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Frugal Innovation and Analogies: Some Propositions for Product Development in Emerging Economies

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Frugal innovation and analogies: some propositions for product development in emerging economies

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Frugal products and services aim at satisfying the unsaturated demand of a large and growing middle class in many "emerging economies". Although research has been conducted in regard to the strategic importance of frugal innovations, so far, the actual development process of such innovations has not been looked into in detail. Some examples show that inventive analogies are used to develop frugal innovations. For instance, the development of a frugal artificial heart was based on the heart structure of cockroaches, which led to a reduction of costs by 20 times.

The aim of this paper is to examine the use of inventive analogies in creating frugal solutions and their impact on project results. Based on three explorative case studies from India, the authors generate preliminary evidence that analogies can make a significant impact on the successful development of innovations in environments that are characterized by severe resource constraints and high price-sensitivity. Furthermore, the inherent aim of frugal innovations to create radically new solutions with very restricted resources seems to stimulate the application of inventive analogies. The results point to some valuable learnings in regard to an effective employment of analogies. Besides, useful insights for companies that want to exploit market opportunities in the emerging economies are generated.

1. Introduction

In the past few years we have seen the emergence of an innovation paradigm that, in a nutshell, emphasizes the need to develop "good enough" products with a strong focus on core functionality and a radically reduced cost-structure. Such products are often known as "frugal innovations" and are predominantly, though not exclusively, found in the fast growing markets of emerging economies like India and China (Basu et al., 2013, Bound and Thornton, 2012, Prahalad, 2012, Prahalad and Mashelkar, 2010, Tiwari and Herstatt, 2012, Zeschky et al., 2011) Rapidly growing middle classes in largely unsaturated markets of emerging economies are turning these countries into "lead markets" for "low cost, high quality" products (Tiwari and Herstatt, 2014), which in the form of "reverse innovations" are increasingly reaching markets in the industrialized nations (Govindarajan and Trimble, 2012).

A study of frugal and standard (non-frugal) entry-level products in 13 different categories by Rao (2013) revealed that frugal products reduced costs anywhere between 58% and 97%. Another study of the healthcare sector in India and the USA by Govindarajan and Ramamurti (2013) showed a cost-difference of over 80% after incorporating the wage differentials. Such radical reduction in cost structure while maintaining the necessary quality standards raises the question: How are innovators of frugal products and services able to manage this seeming paradox?

A close observation of several frugal products reveals that they often tend to make use of inventive analogies by transferring solutions from one industry domain to the other or by transferring solutions from nature. For example, an Indian doctor successfully pioneered the use of "sterilised mosquito nets as a low-cost substitute for the expensive commercial meshes" for repairing hernias; this solution is "around 4,000 times cheaper than imported mesh" and has proven its technological performance in a

long-term study (Lacey, 2013). Another example is delivered by a low-cost artificial heart that is reportedly under clinical trial at Indian Institute of Technology (IIT) in Kharagpur. It uses an analogy from the multi-chamber, fault-resistant heart structure of cockroaches to develop robust and affordable solutions for as low as approx. $ 2,000 (Economist, 2009b, Mukherjee Pandey, 2009).

These examples suggest that inventive analogies (Gick and Holyoak, 1980, Kalogerakis et al., 2010) might constitute a promising approach for developing solutions that can ensure "affordable excellence" (Mashelkar, 2014). Nonetheless, neither the use of inventive analogies nor their impact on results in frugal innovation projects has, so far, been properly researched in the innovation management literature. According to Kalogerakis et al (2010: 427):

The scare literature on analogies in the context of new product ideation hardly addresses the possibility of using analogies to lower development costs or to cut development time.

This research gap is intriguing as it can, in turn, have some interesting implications for analogy research itself. So far, an efficiency effect of analogies was mostly attributed to within-industry analogies. However, some examples indicate that by using cross-industry analogies the cost-structure of products can be massively reduced. Apart from the use of mosquito net to repair hernia we can observe the transfer of the principles of mass production to heart surgeries that have reduced their costs to a fraction. Inspired by the success of discounters such as Wal-Mart, Ryanair and the Japanese automobile industry, "Narayana Hrudayalaya", an Indian hospital chain that conducts more than 11,000 heart surgeries a year has reduced operation costs to less than € 1,400 per operation while complying with the highest industry standards (Bound and Thornton, 2012). The case of "Mitti Cool", a fridge made of clay and based on the principle of natural evaporation is another example of bionic analogies that can be used to develop frugal innovations (Nair et al., 2012).

