A Bricolage Perspective on Technological Innovation in Emerging Markets

By

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Abstract

Due to endogenous and exogenous constraints, companies from emerging markets often adopt surprising and unconventional strategies for their innovative efforts. Various concepts such as jugaad, frugal, and cost innovation have been coined to describe technological innovations originating from emerging markets. However, the organisational and inter-organisational processes underpinning the development of product innovations in emerging markets remain unclear. Consequently, the practical value of these concepts remains limited in the absence of specific insights and guidelines regarding replicable activities that managers can undertake to achieve cost-driven, innovative outcomes.

Drawing on a qualitative case study of Mahindra Reva, the only electric vehicle producer in India, this doctoral thesis explores how emerging-market firms manage to overcome serious contextual constraints and develop affordable, innovative, high-tech products with minimal capital investments. The study adopts the concept of bricolage to underline firms' capabilities to 'make do' with the resources at hand and recombine them to handle novel problems in difficult contexts.

The thesis contributes to the small but growing body of scholarly literature examining technological innovations in emerging markets. It illustrates how multiple forms of bricolage (i.e. creative recombination of resources, component bricolage, and collaborative bricolage) can be implemented and managed at organisational and inter-organisational levels. The thesis argues that bricolage, which is typically regarded as a behavioural trait or skill that allows entrepreneurs and innovators to operate in challenging environments, can also be a carefully planned and executed strategy conducive to the achievement of jugaad solutions and frugal engineering outcomes in emerging markets. The findings also show how different bricolage

activities relate to different stages of the new product development process and highlight the complementarities between bricolage and engineering activities.

This doctoral thesis further suggests that the analytical scope of the notion of bricolage extends beyond resource-constrained emerging market companies and could help explain the delivery of affordable and innovative products more generally. Thus, it suggests that a cost-effective bricolage strategy can underpin companies' development of discontinuity-creating and market-disrupting technology products. This thesis also provides insights regarding the marketing strategies that can be employed by companies offering disruptive technologies in order to communicate more effectively the benefits of their non-mainstream value proposition.

Finally, in conjunction with extant empirical material regarding the development of other innovative products such as Boeing's 787 Dreamliner and Apple's iPod, the findings presented in this study illustrate a new type of product architecture, which has been disregarded by prior innovation literature.

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Related Publications

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Abbreviations

ABS	Acrylonitrile Butadiene Styrene [Plastic]
BOP	Base-of-the-Pyramid
CAD	Computer-aided Design
CEO	Chief Executive Officer
CMM	Coordinate Measuring Machine
DMNE	Developed-country Multinational Enterprise
EV	Electric Vehicle
HPS	Husk Power Systems
IC	Internal Combustion [Vehicle]
IP	Intellectual Property
IEMS	Intelligent Energy Management System
Li-ion	Lithium Ion [Batteries]
LFI	Long Fibre Injection [Plastic]
M&M	Mahindra & Mahindra
MCC	Micro Compact Car AG
MNE	Multinational Enterprise
MOP	Middle-of-the-Pyramid
MPC	Maini Plastics and Composites
MPP	Maini Precision Products
NH	Narayana Hrudayalaya Heart Hospital
NPD	New Product Development
PC	Personal Computer
R&D	Research and Development

Chapter 1: Introduction

When developed-country multinational enterprises (DMNEs) enter emerging markets[1], they tend to offer products which are similar to those sold in their home markets and end up addressing only a limited stratum of affluent customers with well above average incomes (Ernst et al., 2015; Govindarajan and Ramamurti, 2011). Due to the large differences in per capita income between developed and emerging countries, base-of-the-pyramid or BOP (Prahalad, 2004) and even middle-of-the-pyramid (MOP) customers are often untapped by DMNEs (Ernst et al., 2015, Govindarajan and Ramamurti, 2011). Moreover, emerging market customers seem to exhibit a deep distrust regarding large Western corporations (D'Andrea et al., 2010) and tend to remain loyal to local customs and brands (Prahalad and Lieberthal, 2003). Translating these observations into figures, a McKinsey report has shown that DMNEs are deriving only 17% of their revenues from emerging markets, although emerging market countries generate 36% of the global GDP (Atsmon et al., 2012). Thus, emerging market customers are often served by local emerging market firms (Ernst et al., 2015).

