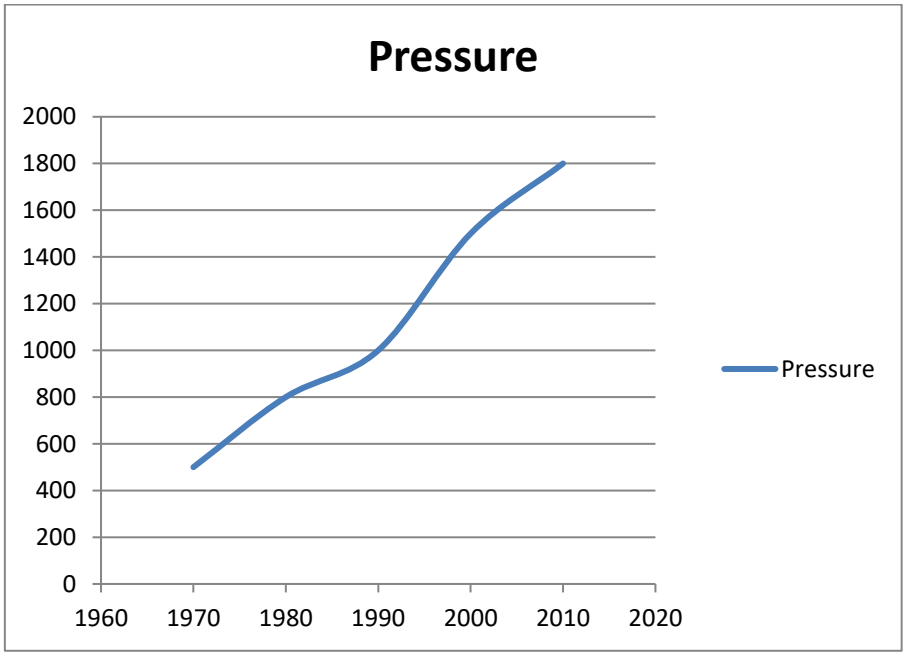

Figure 4 Pressure required in FI systems in India over the years as per emission norms.

5.3. Fuel injectors

FI is a very important part of automotives and is a critical component of diesel engines. In layman terms the FI system ensures that the fuel is delivered to the engine at the right time, in the right quantity and at the right pressure. All these conditions are necessary for proper

combustion of fuel. Fuel that is supplied at the wrong time cannot be of use to the engine. Delivery in wrong quantity will lead to either unburnt fuel being ejected out as emission or low pressure due to lesser fuel in engine. Appropriate pressure ensures that fuel is completely atomized leading to greater energy generation per unit of fuel that is burnt and also low amount of fuel being emitted as exhaust.

FIs are such an important and critical component of the automotive engines that each type of engine has a customized FI to fit it. Given the vastness of the Indian automobile market this leads to a situation that various types of FIs are present in the market. India has a vast array of diesel vehicles including passenger cars, light commercial vehicles, three wheelers, buses and trucks. Each of these vehicles has different fuel emission norms, different engine sizes and thus different FIs. Complicating the situation further is the fact that India is a very price sensitive market. Therefore there is enormous pressure on firms to not only develop solutions that satisfy the emission norms but also ensure the economic viability of those solutions.

Due to tightening of fuel emission norms globally as well as in India the complications in developing a good FI that adheres to the prevalent emission norms have only increased. The technology for FI has to keep pace with the emission regulations resulting in a strong impetus for constant innovation in the FI segment. It is quite understandable from the description of the market space that an industry leader in this product segment has to be a constant technology innovator. Figure 5 shows different types of FIs that are used in the market starting from inline injector to common rail injector.

Conventional mechanical FI | Inline FI with EDC | Common Rail FI

Figure 5 Different types of FIs.

5.4. Platform innovation at Bosch

As discussed above, a diesel FI is expected to do three things:

- Timing: Decide when to inject fuel in the engine so that maximum fuel is utilized
- Amount: Decide how much fuel to inject
- Pressure: Decide how much pressurization to be done to fuel for proper atomization

FIs evolved over time to meet customer demand and regulatory requirement. The same evolution took place for Bosch India as well. The uniqueness of the Indian market and high market pressure forced remarkable innovation to take place at the R&D division of Bosch India. The first of these was the FI with Electronic Device Controller (EDC). Since the introduction of any new technology required large scale changes to adapt to the same by both clients as well as service centers, the pressure to comply with government regulations using an existing model was quite high. The same was observed for Bosch India. The first generation of FIs was inline, mechanical and easily serviceable throughout the country. Besides, the automobile manufacturers had their systems designed for the current version of the injectors and they preferred to keep it the same way. In spite of the pressure to continue with the mechanical FIs, the R&D unit at Bosch came up with the FI with an EDC and chemical treatment of exhaust to ensure high longevity of the existing injection system in diesel vehicles.