Therefore this paper focuses on the process and the outcome of the application of inventive analogies in frugal innovation projects. Based on three explorative case studies from India, the process of using inventive analogies is analysed in regard to a systematic approach and openness towards external solutions. Furthermore, the impact of different types of inventive analogies on the efficiency of the development process and development costs is investigated.

This paper is structured on the following lines: After a brief introduction in section 1, a theoretical fundament is laid in section 2, where the relevant concepts of frugal innovations and inventive analogies are introduced. This section also derives the research questions and presents a research model. Section 3 contains information on the research approach taken and introduces the objects of investigation. In section 4 we present our findings for the research questions. The paper concludes with section 5.

2. Theory and Research Questions

2.1 Characteristics of frugal innovation

Frugal innovations are an emerging phenomenon, and scholarly research on their causes, effects and characteristics is still in a nascent stage. Not surprisingly, a host of terms has been employed by scholars to describe innovative products and services that seek to radically lower the costs and target price-sensitive customers (cf. Baker et al., 2003, Basu et al., 2013, Gupta, 2010, Prahalad, 2005, Radjou et al., 2012, Tiwari and Herstatt, 2012). For the purpose of this paper we use a definition proposed by Tiwari and Herstatt (2014: 30) that considers frugal innovations as:

[…] new or significantly improved products (both goods and services), processes, or marketing and organizational methods that seek to minimize the use of material and financial resources in the complete value chain (development, manufacturing, distribution, consumption, and disposal) with the objective of significantly reducing the total cost of ownership and/or usage while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards.

Frugal innovations are characterized by an enhanced need to offer an attractive value proposition (cf. Rogers, 2003) to ensure diffusion. Firms offering frugal products and services are often competing not merely against a traditional rival but also against "non-consumption" since the potential customer might not be possessing means for buying the product or service on offer and/or (access to) the necessary infrastructure for using it. This value proposition may be achieved by the following (Tiwari and Herstatt, 2014):

(a) Reduced overall cost of ownership: It is not just the price point at the time of purchase, which is a crucial success factor for frugal innovations. Rather, it is the significantly reduced total cost of ownership that is achieved by the low costs of usage, maintenance and repair from acquisition till disposal. For example, in terms of the automobile industry it is not just the low price of a vehicle but also the high mileage and the low costs of repair that positively affect a purchasing decision in the price-sensitive segments of small cars.

(b) Robustness: Frugal innovations are often targeted at customers living in rural and semi-urban areas in developing economies. The products need to cope with various infrastructural shortcomings such as voltage fluctuation, abrupt power-cuts, dust, and extreme temperatures. Practices of planned obsolescence (Economist, 2009a, Slade, 2007) that seek to intentionally limit the life-span of a product without simultaneously reducing the associated costs for the customer are

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incompatible with frugal innovations.

(c) User friendliness: Many (potential) buyers of frugal products have no prior, first-hand experience of using similar products. Companies cannot presume a significant level of familiarity on the consumer side in dealing with their products. Frugal products therefore need to be easy-to-use and fault resistant.

(d) Economies of Scale: Finally, the need for significant cost reduction, and the thin profit margins almost necessarily associated with frugal products necessitate access to voluminous business to reduce unit costs of development and production.

2.2 Characteristics of inventive analogies

Innovations are, to a large extent, based on already existing knowledge. Even radical or breakthrough innovations often result out of new combinations of known technologies. This perspective on the development of innovations can be related to the view of Schumpeter (1934) who defined innovation as a process of newly combining available resources. Hence, one challenge in the process of innovation is the detection of new connections between knowledge from by then separate domains.

The transfer of knowledge from one context to another can be fostered by the use of inventive analogies. In the process of an inventive analogical transfer existing solution elements from a familiar conceptual domain (the base) are used to solve a given problem or engineering challenge at hand (the target). This kind of analogical transfer leads to innovation, if disparate pieces of knowledge are combined in a novel way (Gick and Holyoak, 1980, Holyoak, 2005, Ward, 1998).

Inventive analogies can be categorized depending on the conceptual distance between the source and target domain of the analogy. A general and widespread distinction is made between near analogies and far analogies (Gick and Holyoak, 1980, Keane, 1987, Vosniadou, 1989, Ward, 1998). Generally, near analogies only lead to rather incremental innovations, whereas far analogies have the potential to initiate radical and breakthrough innovations (Dahl and Moreau, 2002, Perkins, 1997).