In order to develop products that address the requirements of local consumers, emerging market firms employ innovation practices that appear surprising and unusual from the perspective of extant management theory (Ernst et al., 2015; Govindarajan and Ramamurti, 2011). Research hints at two possible reasons. First, companies from emerging markets may not always possess the resources or capabilities required for the pursuit of technology innovations (see Prahalad and Mashelkar, 2010; Sharma and Iyer, 2012). Second, even if emerging market companies had such resources, they might find it counterproductive to engage in high-budget research and development (R&D) processes as the resulting products may turn out to be too expensive for their customers. Thus, extant management theories, which are based

[1] By 'emerging markets' we broadly refer to rapidly growing countries, which are struggling with inefficient and less than robust institutional infrastructures. Emerging markets include countries like Brazil, Russia, China, India, South Africa, Turkey, Indonesia and Mexico.

almost exclusively on empirical evidence from advanced economies, are inadequate for explaining developments in emerging markets (e.g. Ernst et al., 2015; Subramaniam et al., 2015; Xu and Meyer, 2013) and new theoretical frameworks are required to fully understand how the innovation process is managed in emerging markets.

In recent years, several emerging market companies have entered the fray with potentially disruptive product innovations such as Tata Nano – the ultra-affordable car, sold for approximately $2,000 (Ray and Ray, 2011) and ChotuKool – the portable refrigerator developed by Godrej & Boyce to address the needs of customers in rural India where the electricity supply is unreliable (Eyring, 2011). Such emerging market companies are paring down mature technologies to develop simpler and more affordable innovative products that serve the same practical purposes as those developed by DMNEs. Other companies such as the Chinese manufacturer of rechargeable batteries BYD (Zeng and Williamson, 2007) and computer makers Dawning (Williamson and Zeng, 2008) and Lenovo (Wan et al., 2015) are providing top performance levels at lower costs than their DMNE competitors. Such Chinese "dragons" often rely on readily available, off-the-shelf parts and components which they creatively combine to develop high-spec products (Zeng and Williamson, 2007). Moreover, some emerging market innovators are developing an entirely new wave of "affordable" products in areas such as regenerative medicine (McMahon and Thorsteinsdottir, 2013) and electric vehicles (the focus of this doctoral study), which feature cutting-edge technologies and represent discontinuities (i.e. the extant capabilities within the industry are not sufficient for the development of such new wave products) for established industries. Regardless of the strategy employed, all these firms intend to tap into the growing consumption in developing countries, which is predicted to create a market of US$ 30 trillion by 2025 (Atsmon et al., 2012).

Firms from emerging markets typically face contextual constraints which can be endogenous and exogenous in nature. The endogenous constraints refer to the limited material and financial resources possessed by most emerging market firms (see Cunha et al., 2014). Due to inefficient financial markets and reduced availability of venture capital (Dhanaraj and Khanna, 2011; Khanna and Palepu, 2010), many emerging market firms must make do with internally generated resources. The exogenous constraints are related to the limited incomes of local BOP-MOP customers which are usually targeted by emerging market firms. As these customers tend to be very price-sensitive, the profit margins of the emerging market firms serving them are generally very thin (see Cunha et al., 2014). Scholarly research is only beginning to explore and explain how despite a slew of such debilitating constraints, emerging market firms are able to develop innovative products at relatively low costs. To capture the essence of these innovative products, new terms have been coined. For example, the term "jugaad" (Radjou et al., 2012) has been used to describe improvised, makeshift artefacts that successfully serve the purpose for which they were created. Frugal innovation (e.g. Kumar and Puranam, 2012; Zeschky et al. 2011) denotes products developed with minimal resources in order to meet the cost requirements of emerging market customers. Similarly, cost innovation refers to the development of low(er)-cost products which incorporate high-end technology (Williamson and Zeng, 2008; Williamson, 2010). In some ways, such terms are back-handed compliments. They praise the companies' product innovation capabilities, but at the same time raise questions about the quality of the products. In addition, these concepts seem to focus on artefacts, products, and outcomes. The bodies of literature surrounding these concepts rarely provide insights regarding replicable processes which could be implemented by innovating companies to achieve the desired outcomes.