This innovation by Bosch can be considered to be an incremental innovation on the existing FI technology to meet the dual demand of regulatory as well as consumer pressure. The innovation by the R&D team at Bosch was well tuned to the requirements of BS III compliant engines. But when BS IV norms were about to be introduced, a new complication arose at Bosch. The FI technology that was available to meet BS IV norm was the Common Rail (CR) FI system. FIs had a long common rail where the fuel could be pressurized to above 1600 bars and then released via several injector nozzles into the engine. This technology was developed by Bosch to meet the earlier demands due to regulation in Europe and elsewhere around the world. Extending the same technology in India and using CR injectors was a logical way forward except for a minor hiccup en route. The Indian market was extremely price sensitive and many small commercial vehicles existed on roads which could be characterized as Low Priced Vehicle (LPV). The LPV segment practically did not exist in many western nations. According to Mr. R. Baskaran, Vice President Engineering and Application – Diesel System, Bosch India: "*The hub and spoke model of product delivery where the warehouses are on highways and product is delivered to cities in small vehicles promotes these LPVs"*

The requirements of such a market were unique and it was categorized and analyzed by Bosch engineers to prepare a complete expectations list. Figure 6 shows the product requirements as drawn up by engineers at Bosch India. Of the various requirements drawn by Bosch's engineers one of the most unique and important was avoiding overdesign, Mr. George Anthony, Deputy General Manager, Engineering Common Rail Systems, explained:

"A truck's fuel injection system is designed for one million kilometers in Europe. We don't need that because the rest of the vehicle itself will not last that long in India!"

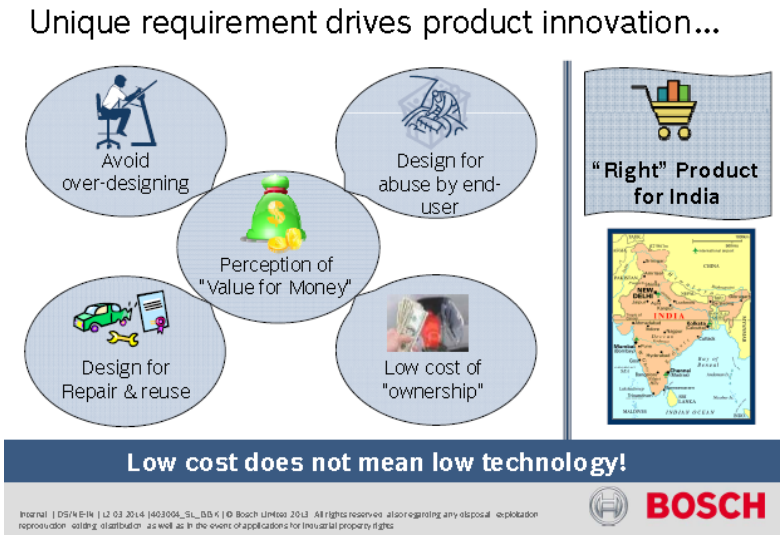

Figure 6 The requirements analysis for the Indian market as done by Bosch India.

The first product that was brought into the Indian market was the original CR based FI system as shown in Figure 7. The CR based system was compliant with all regulatory requirements. In fact, it was compliant with not only BS IV but also BS V as and when it was to be enforced. But the major drawback of the system was recognized very soon. The cost of such a system was quite high. It was a good injector for large trucks and high-end diesel passenger vehicles but it was not appropriate for LPVs because of the following reasons:

- Most LPVs were single cylinder engines and so they didn't require multiple injectors
- The size of a CR injector was so large that fitting it in the chassis of a LPV was difficult
- The cost of a CR injector increased the price of the LPV considerably

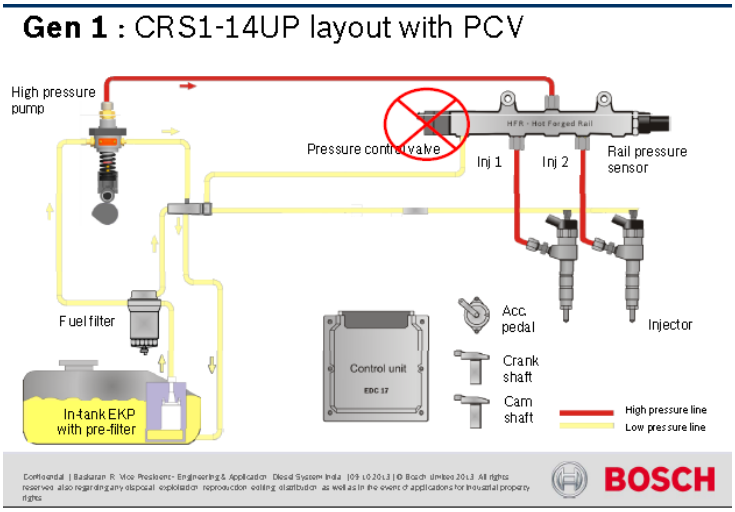

Figure 7 Gen 1 CR based FI.

To solve this issue Bosch started on its mission to develop a remarkably new solution. The aim was to develop a modular product that could cater to not only the LPV segment but also other segments at reasonably low cost. The solution was expected to be a platform that could be as

important as the CR injector itself. Engineers at Bosch delved deep into their organizational culture of innovation and learning to unearth ways to take it forward. A. Krishna, formerly Senior Vice President of Human Resources described this organizational culture as "*right methods and tools, structures, empowerment, and decision making processes to promote greater innovation".*[1]

To develop the new FI Bosch engineers worked together in teams, collaborating with the vehicle manufacturers to understand their exact requirement and also to determine how the new solution could be adapted for their utilization. The solution finally struck Mr. Baskaran. He recalled:

"I told that when there is only a single cylinder why do we need a common rail? What is common in one injector? Why can't we replace the complete common rail of the CR injector?"