In their empirical study, Kalogerakis et al. (2010) specified the rather vague classification of near and far analogies. They distinguish between analogies within one product category, analogies between different product categories and analogies stemming from a non-product domain. A product category is defined as all products that belong to the same use context, for example sports equipment, medical equipment or furniture (Kalogerakis et al., 2010). An approach to measure the conceptual distance between different industries based on the NACE industry-classification did not lead to convincing results (Enkel and Gassmann, 2010). Overall, a further significant refinement of analogy-distance in the context of new product development is still missing. Based on current research in this context, a distinction between (1) near analogies as analogies of the same broad product category or industry, (2) far analogies as analogies across broad product categories or industries and (3) far analogies as bionic analogies seems reasonable (Bonnardel and Marmèche, 2004, Dahl and Moreau, 2002, Enkel and Gassmann, 2010, Gassmann and Zeschky, 2008, Herstatt and Kalogerakis, 2005, Kalogerakis et al., 2010).

In some professional domains the use of inventive analogies is a widespread practice. Empirical studies show that industrial design and engineering consultancies often use analogies in the process of product development. Especially, if they have clients from diverse domains, they are in a privileged position to transfer knowledge between industries based on analogies (Hargadon, 2002, Kalogerakis et al., 2010, Lüthje et al., 2010). From this context it is known, that the inspiration to discover a useful analogy, often stems from knowledge that is already available within the company. The use of local knowledge is for companies that possess knowledge in many diverse domains an efficient way to develop new solutions (Kalogerakis et al., 2010).

However, other people that are not used to solve creative problems from different domains usually have more trouble identifying relevant far inventive analogies. Especially the detection of far analogies based on structural similarities is more difficult if these cannot rest upon own experiences (Blanchette and Dunbar, 2000). Furthermore, functional fixedness can hinder the search for analogies. This psychological phenomenon was first described by Duncker (1945). Functional fixedness occurs if knowledge about the regular use context of a product or technology inhibits the developer to find other applications of the product or technology. Derived from this phenomenon, another problem arises: Engineers who have a profound knowledge in only one single domain experience difficulties to see the usefulness of solutions from other domains for their specific problems. Therefore, a systematic approach expanding the search space to external knowledge often is an inevitable course of action to succeed in detecting far inventive analogies.

2.3 Research Questions

Frugal innovations are characterised by a massive cost reduction of a product – not only concerning acquisition costs, but also costs of use. Simultaneously, frugal innovations need to fulfil certain standards of robustness, user friendliness and quality. In order to reach these aims radically new solutions are required. However, financial resources for development and manufacturing are strictly limited. As shown in the preceding sections of this paper, inventive analogies seem to help in reaching these conflicting goals.

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First, the question arises if premises of using inventive analogies in frugal innovation projects differ from its application in normal innovation projects. So far, the process of finding relevant inventive analogies in frugal innovation projects is still unclear. Industrial engineering and management consultants working for clients from diverse industries frequently apply inventive analogies based on knowledge already available with them (Hargadon, 2002, Hargadon and Sutton, 1997, Kalogerakis et al., 2010). A systematic search for unknown sources of analogies outside the own knowledge base is not reported. Results from other empirical studies suggest that generally only few companies apply systematic search and idea generation methods in the front end of innovation (Barczak et al., 2009). In contrast, the application of creativity methods is mostly limited to simple ad-hoc brainstorming sessions. Due to the special requirements of frugal innovations, it can be expected that frugal innovation development teams are more open to external knowledge and realise the need of systematic search processes compared to "normal" innovation projects. This leads to the first two research questions:

Q1a: Are systematic methods applied in frugal innovation projects to find inventive analogies?

Q1b: Are developers of frugal innovations more open to external solutions from other domains?