To date, very few studies have opened the 'black box' of emerging market innovations and explored in detail the organisational and inter-organisational processes underpinning the development of frugal and low-cost innovations. Thus, our main research question can be articulated as follows: How do emerging market firms manage to overcome contextual (i.e. endogenous and exogenous) constraints and develop innovative, cost-effective and potentially disruptive products? In order to address this question, we draw on the literature on bricolage (Baker and Nelson, 2005; Levi-Strauss, 1966). The notion of bricolage has its roots in anthropology and is unusual and somewhat counter-intuitive in that it demonstrates how deviation from established practices can help foster cutting-edge technological innovation. Further, it illuminates how highly-pragmatic strategies are enacted in practice (see Ray and Ray, 2011; Eyring, 2011). The bricolage theoretical lens is particularly relevant to emerging markets because it draws attention to firms' capabilities to make do with the resources at hand and recombine them to handle novel problems in difficult contexts. In particular, it provides rich insights into the processes underpinning the achievement of what has been termed by practitioners and scholars as jugaad solutions (Radjou et al., 2012) and frugal engineering outcomes (Kumar and Puranam, 2012) in emerging markets.

This doctoral thesis builds on a qualitative case study of Mahindra Reva, India's sole electric vehicle (EV) manufacturer and explains the complexity and sophistication of the innovation process in emerging markets under an overarching bricolage framework. The thesis illustrates multi-dimensional bricolage-based processes and demonstrates how a creative recombination of resources in tandem with component bricolage and collaborative bricolage helps manage the technology innovation process in resource-constrained emerging markets. The Mahindra Reva context also allows us to discuss how bricolage processes may address the challenges posed by "one of the most vexing innovations of our day: the electric vehicle" (Christensen, 1997; p. 159). In the face of alarming air and noise pollution levels in urban areas and fluctuating prices of conventional fuels, EVs are emerging as a viable mobility solution and a possible alternative to internal combustion (IC) cars (see Barkenbus 2009, Klenner et al.

2013, Zimmermann et al. 2012). EVs promise immunity from ever increasing fossil fuels costs, cleaner and pollution-free transportation, and significant financial and strategic benefits for automakers. However, EVs have, thus far, failed to disrupt the global automobile market as predicted by Christensen (1997) almost 20 years ago. The main reason behind this failure is the customers' refusal to pay a price premium for a novel technology that remains inferior to IC vehicles in terms of top-speed and driving-range (ETI, 2011). This suggests that, thus far, EV producers have failed to achieve the price-performance balance demanded by mainstream consumes. Having a strong focus on cost reductions as a consequence of endogenous and exogenous constraints, companies from emerging markets, not unlike the Japanese automakers a few decades ago, may in fact stand a better chance of offering sustainable EV-based mobility solutions (see Hart and Christensen 2002, Ray and Ray 2011).

Thus, this thesis adds to the small, but growing body of scholarly literature exploring emerging market innovations and proposes bricolage as a conceptual framework capturing the organisational processes and strategies of resource-constrained indigenous companies. The study also shows how bricolage strategies can be particularly relevant in the case of discontinuous and disruptive innovations where the technology is in its infancy and the market is ill-defined, leading companies to embark on an iterative market testing process involving the launch of various versions of the product. In this sense, we suggest that the analytical scope of the notion of bricolage extends beyond resource-constrained emerging market companies and could help explain the delivery of affordable and innovative products more generally.

This introductory chapter has outlined the objectives and generic context of this doctoral thesis. The remainder of the thesis is structured as follows: the next chapter provides a comprehensive review of the bricolage literature as well as a summary of relevant themes in the field of innovation. The last section of the second chapter shows why bricolage is an appropriate theoretical lens for exploring the process of technological innovation in emerging markets.

Having presented the theoretical background informing our research endeavour, the third chapter presents the philosophical underpinnings, research methodology, and empirical design of the study. The third chapter introduces Mahindra Reva, the company providing our research setting. We chose to study Mahindra Reva given its highly interesting and atypical profile. Despite being a small (i.e. less than 400 employees) indigenous company, it has managed to produce competitive EVs for almost two decades.

The fourth chapter presents our findings organised around the seven central themes emerging from our data analysis. The first three themes are related to various types of bricolage which seem to underpin technological innovations in emerging markets. The remaining themes refer to the techniques used to implement and manage bricolage on an organisational level, the relationship between bricolage and engineering, the role of the Indian culture in the successful deployment of bricolage strategies, and the company's resource-constrained attempt to advertise and promote its disruptive products using exclusively social media channels.