This thought provoking idea started the development of a FI that was capable of fulfilling BS IV emission norms and that was without a CR. Bosch engineers soon developed a new platform with an injector block and no CR as shown in Figure 8. A common block could have one or more injectors fit into it for small vehicles and LPVs. The unique features of this new system included the following:

- Replacement of the CR with a small fuel distributor block
- A fuel control unit to control the amount of fuel to be pressurized leading to a reduction in the amount of unburnt fuel

The new solution was cost efficient as well as compact enough for LPVs.

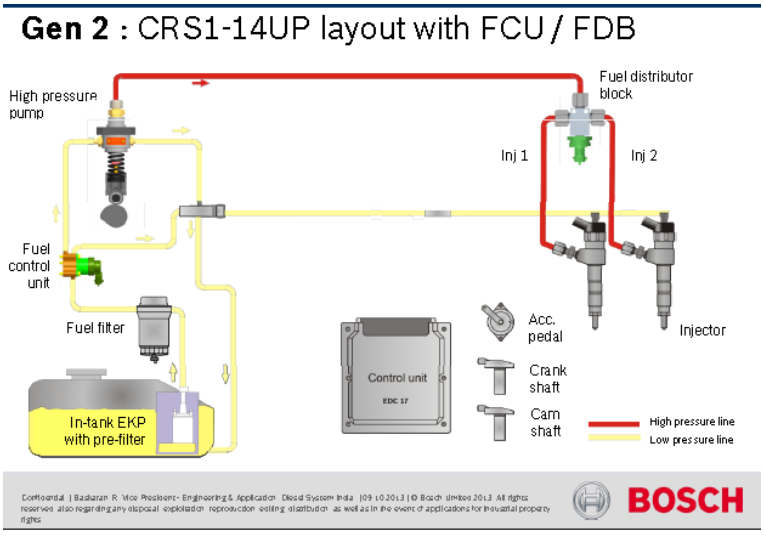

Figure 8 Gen 2 FI with a fuel distributor block.

[1] Details about Bosch's innovation culture is explained in Appendix 1.

The fuel distributor block solution was further enhanced by Bosch engineers to generate higher economy for consumers. The enhancements in Gen 3 were to remove the fuel control unit and integrate it with the fuel filter itself. This ensured even lesser fuel wastage. The Gen 3 FI is shown in Figure 9. One additional benefit of removal of the CR and bringing in a new technology in the form of the distributor block was obvious. Since a lower amount of fuel needed to be pressurized each time to 1800 bar a lot of energy was saved and hence the efficiency of engine increased further. This was an additional welcome benefit for an injector targeted towards LPVs and the extremely cost conscious Indian market.

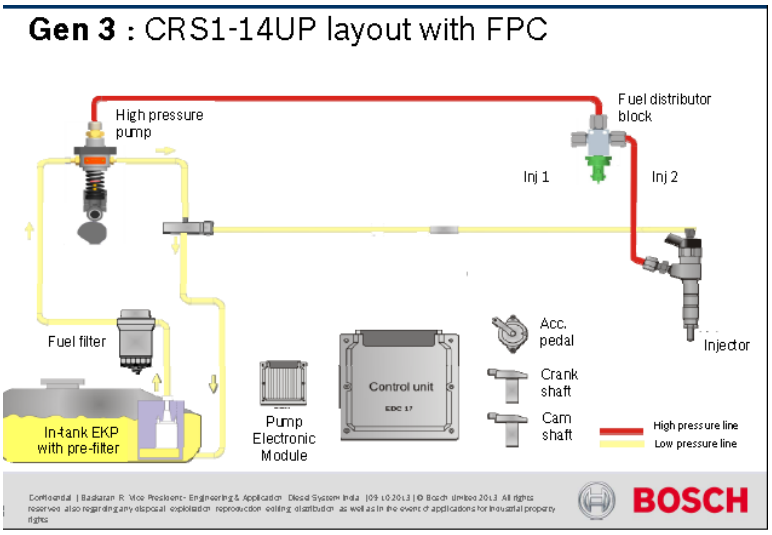

Figure 9 Gen 3 FI with fuel control unit integrated with fuel filter.

The new series of FIs were subjected to benchmark tests and it was found that the new injector based engines performed better than the standard ones in terms of torque and power, as shown in Figure 10.

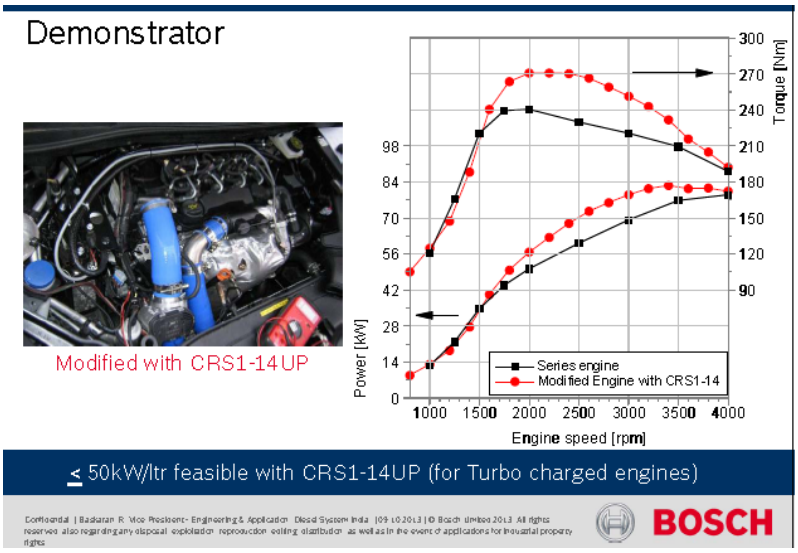

Figure 10 Results of comparison of performance between modified and original engines.