Second, the benefit of different kinds of inventive analogies in frugal innovation projects needs further investigation. Research in inventive analogies suggests that within-industry analogies, cross-industry analogies and bionic analogies have differing effects on the newness of results and the efficiency of the development process. Whereas many researchers analysed creativity effects of inventive analogies (Chan et al., 2011, Dahl and Moreau, 2002, Enkel and Gassmann, 2010, Gassmann and Zeschky, 2008, Kalogerakis et al., 2010, Ward, 1998), evidence about efficiency effects is still sparse. However, Majchrzak et al. (2004) show how organizational pressure concerning very restricted development time and cost inspired NASA researchers to use inventive analogies. Only by looking for reusable technological solutions from other domains, they could reach their development goals. Similarly, industrial designers and engineers reported in a study from Kalogerakis et al. (2010) that only by using inventive analogies, many of their development projects could be accomplished within the limited time and financial resources given by their clients. This leads us to two additional research questions

Q2a: Are inventive analogies used in frugal innovation projects to increase process efficiency?

Q2b: Are inventive analogies used in frugal innovation projects to decrease development costs?

A corresponding research model is given in Figure 1. It shows how process factors might have an effect on the use of different kinds of inventive analogies. The application of inventive analogies in turn is supposed to lead to efficiency effects: increased process efficiency and decreased development time. Finally, a positive impact on the aspirated goals of frugal innovation projects is expected.

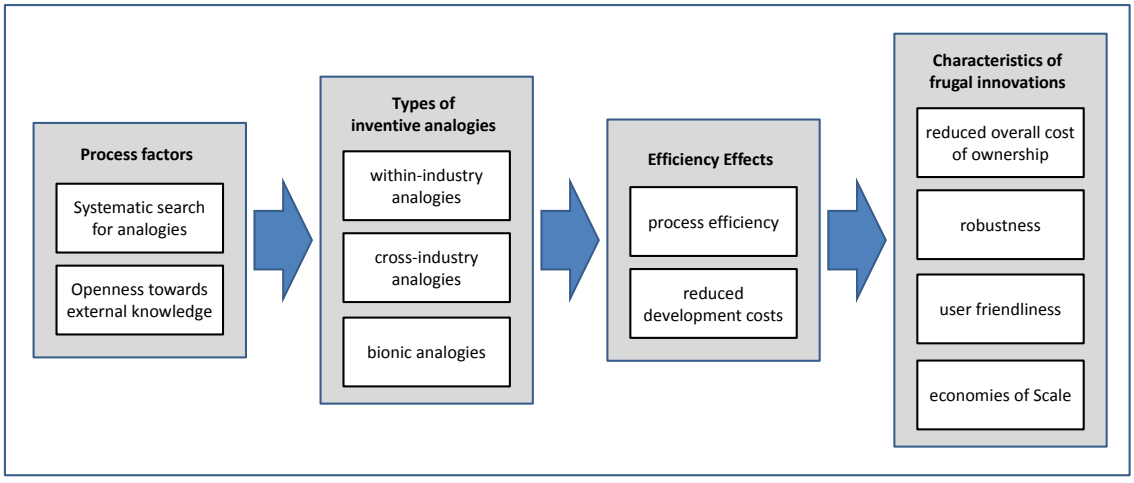

Figure 1: Proposed research model connecting inventive analogies with frugal innovations

3. Research Approach

3.1 Methodology

This paper is based on three case studies of successful frugal innovations from India, which has been identified as a lead market for frugal products and services (Tiwari and Herstatt, 2014). The case study method has been selected since the phenomenon under question is still at a nascent stage and the study has an explorative character (Eisenhardt, 1989, Greenstein and Polsby, 1975). Furthermore, the study intends to not only concentrate on

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the "what" aspects of the phenomenon but also, and especially so, it seeks to generate preliminary insights on the "how" and "why" aspects of the usage of inventive analogies in the product development process of frugal innovations (cf. Yin, 2003). The study is based on an extensive literature review of published information in scholarly journals, company publications and news media. The cases have been identified based on the authors' preceding studies of frugal innovations that have included interviews with concerned officials at the respective firms, see e.g. (Ramdorai and Herstatt, 2013, Tiwari and Herstatt, 2012, Tiwari and Herstatt, 2014). The key selection criterion was the potential to generate preliminary insights and the availability of information.

