

Towards a design for frugal: Review of implications for product design.

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Abstract: Since 2010 the concept of frugal innovation has increasingly attracted the attention of both researchers and industry. Frugal innovation holds much promise in the rapidly changing global economy. It has been suggested that this approach needs to be understood by product designers in order to integrate it into product development and bring frugal products into the market place. This research aims to review the current literature on frugal innovation and identify characteristics and methodologies for designing frugal products that has been proposed until now. Our review has analysed 28 journal articles. The results have found 10 design principles and 2 design methodologies that have been developed to achieve frugal products. More research has to be carried out to relate these methods with product development theories and understand the impact for product design practice.

Keywords: *Frugal innovation, resource-constrained innovation, product design, resource-constrained product development*

1. Introduction

In the past four years, the phenomenon of Frugal Innovation (FI) has been brought to wider attention. In 2010, the Economist presented a special report on innovation in emerging markets, showing the disruptive economic potential of frugal innovation for both developing and developed countries¹. Similarly the interest for this kind of innovation has increased in the scientific community and particularly in the fields of management and innovation studies where many authors have analysed several successful examples in various areas such as medical products, telecommunications, healthcare, energy, music instruments, personal care, consumer electronics, transportation, house-ware and education.²

¹ "The World Turned Upside Down," *Economist* (2010).

² Balkrishna C. Rao, "How Disruptive Is Frugal?," *Technology in Society* 35, no. 1 (2013); Marco B. Zeschky, Stephan Winterhalter, and Oliver Gassmann, "From Cost to Frugal and Reverse Innovation: Mapping the Field and Implications for Global Competitiveness," *Research-Technology Management* 57, no. 4 (2014).

The growing importance of frugal innovation is highlighted in many studies³. The reasons for its raising have been identified in phenomena such as the climate change, loss of bio-diversity, scarcer resources, increasing aspiration to a high standard of living among the huge working class of emerging economies, the increasing world population, tenacity of emerging economies entrepreneurs⁴ and the de-growth of developed countries⁵.

This paper carries out a literature review to identify the main studies on frugal innovation, the current knowledge on the topic, the main implications for product design and the future research directions.

2. Methodology

The studies included in this review were identified primarily from four databases which were considered to be relevant to usability evaluation: 1) Web of Science, 2) IEEE-IET Electronic Library, 3) Scopus, 4) Science Direct, 5) Zetoc, 6) Emerald Insight, and 7) ProQuest. The term 'Frugal innovation' was used to perform the search. The broad search term ensured that no pertinent studies were overlooked. Only studies in English that were published beyond the year 2000 and allowed a full-text access from the University of Nottingham Ningbo were considered. It should also be noted that only studies that contained propositions for frugal innovation and its synonyms in a specific domain were included.

The collected paper were then analysed and coded with Nvivo.

For each study that was included in the review, we identified the five themes as follows:

1. The different terminologies used to define Frugal innovation
2. The definition of frugal innovation
3. The characteristics of frugal products
4. The design principles for frugal innovation
5. The design methodologies for frugal innovation

Findings

Figure 1 provides a flow chart documenting the results of the study selection process, which resulted in the inclusion of a total of 30 studies (based on 116 articles) in this review. Appendix 1 and 2 provides an overview of all of the reviewed studies.

³ N. Agarwal and A. Brem, "Frugal and Reverse Innovation - Literature Overview and Case Study Insights from a German Mnc in India and China" (paper presented at the Engineering, Technology and Innovation (ICE), 2012 18th International ICE Conference on, 18-20 June 2012 2012); Gopalkrishnan R. Iyer, Peter J. LaPlaca, and Arun Sharma, "Innovation and New Product Introductions in Emerging Markets: Strategic Recommendations for the Indian Market," *Industrial Marketing Management* 35, no. 3 (2006); Kevin Zheng Zhou, "Innovation, Imitation, and New Product Performance: The Case of China," *ibid*; Arun Sharma and Gopalkrishnan R. Iyer, "Resource-Constrained Product Development: Implications for Green Marketing and Green Supply Chains," *ibid*.41, no. 4 (2012).