The penultimate chapter provides a discussion of our findings and underscores our main contributions, the implications for practitioners, the limitations of our study, and possible directions for future research. The final chapter summarises this thesis and provides some concluding remarks.

Chapter 2: Literature Review

2.1 Bricolage

Bricolage finds mention in a diverse range of settings. It has been used to explore and explain aspects of entrepreneurship and resource creation (Baker and Nelson, 2005; Di Domenico et al., 2010; Garud and Karnoe, 2003), development and utilization of information technology artefacts (Lanzara, 1999), organisational resilience and improvisation (Baker et al., 2003; Weick, 1993), education and academic performance (Hatton, 1989), jurisprudence and creation of new laws (Hull, 1991), genetics and biological evolution (Duboule and Wilkins, 1998; Jacob, 1977), musical instrument manufacturing (Smith and Blundel, 2014), French gastronomy (Rao et al., 2005).

2.1.1 Bricolage in anthropology

The notion of bricolage goes back to the work of French anthropologist Claude Levi-Strauss (1966) who proposed two modes of thinking – the mythical and the scientific. In order to better explain the scientific-mythical distinction, Levi-Strauss (1966) invoked an imagery of two opposing figures - the engineer and the bricoleur. The former stands as an analogy for scientific reasoning, while the latter represents mythical thought. The engineer attempts to design an optimal solution for problems, while the bricoleur solves problems by relying exclusively on “whatever is at hand” (Levi-Strauss, 1966; p. 17). The bricoleur is someone who works with his hands and uses, often out of compulsion, “devious” or unorthodox means compared to those of a craftsman or engineer (Levi-Strauss, 1966; p. 16). The bricoleur expresses himself within the confines of a finite repertoire of tools and resources (Levi-Strauss, 1966). Explaining the nature of his analogy, Levi-Strauss (1966) stated that “mythical thought is a kind of intellectual bricolage” (p. 17).

The mythical thought does not denote primitive or archaic reasoning, but rather refers to the “untamed state as distinct from mind cultivated or domesticated for the purpose of yielding a return” (Levi-Strauss, 1966; p. 219). The main characteristic of the untamed mind is the continuous gathering of information, which is stored in “a memory bank” (p.16) and applied whenever that knowledge proves useful (Levi-Strauss, 1966). As an illustration, Levi-Strauss, who based his theory on empirical studies of various aboriginal populations, pointed to the Coahuila Indians. Despite living in a desert region in South California, this Native-American tribe “lived in a land of plenty, for in this apparently completely barren territory, they were familiar with no less than sixty kinds of edible plants and twenty-eight others of narcotic, stimulant or medicinal properties” (Levi-Strauss, 1966; p. 5). The French anthropologist also argued that resources are not known to us due to their usefulness, rather they can prove useful because they are known in the first place (Levi-Strauss, 1966; p. 9). Therefore, the criteria underlying the classification and systemising of information by the untamed or mythical mind can never be established in advance or at the time when the piece of information enters the “memory bank”. These principles and purposes of classification are to be discovered “a posteriori […] by experience” (Levi-Strauss, 1966; p. 58). Once established, the structures comprising of classified knowledge and its applicability are preserved and transmitted until the present time through myths and rites (Levi-Strauss, 1966). The classified inventories of knowledge, its applicability, and associated myths and rites comprise what Levi-Strauss (1966) labels as “the science of the concrete” whose results are often different than the results of modern sciences (i.e. natural sciences). However, the results of the science of the concrete are “no less scientific and […] no less genuine” (p. 16). In fact, these results were obtained some ten thousand years earlier and represent “the basis of our own civilization” (Levi-Strauss, 1966; p. 16).