3.2 Objects of investigation

• Tata Ace: The "Tata Ace" is a small commercial vehicle (SCV) from the stable of India's Tata Motors Limited (TML). It was first launched in 2005 and has a payload capacity of 0.75 tons. TML conceptualized the Ace as a competitor to the 3-wheeled commercial vehicles and went on to create a new product category of SCVs that was not existent in India's automobile market till then. The development budget of the Ace was fixed at a maximum of INR 2.2 billion (approx. $49 million in then exchange rates), which was less than one-tenth of what MNCs then typically spent on a similar project (Palepu and Srinivasan, 2008). The Ace was targeted at price-sensitive buyers, costing INR 225,000 (about $ 4,000 in then exchange rates), which was at least 50% less than any other 4-wheeled commercial vehicle in India (Freiberg et al., 2011, Palepu and Srinivasan, 2008). The Ace fulfils the requirements of a frugal product and was conceived as a "cheap, nasty and rugged vehicle for India" (Palepu and Srinivasan, 2008), with low-cost and low-maintenance features that can ideally be used on India's narrow and crowded roads within towns, as well as for long highway journeys (Khanna and Palepu, 2010, Singh and Chaudhuri, 2009).

• Tata Nano: The "Tata Nano" is one of the best known (radical) frugal innovations from the product portfolio of TML and has been promoted in the press as "the cheapest car of the world" (Schuster and Holtbrügge, 2011). It was launched for a price of INR 100,000 (approx. $2,200 in then exchange rates) in March 2009 (Palepu et al., 2011). The driving force behind the development of the Nano was the vision of Ratan Tata, then Head of the Tata Group, to provide a safe and affordable medium of transport to millions of Indian (lower) middle class families that often use a 2-wheeler for transporting a family of 4-5 members including children. An affordable car should provide better comfort and increase traveling safety while providing protection against natural elements such as rains or extreme weather conditions (Tiwari and Herstatt, 2012). The Nano was a unique project as the maximum retail price of the end product was already fixed by the highest level of management at INR 100,000 which was less than 50% of a standard entry-level product thereby forcing the developers to employ target costing in the development process. Despite its development in a strongly resource-constrained atmosphere the Nano fulfils all prescribed safety norms in India and was developed in an "open innovation" project that included several global automotive suppliers (Chacko et al., 2010).

• GE's MAC 400: The "MAC 400" is an electrocardiogram device (ECG) from the product portfolio of US-based multinational General Electric (GE). This ECG was developed at GE's Jack F. Welch Technology Centre in Bangalore in India (Govindarajan and Trimble, 2012, Ramdorai and Herstatt, 2013). The MAC 400 enables radical cost reduction for its users: Whereas a standard ECG device costs $15,000 and more, the MAC 400 was launched in India's domestic market for about one-tenth of that price (Jana, 2009). Furthermore, it is a robust device that is equipped with ultra-portability (Ramdorai and Herstatt, 2013): It weighs only 1.3 Kg. and can run on battery (GE Healthcare, 2010). The reduced need for electricity makes it suitable for usage in rural and semi-urban areas with poor infrastructure. In 2009 a next generation version the "MACi" was introduced in the Indian market that reduced the price once more substantially to $535 (Ramdorai and Herstatt, 2013). Another variant the "MAC 800" which is endowed with more features is sold in western countries such as Germany and the USA and is reportedly used for doctors on ambulant emergency duty (Govindarajan and Trimble, 2012).

4. Findings

4.1 Systematic Search for Analogies

The case studies provide ground for assumption that development teams of frugal innovation projects apply systematic methods to find inventive analogies. In all cases a deliberate attempt to actively seek and employ inventive analogies could be observed. This was mostly motivated by the restrictive development budgets and the resultant pressure to achieve process efficiency and reduce development costs. The management expected from its product developers a substantial reduction in cost/price of the products targeted at price-sensitive customers. Development budgets were as low as one-tenth of comparable projects in the developed world.

While developing the Tata Ace, TML's management intentionally created strong resource constraints to induce the developers into searching for existing solutions and technologies that could meet the set performance criteria and reduce the development costs. A similar approach can also be observed in the development of the Tata Nano. In the words of Chacko et al. (2010: 124):

Much of the creativity that characterized the Nano project involved taking existing, patented components and

technologies and rejigging them to the small car's advantage.