⁴ Rao, "How Disruptive Is Frugal?."

⁵ *Ibid. ibid.*

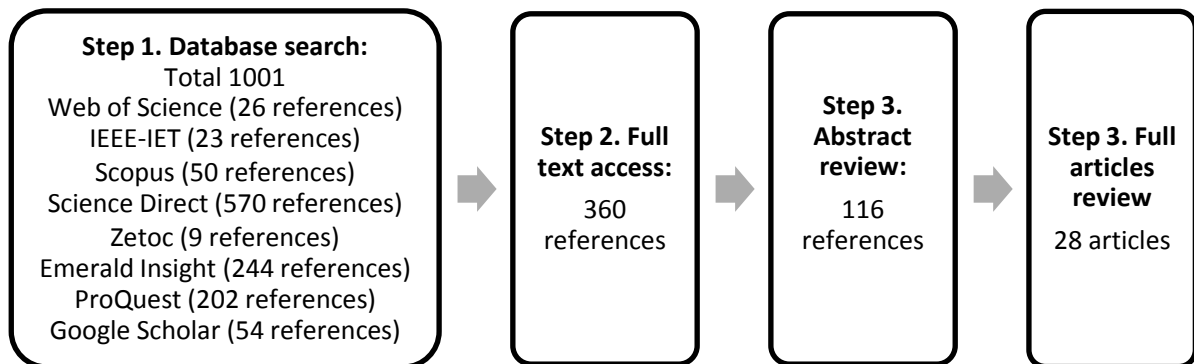


Figure 1. The results of articles selection process

The growing interest for this topic of research can be seen from a search of the keyword ‘frugal innovation’ on the database ScienceDirect. The search reports that during the years 2012-2014, the number of scientific publications on this topic has increased constantly and rapidly (Table 1) from 31 in 2010 to 93 in 2014.

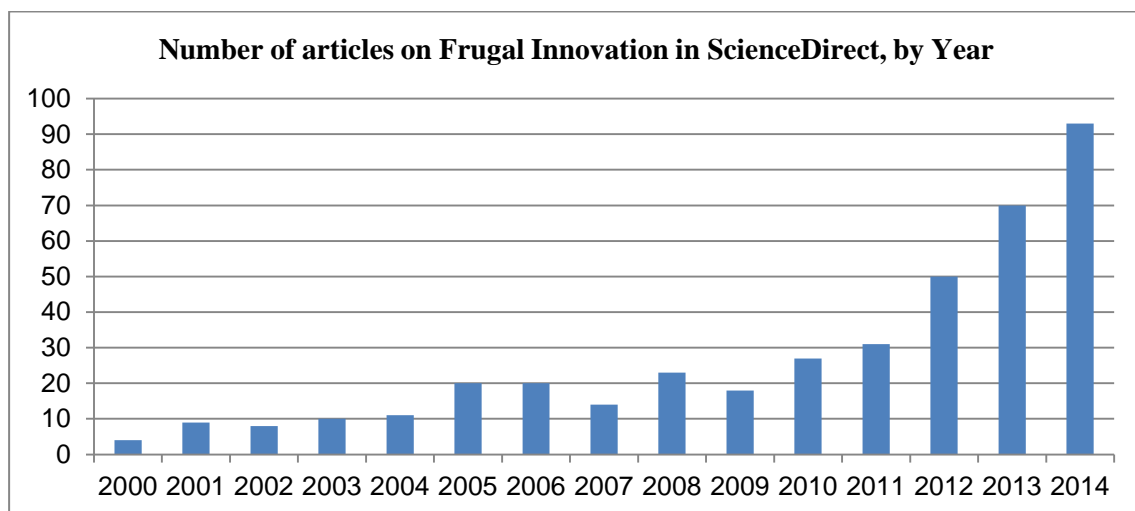


Table 1 Number of publications on frugal innovation in ScienceDirect

This interest could be explained by the rising importance of emerging markets and their innovation centres due to large market size⁶, growing demands, plentiful of R&D talent⁷ and entrepreneurial spirit⁸ of their companies⁹.