6. Validation

We used the information gathered in the case study of Bosch India as well as the SPINS framework to derive implications for indulging in new product development as well as to determine the requirements of platform based innovation. Table 4 summarizes the findings of the validation exercise. We analyze each factor of our proposed framework with respect to the platform based innovation at Bosch India and examine how that factor either enables or disables the incentive for innovation and the movement towards a product platform.

Factor	Sub-factor	Situation	Implications
Product	Brand	Very strong brand in the segment, considered trustworthy by end consumers	Demand for different varieties of products for different types of vehicles
	Solutions	Provides end to end solutions for FIs from development to customization; Repair and reuse important	Expectations for higher innovation to cater to changing needs; Development of reusable solutions
Process	Innovation culture	'Invented for Life' taken very seriously; Innovation promoted at every level	Fast turnaround time for any new innovation; Complete galvanization toward new developments
	Standardization	High degree of standardization in the firm; Processes and modules standardized	Easy to move towards product families
	Organization	Modular and dedicated teams; Nimble organizational structure	Organization tuned for fast paced development and innovation
Investment	Supply chain	Highly integrated supply chain both in the upstream and downstream directions	No impact on innovation capabilities
	Research and Development	Dedicated research wing with a good budgetary allocation to promote new product development	High investment in R&D to promote new product development
Industry	Competition	Limited but presence of other large players; Medium to heavy competition	Competition structure promotes innovation to stay ahead
	Maturity	Industry consolidated and matured; Product innovation by all players to some extent	Maturity of industry in this case has no major impact owing to regular introduction of new products

Customer	Perceived value	Fuel efficiency defines perceived value in this segment; Average salary lower than western counterparts	Very price sensitive customers; Demand for low priced and high efficiency products
	Service	High expectations for service delivery in this segment for all products	Modular products to increase service quality strong enabler for development of product platform
Regulations	Institutional	No major institutional regulation on FI or allied businesses	No impact
	Social	Environmental regulations aimed at fuel emission norms; Different emission norms for different cities and different vehicles	Promotes requirement of various types of FIs to suit demands for different types of norms
	Economic	Diesel subsidised by government is considered to be a fuel of the poor	Incentive for higher demand for cheap diesel vehicles

Table 4 Validation of the SPINS framework using the case of Bosch India.

It can be seen from Table 4 that most of the factors point to the need for innovation in the LPV segment. Also, the organization and its settings over the years, due to the innovation culture at Bosch, are always ready for such a challenge. The framework highlights the strong possibility of innovating and developing a modular product family by Bosch India and also points to the various organizational aspects that enable such a development.

7. Analysis and discussion

Managing innovation in any firm is a herculean task and managing successfully a platform development under strict regulatory as well as consumer pressure is all the more difficult. Bosch India has successfully achieved that and is an exemplar for many other firms in similar situations. To quote Mr. Baskaran:

"*The average salary of Indians is a lot lower than the average salary in west and coupled with that is the government's preference for diesel. We have a situation that is not present in the western world. We cannot use the solutions that can be used in Europe. The situation demands something else. The LPV segment is very crucial in a country like India.*"

The ability to recognize the need of a new solution for existing product and not force-fitting solutions from other markets is a decision that has helped Bosch India maintain its leadership in a competitive market like India. The most important aspect of maintaining an advantage over

your competitors is recognizing the right opportunities which Bosch has done very well through close collaboration with end consumers. Understanding the market and the economic regulations has helped Bosch ascertain the nerve of the consumers in the LPV segment. Such vehicles that are very commonly used for commercial transportation in cities are highly cost sensitive and so costly solutions used in Europe cannot be implemented directly in this market.
The second important point after recognition of opportunity is the ability to capitalize on the opportunity. The capability to capitalize on available opportunity is what makes a firm the undisputed leader in its domain. Bosch India capitalized on this opportunity by developing the required product. The company was helped in this endeavor by its deep innovation culture and the management's thrust to invest in R&D.

As discussed before, the development of the new FI systems required a close collaboration between various stakeholders, both internal and external. Bosch India collaborated with its clients to not only develop custom solutions for their new requirements at the required price point but also ensured support for older vehicles by providing them with innovations like EDC as well as chemical treatment of exhaust. This was done to ensure that the older mechanical injectors could still function well even in the new emission regime. These efforts ensured that Bosch India's clients had high faith in their new initiatives. The brand of Bosch India just got stronger with this with this strong orientation toward customer relationship.

To meet the emission norms a new platform was developed which was in stark contrast to the solutions offered in developed markets. Moving away from the CR FI system to a single injector-no rail system was a development that not only decreased the cost of moving to BS IV and BS V emission norms but also increased fuel efficiency, thereby creating a strong USP in the cost conscious Indian market. To develop this system the collaboration within Bosch India's research team had to be very high. The pressure of deadlines was looming large as emission norms enforced by the government forced non-negotiable deadlines. Each step was closely tracked by senior managers and the development was done in a time bound manner in close collaboration with automobile manufacturers.