Another example of systematic use of inventive analogies is provided by TML's search for inspirations in the Tata Nano project:

He [Ratan Tata] was also keen that the group explores every avenue in the development process, even the most unconventional, suggesting, for instance, that they look at furniture catalogues before deciding how the car's seating could be styled and positioned. The message was unambiguous: break out of the mould. (Chacko et al., 2010: 16)

Ratan Tata, whose vision behind the Nano drove the entire project, wished to create a car around a scooter and motivated his team to explicitly seek insights from the 2-wheeler segment (Chacko et al., 2010). At GE, too, product developers searched extensively for existing, proven technologies both within and outside the firm to reach strong cost reduction requirements set by the management for the MAC 400:

[Davy] Hwang and [Oswin] Varghese [project leaders] also kept costs low by studying other products. From the team responsible for GE's portable ultrasound machine, they learned about a low-cost source for [a] technology which can cut plastic mold prototypes far earlier in the process than usual. That let them get feedback from doctors before changes got costly. (McGregor and Kripalani, 2008)

These examples confirm that (successful) innovators seem to apply systematic methods in frugal innovation projects to find inventive analogies.

4.2 Openness of the development process

In all the analysed cases product developers displayed a remarkable openness for external solutions, both from outside the boundaries of their own firms as well as from other domains. One example is provided by the Tata Nano project where this openness for external knowledge was not just passively present, but was actively fostered and is well documented:

[Sam] Johnny's immediate task was to scout for information on engines and transmission systems. The internet was an important source for data and he frequently found himself spending his after-office hours in cyber cafes. Johnny and his colleagues – there were some 10 people in the small-car team then – looked at small cars and small engines from around the world, with new and old technology, proprietary and those for sale. Calls were made and contact established with engine vendors in, among other places Australia, Italy and the United States. (Chacko et al., 2010: 18 f.)

The Warwick Manufacturing Group of the School of Engineering at Britain's University of Warwick was involved in the development of the Nano. Seven suppliers of construction material including GE, DuPont and Reliance, made several experiments on behalf of and together with TML to test various materials and their possible use in automobiles. GE even stationed 3 engineers at TML for the duration of 6 months to carry out various experiments at TML. The Nano team considered even solutions from 2- and 3-wheeler industries that would make the final product look totally different from a conventional car.

Although Ratan Tata had already described the Nano to the press as something that would look like a real car, […] No idea was off the table. All ideas were considered worthy of discussion. (Freiberg et al., 2011: 48)

Also at GE, this practice was followed; even though taking recourse to external knowledge meant nothing less than breaking a taboo since the company had till then pursued a strong in-house policy (Govindarajan and Trimble, 2012). Within the GE concern too, concerted and proactive efforts were made to benefit from existing technologies in different business divisions of the company (Immelt et al., 2009). This indicates an important role of cross-divisional innovations within big corporate houses (Grote et al., 2012).

These examples confirm the proposition that developers of frugal innovations appear to be open to external solutions from other domains.

4.3 Effects of inventive analogies on process efficiency

The case studies demonstrate that the use of inventive analogies helped increase process efficiency. While developing the Ace, TML intentionally and proactively created synergies to its small passenger car the Indica. For example, the Indica's engine was enhanced and upgraded for use in the Ace. Additionally, the Ace was designed in a way that about 40% of its components are shared with other TML models (Palepu and Srinivasan, 2008). This sharing led on the one hand to significant synergies in procurement and maintenance. On the other hand, TML could utilize existing production processes and facilities for the new platform. Buoyed by the success of the Ace, TML decided to exploit analogies even further by transferring the Ace platform from commercial goods sector to commercial passenger vehicles. Two years after launching Ace, in 2007 TML introduced the "Tata Magic", a minivan for transporting 7-8 passengers in rural areas where narrow roads restrict movement of passenger buses (TML, 2013b). In the meantime an even smaller variant the "Tata Iris" has been launched to commercially carry 4-5 passengers (TML, 2013a).

In case of the Nano too many ideas were generated and implemented by using within-industry analogies that led to faster development and reportedly even enabled better performance:

Tata Motors engineers say the car's body is stronger than

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that of a conventional car due to it being a combination of monocoque and the space frame that motor cycles employ. (Chacko et al., 2010: 126)

Even component suppliers of the Nano are reported to have used such (within-industry) analogies. For example, German component supplier Bosch reportedly adapted a motorcycle starter to supply for the Nano and helped remove several ounces of weight from the generator (Sehgal et al., 2010) while reducing development costs and time.