⁶ Zeschky, Winterhalter, and Gassmann, "From Cost to Frugal and Reverse Innovation: Mapping the Field and Implications for Global Competitiveness; Thomas Birtchnell, "Jugaadas Systemic Risk and Disruptive Innovation in India," *Contemporary South Asia* 19, no. 4 (2011); Arpita Agnihotri, "Low-Cost Innovation in Emerging Markets," *Journal of Strategic Marketing* (2014); Richard T. Watson, K. Niki Kunene, and M. Sirajul Islam, "Frugal Information Systems (Is)," *Information Technology for Development* 19, no. 2 (2013); Chaisung Lim, Seokhee Han, and Hiroshi Ito, "Capability Building through Innovation for Unserved Lower End Mega Markets," *Technovation* 33, no. 12 (2013); Iyer, LaPlaca, and Sharma, "Innovation and New Product Introductions in Emerging Markets: Strategic Recommendations for the Indian Market." Rainer Quitzow et al., "The Concept of "Lead Markets" Revisited: Contribution to Environmental Innovation Theory," *Environmental Innovation and Societal Transitions* 10(2014).

⁷ Agarwal and Brem, "Frugal and Reverse Innovation - Literature Overview and Case Study Insights from a German Mnc in India and China."

This trend has been seen at the same time beneficial and threatening for developed countries¹⁰. Looking at the positive aspects, the development of low-cost product and services, especially in the healthcare sector, can have a substantial beneficial effect, especially in European countries¹¹ which are experiencing a reduction of financial resources due to the 2008 financial crisis. The key issue for those governments is to find innovative solutions that can ensure a high quality of the welfare state with decreased resources.

3. What is frugal innovation?

There is still no agreement amongst the scientific community on the specific terminologies which should be used to define frugal innovation and the specific definition of frugal innovation is widely debated in the literature. The authors have found 19 different sets of terminology used to define frugal innovation¹² (Please refer to table 1). The debate is not focused on the key characteristics of the phenomenon, which are generally agreed, but on the boundaries of frugal innovation in relation to other forms of low-cost innovation¹³ such as cost innovation, Jugaad innovation and good-enough innovation.

Terminology adopted for frugal innovation

Catalytic innovation¹⁴
Constraint-based innovation
Cost innovation
Low-cost innovation
Disruptive innovation
Entrepreneurial bricolage¹⁵
Frugal engineering¹⁶
Indigenous innovation
Ghandian innovation
Good-enough innovation
Grassroots innovation
Jugaad innovation¹⁷
Resource-constrained innovation
Resource-constrained product development

⁸ Sharma and Iyer, "Resource-Constrained Product Development: Implications for Green Marketing and Green Supply Chains; Gopalkrishnan R. Iyer, Peter J. LaPlaca, and Arun Sharma, "Innovation and New Product Introductions in Emerging Markets: Strategic Recommendations for the Indian Market," *ibid.*35, no. 3 (2006).

⁹ Björn Ivens Alexander Brem, "Do Frugal and Reverse Innovation Foster Sustainability Introduction of a Conceptual Framework.Pdf," *Journal of Technology Management for Growing Economies* 4, no. 2 (2013); C.C. Hang, Chen, J. and Subramian, A.M., "Developing Disruptive Products for Emerging Economies: Lessons from Asian Cases," *Research-Technology Management* 53, no. 4 (2010).

¹⁰ M Howard, "Will Frugal Innovation Challenge the West?," *Market Leader Quarter* 3(2011).

¹¹ Jacqueline W DePasse and Patrick T Lee, "A Model for 'Reverse Innovation' in Health Care," *Globalization and Health* (2013).

¹² Alexander Brem, "Do Frugal and Reverse Innovation Foster Sustainability Introduction of a Conceptual Framework.Pdf; CM Christensen, Baumann, H, Ruggles, R, & Sadtler, TM., "Disruptive Innovation for Social Change," *Harvard Business Review* 84, no. 12 (2006).

¹³ Agarwal and Brem, "Frugal and Reverse Innovation - Literature Overview and Case Study Insights from a German Mnc in India and China."

¹⁴ Christensen, "Disruptive Innovation for Social Change."