An important aspect that has been one of the core reasons for success of Bosch's inventions even in trying circumstances was its focus on creating monetary value for its customers. Value for money innovation is not a buzzword at Bosch but has become ingrained into the corporate culture. This latent aspect is well highlighted by Dr. Steffen Burns, Managing Director, Bosch Group India

"Ultimately, the customer is looking for low total cost, limited changes, robustness, ability to meet regulations and easy upgradability for the future." Another important lesson from this

case relates to the innovation approaches taken by a firm. A firm does not always need radical innovation. But incremental innovation also does not serve the purpose all the time. Firms need to adopt a mixed of strategy based on radical and incremental approaches. This was done very well at Bosch India as is evident from Figure 11 that explains the innovation approach that was adopted. A good innovation approach was to develop a breakthrough technology once in a while to get significant competitive advantage and then incrementally improve on that innovation. This is because radical innovation requires much higher investment which is not warranted at all times. Another impact of such an approach is that the process of innovation has never slowed down. Figure 12 shows the number of patents filed by Bosch India from 2011-13. The figure has seen an overall jump of about 176% from 2012 to 2013 and has been driven by the philosophy and drive to continuously innovate.

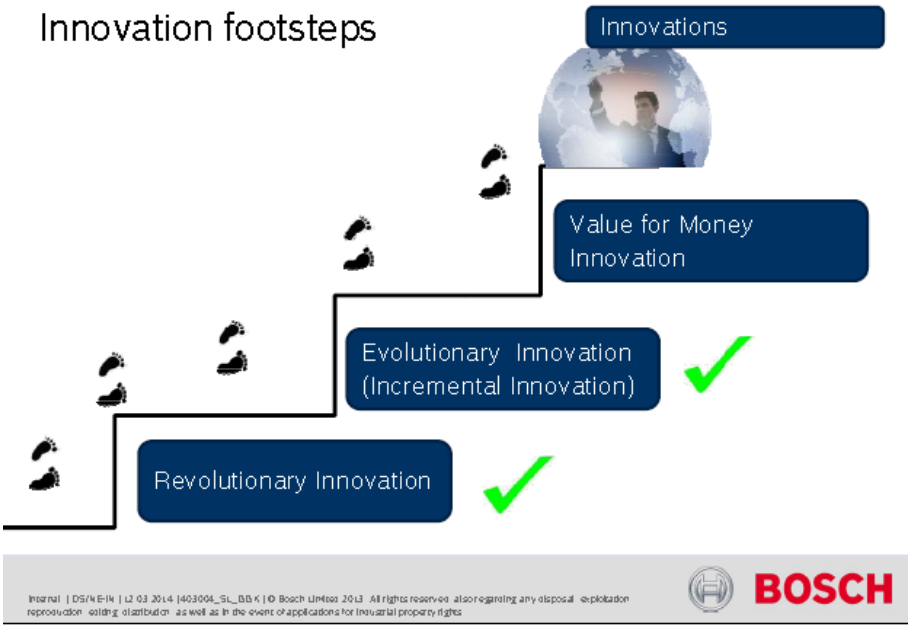

Figure 11 The innovation process at Bosch.

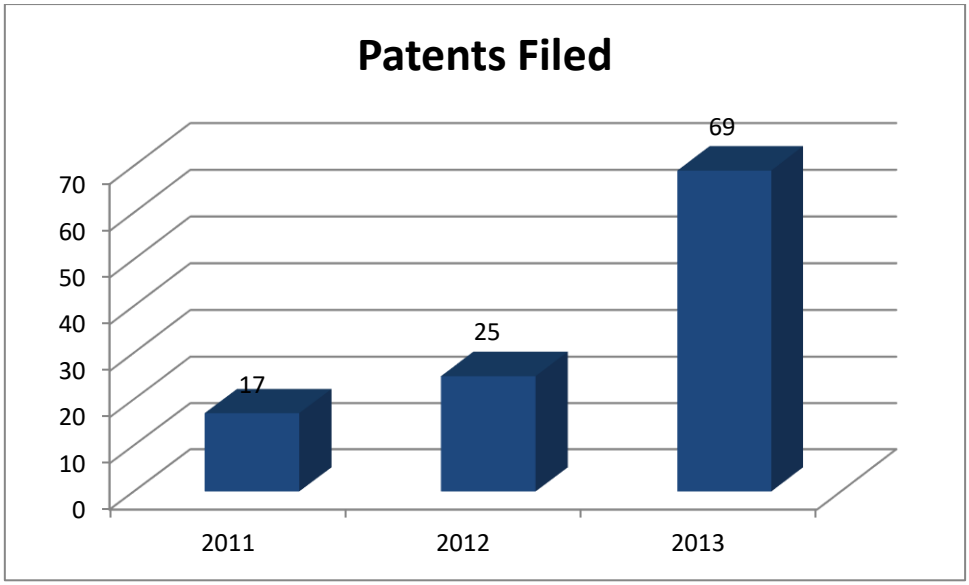

Figure 12 Number of patents filed at Bosch India.