The use of analogies to increase process efficiency is, however, not limited to within-industry analogies alone. In case of GE's MAC 400 we can also observe the use of cross-industry analogies to increase similar results. Developers at GE took recourse to analogies from other industries like telecommunication and transport while developing the MAC 400. They searched and identified relevant knowledge from non-related fields. For example, they integrated in the MAC 400 compatibility to commercial available mobile phone batteries. It helped not only to reduce the costs of development for GE but also costs of usage for the user; besides ensuring portability of the equipment. Similarly, the MAC 400 was equipped with a printer that is typically used in India to sell tickets in buses in local public transport or in cinema halls. This mass-product with proven utility and robust features (dust & temperature tolerance) could enhance these attributes of the MAC 400 as well (Govindarajan and Trimble, 2012, McGregor and Kripalani, 2008, Ramdorai and Herstatt, 2013).

The examples above confirm that the use of inventive analogies can increase process efficiency, e.g. reducing development time, in frugal innovation projects.

4.4 Effects of inventive analogies on development costs

In all the products examined in this study the usage of analogies led to a significant reduction in the costs of development. Use of cross-industry analogies enabled GE's developers to reduce costs by 90% while allowing new features like portability. Similarly, the development of the Tata Ace would not have been possible for one-tenth of costs in comparable projects without taking recourse to the various within-industry analogies described in section 4.3.

This can be demonstrated using the case of the Nano as one detailed example. The development team of the Tata Nano extensively explored possible use of analogies from TML's own commercial vehicles division as well as from the 2-wheeler and 3-wheeler industries to reduce the Nano's costs (Chacko et al., 2010, Freiberg et al., 2011). In words of Freiberg et al (2011: 48), it was "the cost imperative [that] drove the design team to keep looking for solutions coming out of the world of scooters".

From the very beginning options were explored to use engineering plastics and other new materials from the chemical industry instead of steel (Freiberg et al., 2011) to reduce development and manufacturing costs. According to Chacko et al (2010: 6):

"There was a host of ideas flying about, […] among them a car created by engineering plastics and new materials, the use of aerospace adhesives instead of welding, and making one part perform multiple functions."

Various external partners from several industries brought in their know-how in the development of the Tata Nano. Especially some chemical firms worked very closely with TML to enable fundamentally new solutions. The examples above endorse the proposition that frugal innovators employ inventive analogies to reduce development costs.

5. Conclusion

Successful frugal innovations usually can be characterized as breakthrough innovations. Traditional approaches of product development for emerging economies have built upon stripping down of features or replacing high quality material with cheaper substitutes. These practices are generally insufficient to reach radically reduced cost structures while at the same time ensuring robustness, user friendliness and a good-enough quality.

The results of this study show that development teams are willing to follow untrodden paths in order to create successful frugal products targeted at highly price-sensitive customers. Strict target costing objectives in conjunction with inspirations derived from conceptual solutions and/or proven technologies from other industry domains can enable frugal innovators to achieve the conflicting development goals of "affordable excellence". Hence, inventive analogies seem to be essentially important in the development process of frugal products.

The cases analysed in this study deliver some valuable insights for intentional and systematic use of inventive analogies in frugal innovation projects. The research model and the interdependences presented in Figure 1 seem to have been confirmed by our case studies. Altogether three propositions for product development in emerging economies can be derived:

• Actively and systematically searching for inventive analogies in other industry domains is an essential step to the successful development of frugal innovations.

• The openness of the management as well as of the development team towards external solutions from other domains is a necessary premise to find and apply inventive analogies for frugal products.

• Inventive analogies, especially cross-industry analogies but also within-industry analogies, can substantially reduce development costs and time.

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Generally speaking, it seems recommendable that firms aspiring to serve unsaturated, price-sensitive markets of emerging economies should make systematic use of inventive analogies for developing products that have a better fit to market demand. These products would be characterized not only by their affordability but also by a high value proposition enabled by radically new innovations. For analogy research, too, there seems to be a potentially significant insight from the frugal context: The willingness of product developers to systematically search and effectively utilise external solutions, especially from non-related industry domains, appears to correlate with the level of resource constraints. Moreover, the use of inventive analogies does not have to be restricted to the ideation phase. The cases analysed here provide preliminary evidence that the use of analogies can extend to product development and market introduction phases.

Finally, it may be noted that the results of this study are based upon three case studies of successful frugal products from India. Therefore the findings are based upon qualitative analyses from a rather small sample and still need to be verified in different contexts. Further research should explore the phenomenon of inventive analogies in a greater variety of frugal development cases. Additionally, it would be interesting to deepen insights of the process of analogy-usage by conducting specific interviews with involved engineers.

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