¹⁵ Sandeep Salunke, Jay Weerawardena, and Janet R. McColl-Kennedy, "Competing through Service Innovation: The Role of Bricolage and Entrepreneurship in Project-Oriented Firms," *Journal of Business Research* 66, no. 8 (2013).

¹⁶ John Satish and Ketan Thakkar, "Frugal Engineering Is Fine, but Not Jugaad, Says Anand Mahindra [Interviews]," *The Economic Times (Online)*, 2012 Apr 13 2012.

¹⁷ V. Gupta, "An Inquiry into the Characteristics of Entrepreneurship in India," *Journal of International Business Research, Special Issue 1* 7, no. 51 (2008).

Reverse innovation¹⁸
Scarcity-induced innovation
Trickle-up innovation
User-centred innovation
Value innovation

Table 2 A list of different terms used as synonymous of frugal innovation.

In this paper; we considered 3 definitions of frugal innovation. Tiwari and Herstatt for instance define 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 reducing the cost of ownership while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards*”¹⁹. In the other hand, Gupta states that “*frugal innovation is a new management philosophy, which integrates specific needs of the Bottom of Pyramid (BoP) markets as a starting point and works backward to develop appropriate solutions that may be significantly different from existing solutions designed to address needs of upmarket segments*”²⁰. Bound and Thornton wrote that: “*Frugal innovation responds to limitations in resources, whether financial, material or institutional, and using a range of methods, turns these constraints into an advantage. Through minimising the use of resources in development, production and delivery, or by leveraging them in new ways, frugal innovation results in dramatically lower-cost products and services. Successful frugal innovations are not only low cost, but outperform the alternative, and can be made available at large scale. Often, but not always, frugal innovations have an explicitly social mission.*”²¹

Among these 3 definitions, we found that Tiwari-Herstatt and Bound-Thornton have very similar elements; in contrast Gupta’s definition presents a complete different viewpoint. Both Tiwari-Herstatt and Bound-Thornton define frugal innovations using three characteristics. The first characteristic is that frugal innovations minimize the amount of resources consumed in the all the stages of the product life cycle, from the conception to the final disposal. The meaning of resources is very wide and considers not only material resources, but also financial and institutional resources. The second characteristic is the realisation of low-cost products, both in terms of purchase price than in terms of cost of exercise. The third characteristic is the attainment of the same or better functionalities compare to standard products. The only difference we found between Tiwari-Herstatt and Bound-Thornton definitions is the emphasis of the Bound-Thornton definition on the condition of lack of resources as advantage for generating innovative solutions.

On the other hand, Gupta’s definition has a different viewpoint that focuses on the target market. In this definition, frugal innovation is considered a method that aims to develop products for the base of the pyramid consumers. Despite Gupta does not mention other characteristics, we identified a possible relation in these three definitions. If we consider that base of pyramid consumers have a disposal income of less than 2 dollars per day,

¹⁸ PF Nunes, & Breene, TS., *Jumping the S-Curve: How to Beat the Growth Cycle, Get on Top, and Stay There*, ed. Harvard Business Review Press (Harvard2011).

¹⁹ Rajnish Tiwari and Cornelius Herstatt, "Assessing India's Lead Market Potential for Cost-Effective Innovations," *Journal of Indian Business Research* 4, no. 2 (2012).

²⁰ Bindu Gupta, "A Comparative Study of Organizational Strategy and Culture across Industry," *Benchmarking: An International Journal* 18, no. 4 (2011).

²¹ Kirsten Bound and Ian Thornton, "Our Frugal Future: Lessons from India’s Innovation System," (Nesta Operating Company, 2012).

they can only purchase products which fulfil their needs in the most cost-effective way. The most cost-effective way to fulfil those needs involves, this is our assumption, the consumption of minimum amount of resources. Therefore, we can say that frugal innovation develops product-service systems or technologies that realise functionalities at the minimum cost. Ramani and Vivekanada also add that frugal innovation goes further, by realising functionalities at the minimum cost, frugal innovation also increases the livelihood and competences of base of pyramid users²².