8. Conclusion

The study of Bosch India has provided a number of insights on various issues. It has highlighted the fact that a culture of cultivating and promoting innovation has a lot of takeaways for the firm. A firm which is primarily in B2B manufacturing can also derive significant advantage by investing in development of an innovative product platform to satisfy both regulatory considerations as well as consumer demands. Having a product family also provides cushion to the firm against the inconsistencies in the implementation of regulations, which is a common phenomenon in emerging economies. Developing a product family is not a one-step approach and firms need to invest and plan strategically for such a development. They need to weigh the pros and cons of such a massive investment exercise. The theoretical framework presented in this paper is a comprehensive tool which can be handy for managers who are keen to explore product innovation in their organizations. It can help them analyze a firm's abilities to deal with internal and external factors and understand the need to engage in product platform development. The proposed framework presents an integrated vision bringing in concepts from product development, economics, regulations, and strategy together. A key lesson from the validation of the framework with the case study of Bosch India is that a culture of innovation is an invaluable investment for the organization that can help the firm tide over several difficulties arising out of unforeseen circumstances. The case study identifies that the critical factors for the success of the product platform development for Bosch India were innovation culture and organization as internal factors and industry dynamics and social regulations as external factors.

The proposed framework is itself limited with the limitations of the choice of the method. A single case study based derivation of theory, though rich in content, comes with its bias (Yin, 2014). One of the enhancements to this research is the possibility of making it more generic by performing more case experiments in different industries as well as global locations. Another limitation to the work may have arisen due to the choice of the firm for the case study. This choice has enabled us to get detailed information on all aspects of the development by providing access to interviews with the R&D team, distribution team and top management. The firm being a B2B manufacturing firm at one hand provides a unique perspective but also necessitates the testing of the framework on more consumer facing businesses to establish the generalizability of the findings. The new framework and the important lessons learnt from the case study on product platform development are important contributions to the academic literature on innovation that we hope that this can be utilized by more firms to herald an era of modular products.

References

Aaker, D. A. (2004). Leveraging the corporate brand. California Management Review, 46(3), 6-18.

Abraham, J., Davis, C. (2007). Interpellative sociology of pharmaceuticals: Problems and challenges for innovation and regulation in the 21st century. Technology Analysis & Strategic Management, 19(3), 387-402.

Acs, Z. J., Audretsch, D. B., & Feldman, M. P. (1994). R&D spillovers and innovative activity. Managerial and Decision Economics, 15(2), 131-138.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P. (2002). Competition and innovation: An inverted U relationship (No. w9269). National Bureau of Economic Research.

Atuahene-Gima, K. (1996). Market orientation and innovation. Journal of Business Research, 35(2), 93-103.

Atuahene-Gima, K. (2005). Resolving the capability rigidity paradox in new product innovation. Journal of Marketing, 69(4), 61-83.

Audretsch, D. B., Feldman, M. P. (1996). Innovative clusters and the industry life cycle. Review of Industrial Organization, 11(2), 253-273.

Benbasat, I., Goldstein, D. K., Mead, M. (1987). The case research strategy in studies of information systems. MIS Quarterly, 11(3), 369-386.

Berg, B. L., Lune, H. (2004). Qualitative research methods for the social sciences. Vol. 5. Boston: Pearson.

Berger, J., Draganska, M., Simonson, I. (2007). The influence of product variety on brand perception and choice. Marketing Science, 26(4), 460-472.

Berry, S., Pakes, A. (2007). The pure characteristics demand model. International Economic Review, 48(4), 1193-1225.

Bessant, J., Caffyn, S. (1997). High-involvement innovation through continuous improvement. International Journal of Technology Management, 14(1), 7-28.

Blind, K. (2012). The influence of regulations on innovation: A quantitative assessment for OECD countries. Research Policy, 41(2), 391-400.

Carlin, W., Soskice, D. (2006). Macroeconomics: Imperfections, institutions & policies. Oxford: Oxford University Press.

Central Pollution Control Board. (2000). Available at: http://cpcb.nic.in/Vehicular_Exhaust.php (last accessed on August 26, 2014).

Chai, K. H., Wang, Q., Song, M., Halman, J. I., Brombacher, A. C. (2012). Understanding competencies in platform-based product development: Antecedents and outcomes. Journal of Product Innovation Management, 29(3), 452-472.

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.

Chataway, J., Tait, J., Wield, D. (2006). The governance of agro-and pharmaceutical biotechnology innovation: Public policy and industrial strategy. Technology Analysis & Strategic Management, 18(2), 169-185.

Chen, K.-M., Liu, R.-J. (2005). Interface strategies in modular product innovation. Technovation, 25(7), 771-782.

Cohen, W. M., Levinthal, D. A. (1990). Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly, 35(1), 128-152.

Cooper, R. G., Kleinschmidt, E. J. (1995). Benchmarking the firm's critical success factors in new product development. Journal of Product Innovation Management, 12(5), 374-391.

Crafts, N. (2006). Regulation and productivity performance. Oxford Review of Economic Policy, 22(2), 186-202.

Damanpour, F. (1991). Organizational innovation: A meta-analysis of effects of determinants and moderators. Academy of management journal, 34(3), 555-590.

Danneels, E. (2002). The dynamics of product innovation and firm competences. Strategic Management Journal, 23(12), 1095-1121.

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. Journal of Economic Literature, 26(3), 1120-1171.

Dubé, L., & Paré, G. (2003). Rigor in Information Systems Positivist Case Research: Current Practices, Trends, and Recommendations. MIS Quarterly, 27(4), 597-636.

Duchesneau, T. D., Cohn, S. F., Dutton, J. E. (1979). A study of innovation in manufacturing: Determinants, processes, and methodological issues. University of Maine at Orono: Social Science Research Institute.