Features of frugal products

Another key question is how to achieve frugal innovation. Analyzing the literature we tried to identify the factors that define a frugal product, the design principle that have to be used to design frugal products and the design methodologies that have been developed for frugal innovations.

Among our literature review, two authors have proposed a list of features to characterize and classify frugal products. Rao created a list of 13 product features by reviewing 30 examples of frugal innovations. These features are: lower cost, sophisticated technology, easy to use, Independent business team, portable, start-up, simple technology, robust, large-scale outsourcing, zero maintenance cost, zero energy consumption, sustainability and economies of scales. Where, simple technology means any or combinations of simple design, low part count, ease of assembly and other features. While, sophisticated technology entails the use of cutting edge technologies to make frugal products. Lastly, sustainable design refers to the reuse of existing components.²³ Some of these features such as independent business team, start-up, large-scale outsourcing and economy of scale are related to the structure or the R&D or business organization that developed the frugal product and not directly to the design of the product itself. The other 10 features lower cost, sophisticated technology, easy to use, portable, simple technology, robust, zero maintenance cost, sustainable design and zero energy consumption, are characteristics that are the direct result of design decisions and methods.

Zeschky also created a list of characteristics for classifying products made with cost innovation, good-enough innovation and frugal innovation approaches. The author identifies 13 typical traits such as: cost-effective raw materials, local sourcing, local production, standard components, commodities, smaller package sizes, limitation to core features, less automation, high robustness, high ease of use, reduction of size, new applications (e.g., portability) and tailored for environments with poor infrastructures. Also in this case, there are feature related to the production stage such as local sourcing and local production which could be considered as not directly to the design stage. The other 11 traits instead cost-effective raw materials, standard components, commodities, smaller package sizes, limitation to core features, less automation, high robustness, high ease of use, reduction of size, new applications (e.g., portability) and tailored for environments with poor infrastructures could be considered as the direct result of design decisions.

Table 3 Comparison of features in frugal products

<i>Rao</i>	<i>Zeschky</i>
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²² Shyama V. Ramani and Vivekananda Mukherjee, "Can Breakthrough Innovations Serve the Poor (Bop) and Create Reputational (Csr) Value? Indian Case Studies," *Technovation* 34, no. 5–6 (2014).

²³ Rao, "How Disruptive Is Frugal?."

Design features	Lower cost	Cost-effective raw materials
	Sophisticated technology	Smaller package sizes
	Easy to use	High ease to use
	Portable	New application (e.g., portability)
	Simple technology	Less automation
	Robust	High robustness
	Zero maintenance cost	Commodities
	Zero energy consumption	Reduction of size
	Sustainability	Standard components
		Limitation to core features
Production features		Tailored for environments with poor infrastructure
	large-scale outsourcing	Local production
	Independent business team	Local sourcing
	economies of scales	
	start-up	

The comparison between Rao and Zeschky features, highlights 5 common features, lower cost-cost-effective raw materials, easy to use-high ease to use, portable-new application, robust-high robustness, sustainability-standard components. While other 10 features are mentioned only by one of the authors: sophisticated technology, smaller packaging sizes, new application, simple technology, less automation, zero maintenance cost, commodities, zero energy consumption, reduction of size, limitation to core features, tailored for environments with poor infrastructure. Finally, 6 features are related to production: large-scale outsourcing, local production, independent business team, local sourcing, economies of scale and start-up.

Design principles for frugal

In our analysis of the literature, we isolated 7 design principles that were used in combination or alone to design frugal innovations. These principles are: minimal use of resources, integrating bottom of the pyramid consumer in the design process, frugal mindset, design to cost, combination of basic technologies, elimination of unnecessary functions and innovation on a system perspective. We discuss these approaches below.

Minimal use of resources

As mentioned by the definitions of frugal innovation that we analyzed, one of the main principles that leads to frugal innovation is the minimal use of resources. Rao for instance states that the adoption of frugality involves design principles that ensure a minimal use of resources for realizing efficient functioning of products. Other than minimal amounts of raw materials, the economizing of resources would also involve the reuse of components and simpler designs that result in products without extra accessories.²⁴ The Economist also describes frugal as “*being sparing in the use of raw materials and their impact on the environment.*”²⁵ Thornton goes further and says that methods and techniques involved in creating frugal innovations respond to limitations in resources, whether financial, material or institutional, and turns these constraints into an advantage. This

²⁴ Ibid.

²⁵ "The World Turned Upside Down."

minimization of resources can also be achieved in different stage of the product life cycle or by control them in new ways, also a drastic reduction of cost can be achieve.²⁶

Integrating base of the pyramid

Throughout our review, one of the principles most cited by the authors to achieve frugal innovation is the understanding and involvement of bottom of the pyramid consumers. Base of the pyramid is an expression used to identify the consumers that live with less than 2 dollars per day.²⁷ Jagtap et al. highlighted how the design process is different when the designers focus on base of the pyramid consumers instead than focusing on the top of pyramid consumers. They conclude that by focusing on the base of the pyramid consumers, designers adopt a more problem-based approach instead than a solution-based approach²⁸. Brabham also advocates the use of crowdsourcing as early step for a frugal design process in order to reveal potentially novel and low-cost ways of providing information in a highly constrained environment and explore ways to take costs and complexity out of existing or proposed systems.²⁹ Srivardhini and Rishiksha not only reinforce the analysis of base of pyramid consumers for the development of frugal product, but they also propose that by analysing the local needs of the base of the pyramid users, companies can succeed in global markets.³⁰

Frugal mindset

Another design principle is what Agnihotri recognises amongst the most important skills required for frugal innovation, what he calls the 'frugal mindset' where resources constrains are not perceived as impediment to research and development, but they are seen as an 'opportunity'³¹. Also Thornton in his definition of frugal innovation identifies this aspect as one of the elements of frugal innovation.³²

Less advanced technologies

Due to resource constraints, innovations developed under a frugal standpoint are often technologically less advanced in comparison to the sophisticated counterparts who have been produced using the traditional techniques of innovation. However, these innovations developed under a frugal standpoint are good-enough to provide the needed functionality for the intended market.³³ Sangeeta also suggests combining existing technologies and embedding them in modular designs;³⁴ while, Agarwal and Brem propose to identify newer ways of using old technologies³⁵

²⁶ Thornton, "Our Frugal Future: Lessons from India's Innovation System."

²⁷ Santosh Jagtap et al., "How Design Process for the Base of the Pyramid Differs from That for the Top of the Pyramid," *Design Studies* 35, no. 5 (2014).

²⁸ Ibid.

²⁹ D.C. Brabham, "Crowdsourcing as a Model for Problem Solving," *Convergence: The International Journal of Research into New Media Technologies* 14, no. 1 (2008).

³⁰ Srivardhini K. Jha and Rishiksha T. Krishnan, "Local Innovation: The Key to Globalisation," *IIMB Management Review* 25, no. 4 (2013).

³¹ Agnihotri, "Low-Cost Innovation in Emerging Markets; ibid.

³² Thornton, "Our Frugal Future: Lessons from India's Innovation System."

³³ Ramani and Mukherjee, "Can Breakthrough Innovations Serve the Poor (Bop) and Create Reputational (Csr) Value? Indian Case Studies."

³⁴ Sangeeta Ray and Pradeep Kanta Ray, "Product Innovation for the People's Car in an Emerging Economy," *ibid.* 31, no. 5-6 (2011).

³⁵ Agarwal and Brem, "Frugal and Reverse Innovation - Literature Overview and Case Study Insights from a German Mnc in India and China."