Eisdorfer, A., & Hsu, P. H. (2011). Innovate to survive: The effect of technology competition on corporate bankruptcy. Financial Management, 40(4), 1087-1117.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of Management Review, 14(4), 532-550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: opportunities and challenges. Academy of management journal, 50(1), 25-32.

Ettlie, J. E., Bridges, W. P. (1982). Environmental uncertainty and organizational technology policy. IEEE Transactions on Engineering Management, 29(1),2-10.

Fagre, N., Wells Jr., L. T. (1982). Bargaining power of multinations and host governments. Journal of International Business Studies, 13(2), 9-23.

Farrell, R. S., Simpson, T. W. (2003). Product platform design to improve commonality in custom products. Journal of Intelligent Manufacturing, 14(6), 541-556.

Faulkner, A. (2009). Regulatory policy as innovation: Constructing rules of engagement for a technological zone of tissue engineering in the European Union. Research Policy, 38(4), 637-646.

Flint, D. J., Larsson, E., Gammelgaard, B., Mentzer, J. T. (2005). Logistics Innovation: A customer value-oriented social process. Journal of Business Logistics, 26(1), 113-147.

Fogliatto, F. S., da Silveria, G. J., Borenstein, D. (2012). The mass customization decade: An updated review of the literature. International Journal of Production Economics, 138(1), 14-25.

Gallouj, F., Weinstein, O. (1997). Innovation in services. Research Policy, 26(4), 537-556.

Gunday, G., Ulusoy, G., Kilic, K., Alpkan, L. (2011). Effects of innovation types on firm performance. International Journal of Production Economics, 133(2), 662-676.

Haiyang, L., Atuahene-Gima, K. (2001). Product innovation strategy and the performance of new technology ventures in China. Academy of Management Journal, 44(6), 1123-1134.

Henderson, R. M., Clark, K. B. (1990). Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quarterly, 35(1), 9-30.

Jiao, J. R., Simpson, T. W., Siddique, Z. (2007). Product family design and platform-based product development: A state-of-the-art review. Journal of Intelligent Manufacturing, 18(1), 5-29.

Kemp, R. (1998). Environmental regulation and innovation: Key issues and questions. In: F. Leone, J. Hemmelskamp (eds.), The Impact of EU Regulation, Seville: IPTS. 12-39.

Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. The American Economic Review, 86(3), 562-583.

Krishnan, V., Gupta, S. (2001). Appropriateness and impact of platform-based product development. Management Science. 47(1), 52-68.

Lee, A. S. (1989). A scientific methodology for MIS case studies. MIS Quarterly, 13(1), 33-50.

Lee, H. L. (2002). Aligning supply chain strategies with product uncertainties. California Management Review, 44(3), 105-119.

Lehnerd, A. P. (1987). Revitalizing the manufacture and design of mature global products. Technology and Global Industry: Companies and Nations in the World Economy, 49-64.

Leiponen, A., Drejer, I. (2007). What exactly are technological regimes? Intra-industry heterogeneity in the organization of innovation activities. Research Policy, 36(8), 1221-1238.

Lundvall, B. A., Borrás, S. (2005). Science, technology and innovation policy. In: The Oxford Handbook of Innovation, 599-631.

Meyer, M. H. (1997). The power of product platforms. Simon and Schuster.

Meyer, M. H., Lehnerd, A. P. (1997). The power of product platforms: Building value and cost leadership. New York: The Free Pass.

Mikkola, J. H., & Gassmann, O. (2003). Managing modularity of product architectures: toward an integrated theory. IEEE Transactions on Engineering Management, 50(2), 204-218.

Ministry of Petroleum & Natural Gas. (October 2003). National auto fuel policy announced. Available at: http://pib.nic.in/archieve/lreleng/lyr2003/roct2003/06102003/r0610200313.html (last accessed August 26, 2014).

Nidumolu, R., Prahalad, C. K., Rangaswami, M. R. (2009). Why sustainability is now the key driver of innovation. Harvard Business Review, 87(9), 56-64.

Park, J., Simpson, T. W. (2008). Toward an activity-based costing system for product families and product platforms in the early stages of development. International Journal of Production Research, 46(1), 99-130.

Pessina, M. W., Renner, J. R. (1998). Mass customization at Lutron electronics - A total company process. Agility and Global Competition, 2, 50-57.

Petersen, K. J., Handfield, R. B., Ragatz, G. L. (2005). Supplier integration into new product development: coordinating product, process and supply chain design. Journal of Operations Management, 23(3), 371-388.

Pirmoradi, Z., Wang, G. G., Simpson, T. W. (2014). A review of recent literature in product family design and platform-based product development. In: Advances in Product Family and Product Platform Design, New York: Springer, 1-46.

Porter, M. E., van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. Journal of Economic Perspectives, 9(4), 97-18.

Priest, J., Sanchez, J. (2001). Product development and design for manufacturing: A collaborative approach to producibility and reliability. CRC Press.

Sanchez, R., Mahoney, J. T. (1996). Modularity, flexibility, and knowledge management in product and organization design. Strategic Management Journal, 17(S2), 63-76.

Sanderson, S. W., Uzumeri, M. (1997). The innovation imperative: Strategies for managing product models and families. Chicago: Irwin.

Sawhney, M., Wolcott, R. C., Arroniz, I. (2006). The 12 different ways for companies to innovate. MIT Sloan Management Review, 47(2), 28-34.

Shirley, G. V. (1990). Models for managing the redesign and manufacture of product sets. Journal of Manufacturing and Operations Management, 3(2), 85-104.