Design to cost

Another fundamental principle that has been highlighted in our study is the principle of design to cost also called cost innovation. Cost innovation is not a novel concept. There are numerous cases in which low-cost competitors have turned an expensive good into a commodity by drastically reducing costs (e.g., low cost airlines).³⁶ Firms can achieve huge cost reductions through process innovations largely grounded in cost advantages enabled by low labour costs, local sourcing, standardized components, and cost-effective raw material sourcing, as well as scale and efficiency.³⁷ Lim et al. defines the design to cost approach as an innovation process which as the objective to control cost while fulfilling all the functional requirements. The innovation in the reduction of the cost is achieved by a continuous examination of feasibility for a given product concept or design. The authors describe also the process to achieve design to cost. Components with expensive designs has to be eliminated or modified. Examples of this included the elimination of low-value-added functions (e.g. using single wiper instead of two wipers) and reducing the number and size of components (e.g. reducing the number of 100 fasteners), and substitution of cheaper materials (e.g. use of engineering plastics).³⁸ Palepu et al. describe the process used to develop the Tata Nano low cost car. They write that given a strategic price, every assumption about materials, design and manufacturability is questioned and alternative designs found. The cost of the product in development is placed under tight control. Any design that does not reduce cost or forces a raise in the price of the product is rejected and redesigned.³⁹ Agrawal also describes the process used to achieve the Tata Nano. In his description he points the attention to the use of a design for manufacturing approach to cut the cost of production of the components. *“Basically, this means determining how many useful parts there are in the design. We involved the suppliers also in this exercise and they realized that some functions could be integrated in parts. That is how we got some cost benefit”*⁴⁰. Zeschky presenting the case of the Mettler Toledo weighing scale, states that cost reductions can be achieved not only through low-cost manufacturing and materials, but also by incorporating a more basic minimum feature⁴¹. Rao also highlights how in frugal innovation cost cutting has to be built into initial design process of a frugal-innovation, in order to realise products that are cheaper than the cheapest ordinary products.⁴²

Elimination of unnecessary functions

Functions or elements that are not necessary to insure that customers see basic value in the product are eliminated. For example, many mobile phones offer functions going clearly beyond the basic value expectations large customer groups have. By restraining functionalities to the core, fewer resources (material, human,

³⁶ Zeschky, Winterhalter, and Gassmann, "From Cost to Frugal and Reverse Innovation: Mapping the Field and Implications for Global Competitiveness."

³⁷ P. Williamson "Cost Innovation: Preparing for a 'Value-for-Money' Revolution," *Long Range Planning* 43(2010).

³⁸ Lim, Han, and Ito, "Capability Building through Innovation for Unserved Lower End Mega Markets."

³⁹ K. Palepu, Anand, B., Tahilyani, R., "Tata Nano—the People's Car," in *Harvard Business School*, ed. Harvard Business School Case (Harvard, 2010).

⁴⁰ S. Agrawal, Wadia, J., "Tata Nano: The Big Wonder,"

[http://www.tata.com/company/articlesinside/pJI3huSRc!\\$\\$\\$!0=/TLYVr3YPkMU=](http://www.tata.com/company/articlesinside/pJI3huSRc!$$$!0=/TLYVr3YPkMU=).

⁴¹ Marco Zeschky, Bastian Widenmayer, and Oliver Gassmann, "Frugal Innovation in Emerging Markets: The Case of Mettler Toledo," *Research-Technology Management* 54, no. 4 (2011).

⁴² Rao, "How Disruptive Is Frugal?."

logistics, etc.) are required when manufacturing the product.⁴³ For example, the cardiogram developed by General Electric shows that those components which are unnecessary and make a product complex to use shall be removed. Thus, the product can be used by not specialists at a lower price, making it affordable for small hospitals and clinics in remote areas.⁴⁴

Simplification of use

Another key design principle of frugal innovation is the simplification of use. Brem writes that compared to existing products sold on developed markets, frugal innovation aims at creating simpler solutions.⁴⁵ Christensen validates this assumption by saying that frugal innovations are cheaper, smaller, simpler and convenient to use.⁴⁶ Lee also adds that the easy-to-use feature facilitates the adoption of frugal innovations.⁴⁷ Jha and Krishna instead explains the value of simplicity of use in terms of reduction of specialised knowledge needed to operate a product.⁴⁸

Innovation on a system perspective

Brem highlights that in designing a new product in a frugal perspective, companies are able to, but also need to understand that they need to rethink the systems.⁴⁹ In other words, the approach that should be taken when conceiving a new frugal innovation has to be on a product-service system perspective rather focusing only on the product. Also Watson et al. underline the importance of the system perspective over the product perspective.⁵⁰ Especially when conceiving new frugal solutions, they propose to build simplicity on top of complex systems and infrastructure.