Simpson, T. W., Siddique, Z., Jiao, R. J. (2006). Product platform and product family design: methods and applications. Springer.

Škerlavaj, M., Štemberger, M., Škrinjar, R., Dimovski, V. (2007). Organizational learning culture - the missing link between business process change and organizational performance. International Journal of Production Economics, 106(2), 346-367.

Sood, A., Tellis, G. J. (2005). Technological evolution and radical innovation. Journal of Marketing, 69(3), 152-168.

Veenstra, V. S., Halman, J. I., Voordijk, J. T. (2006). A methodology for developing product platforms in the specific setting of the housebuilding industry. Research in Engineering Design, 17(3), 157-173.

Viscusi, W., Moore, M. J. (1993). Product liability, research and development, and innovation. Journal of Political Economy, 101(1), 161-184.

Wheelwright, S. C., Clark, K. B. (1992). Creating project plans to focus product development. Harvard Business School Publishing.

Yin, R. K. (2011). Applications of case study research. Sage Publications.

Yin, R. K. (2014). Case study research: Design and methods. Sage Publications.

Appendix 1

Innovation runs deep into Bosch's culture and has been carefully nurtured over the years. This, as explained in the paper above, has been one of the most important reasons for the success of the firm under immense competition as well as regulations. Dr. Steffen Burns spoke about the innovation culture at Bosch:

"Innovation is part of our culture at Bosch, and I am happy that India and in particular TCI is no exception to that".

Bosch's innovation culture is best reflected by the four key elements of their culture and the house of orientation at Bosch as shown in Figures A1 and A2 below.

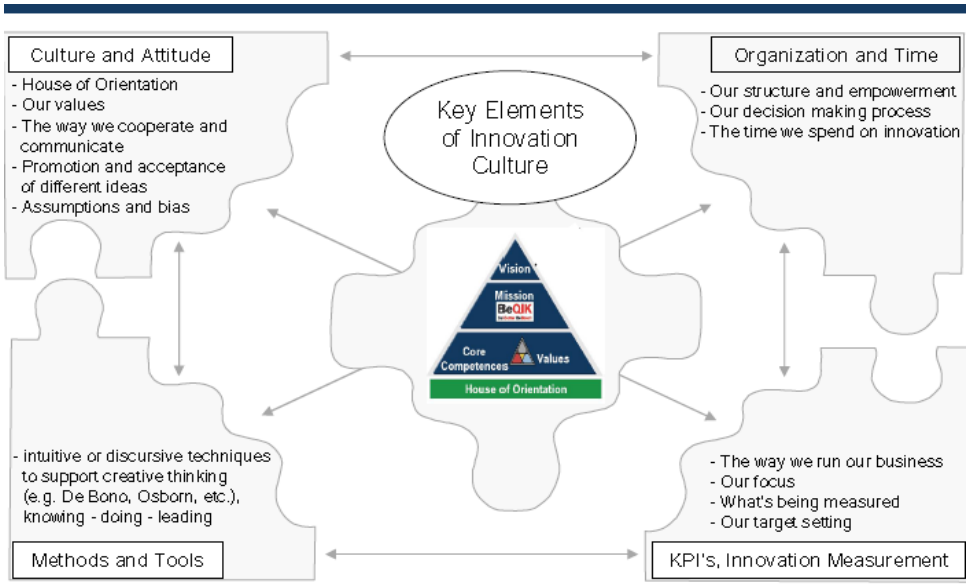

Figure A1 Key elements of the innovation culture at Bosch.

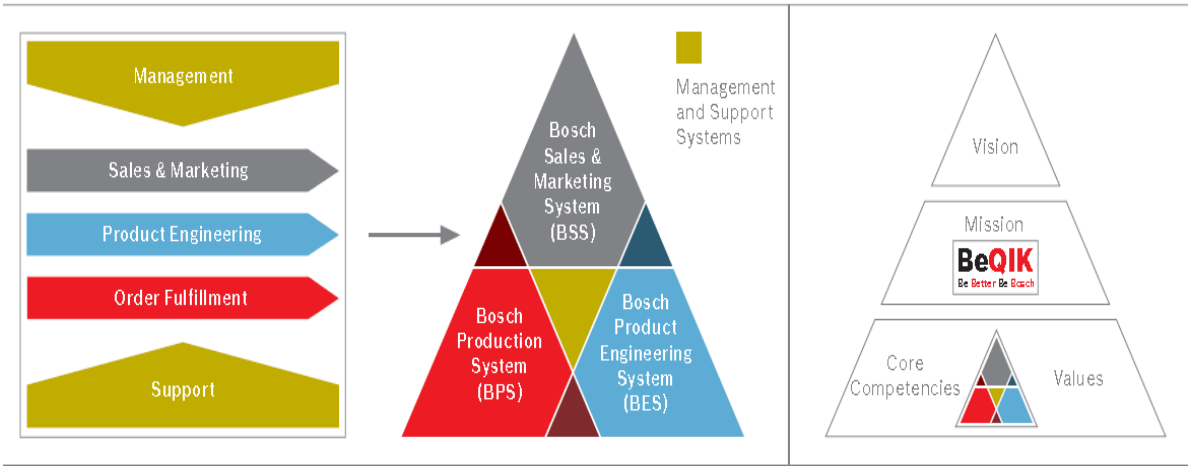

Figure A2 House of orientation at Bosch.