Design methodologies for frugal

In our review we have also found two design methodologies for frugal innovation.

The first methodology is proposed by Rao and it is made by three stages. The stages of the methodology are: modelling of functionality, frugal product feasibility and optimization of basic design. Modelling of functionality is based on the traditional design process methods in order to understand the feasibility of undertaking a frugal-innovation process. The outcome is a list of all the factors that influence the functionality of a given product. The second stage called frugal product feasibility examines the viability of developing a frugal version of a given product. Especially this second step infers the impact of frugality on the product functionality. Finally, the third step concerns the optimization of the functionality for a minimum cost by modifying the modifying the

⁴³ Alexander Brem, "Do Frugal and Reverse Innovation Foster Sustainability Introduction of a Conceptual Framework.Pdf."

⁴⁴ Agnihotri, "Low-Cost Innovation in Emerging Markets."

⁴⁵ Alexander Brem, "Do Frugal and Reverse Innovation Foster Sustainability Introduction of a Conceptual Framework.Pdf."

⁴⁶ Christensen, "Disruptive Innovation for Social Change."

⁴⁷ Lee, "A Model for 'Reverse Innovation' in Health Care."

⁴⁸ Jha and Krishnan, "Local Innovation: The Key to Globalisation."

⁴⁹ Alexander Brem, "Do Frugal and Reverse Innovation Foster Sustainability Introduction of a Conceptual Framework.Pdf."

⁵⁰ Watson, Kunene, and Islam, "Frugal Information Systems (Is)."

parameters of the product and by keeping the value constraints such as basic design, production, quality, robustness and ease of use.⁵¹

Another example of a design methodology for frugal innovation is the product development process developed by Siemens for its SMART project⁵². In this methodology, we could identify a combination of three of the design principles above-mentioned. The methodology is made by three phases: need identification, cost reduction and mix & match. Need identification means identifying the core value of the product and is connected with the principle we called '*integrating the base of the pyramid*'. In fact, even if the core idea of this phase does not consider explicitly the integration of the base of the pyramid consumers into the design process, Siemens uses researchers and research centers from developing countries to identify the core values. Cost reduction can be associated to the design to cost method, since this phase is described as a review on how the manufacturing costs can be minimized, for example by using cost-effective materials, new technologies or exploiting synergies during the production process. Finally, the Mix & match phase can be associated with the design principle we called '*less advance technologies*'. Even if, the mix & match stage goes further our method. In fact, Siemens describes this stage as the stage where 'individual components of a solution are assembled, focusing primarily on interactions among individual building blocks, we could observe a similarity with what the idea of combining together basic technologies.'⁵³

Conclusion

Frugal innovation in emerging markets has received increasing attention, but the discussion thus far has lacked a common understanding with regard to the definition of the various types of resource-constrained innovation. As global population continues to grow and lack of resources increases even in developed countries, capabilities for resource-constrained innovation of all types will become key elements for product designers. In this paper we tried to identify the current knowledge on frugal innovation relevant to product design. We started by defining the concept of frugal innovation and the characteristics of frugal products, then we listed the design principles and finally we described two design methodologies for frugal innovation. Our review contributes to a clearer understanding of existing knowledge on design for frugal and thereby provides the grounds for systematic future research. Future studies has to connect the findings with theories and methods of product development, investigate which tools can used to design frugal product and study how a frugal innovation approach can be employed in developed countries.

⁵¹ Rao, "How Disruptive Is Frugal?."

⁵² Agarwal and Brem, "Frugal and Reverse Innovation - Literature Overview and Case Study Insights from a German Mnc in India and China."

⁵³ Ibid.

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- Agarwal, N., and A. Brem. "Frugal and Reverse Innovation - Literature Overview and Case Study Insights from a German Mnc in India and China." Paper presented at the Engineering, Technology and Innovation (ICE), 2012 18th International ICE Conference on, 18-20 June 2012 2012.
- Agnihotri, Arpita. "Low-Cost Innovation in Emerging Markets." *Journal of Strategic Marketing* (2014): 1-13.
- Agrawal, S., Wadia, J.,. "Tata Nano: The Big Wonder."
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