The science of the concrete produced by the savage, untamed mind and the modern science are not mutually exclusive (Levi-Strauss, 1966). They can co-exist and can be related one to another just like, in the realm of nature, some species in their savage, "spontaneous" state co-exist and are intertwined with others which were transformed by agriculture or domestication (Levi-Strauss, 1966; p. 219). However, the differences between the two modes of thinking can be significant and are similar in nature to those between engineering and bricolage. Both the engineer and the bricoleur are able to perform a large number of tasks and solve a wide variety of problems. Nonetheless, while an engineer's actions are inextricably dependent on the availability of raw materials and tools designed and procured for a specific project, the bricoleur makes do with whatever he can find in his finite set or repertoire of resources. If for an engineer there can be as many "instrumental sets" (i.e. specialized tools and resources) as there are projects, for the bricoleur there is always only one set of heterogeneous resources which have no relation to any particular project (Levi-Strauss, 1966; p. 17). The differences in resource availability impact the scopes of the engineer's and bricoleur's activities. The engineer "questions the universe, while the bricoleur addresses himself […] only to a sub-set of the culture" (Levi-Strauss, 1966; p. 19). Thus, the mythical mind is constrained by the limited number of events and experiences it classifies and adds to the "memory bank", but it is also "liberated" from the idea that "anything can be meaningless" (Levi-Strauss, 1966; p. 22). For the savage, mythical mind everything has meaning, it is just a matter of searching and identifying the meaning or purpose for every element within the repertoire (Levi-Strauss, 1966). It is this willingness to search for meaning that allowed the Coahuila Indians mentioned earlier to adapt to and survive in an otherwise barren and unfriendly environment.

2.1.2 Bricolage in entrepreneurship

This 'making do' with resources at hand, first discussed by Levi-Strauss (1966), reflects a fundamental attitudinal and behavioural trait - an inclination towards action and active tackling of challenges rather than extensive contemplation and evaluation of the situation at hand (Baker and Nelson, 2005).

Baker and Nelson (2005) expanded upon Levi-Strauss' ideas and provided a much richer definition for bricolage. They emphasized two important features of bricolage. First, the person or organisation engaging in bricolage creatively combines the resources at hand and uses them in new contexts or applications, departing substantively from their original or conventional usage. The origins of this idea trace back to Plato who argued that new knowledge can only emerge as a combination of existing knowledge (Kogut and Zander, 1992). Similarly, Schumpeter (1934) claimed that innovation and progress result from combinations of existing resources, while Penrose (1959) suggested that firms possessing similar sets of resources may offer significantly different products and services reflecting their ability to recognize potential uses for and combinations of resources. Attempting to clarify the distinctive features of bricolage, Baker and Nelson (2005) argued that bricoleurs successfully combine and assign value to discarded, unwanted, worn, idle, or otherwise "worthless resources" (p. 362). They also noted that their study focused on extreme cases of "creating something from nothing" and that, in less extreme and penurious environments, bricolage should be taken to mean the achieving of "more from less" (Baker and Nelson, 2005; p. 357). From this broader perspective, which we adopt for this doctoral thesis, *bricolage is the creative and strategic deployment of diverse, generic, nonspecialized resources in novel contexts*.

The second crucial feature of bricolage relates to the bricoleur's refusal to be cognitively constrained by current practices and methodologies (Baker and Nelson, 2005). Weick (1979) argued that restrictions and constraints on behaviour originate from the a priori acceptance of prevailing assumptions and prescriptions which results in a "failure to act" (p. 149), thus preventing actors from testing whether something can actually be achieved. An important characteristic of the bricoleur is the conscious disregard for extant practices and methodologies and the concomitant engagement in a process of experimentation, which continuously tests the limits of the environment (Di Domenico et al., 2010).

Baker and Nelson (2005) also found that the perpetuated reliance on bricolage (referred to by the authors as parallel bricolage) allows firms to survive but stifles organisational growth. The reason is that the outcomes of bricolage are usually hybrid, imperfect artefacts which serve the intended purposes but require significant improvement (Lanzara, 1999). Such outcomes usually represent inexpensive, non-standardized products which do not provide margins for growth to the bricoleur. In fact, the perpetuated reliance on bricolage provides a self-reinforcing pattern as the lack of growth forces the bricoleurs to make do with whatever is at hand, thereby recurrently engaging in bricolage activities (Baker and Nelson, 2005). However, entrepreneurial firms using bricolage selectively (rather than consistently and repeatedly in all aspects of the business) to solve certain problems for which they lack conventional resources are more likely to experience growth (Baker and Nelson, 2005). Thus, the selective use of bricolage at key stages in the life of the organisation followed by a return to prevalent practices and methodologies can support consistent firm growth (Baker and Nelson, 2005).

Effectuation (see Sarasvathy, 2001) and bricolage have been proposed as emerging theories which often describe the behaviours of entrepreneurs (Fisher, 2012). Effectuation and bricolage have been contrasted with causation (Fisher, 2012) which was seen as the embodiment of the more traditional perspective on entrepreneurship (Fisher, 2012; Sarasvathy, 2001). This traditional causal model held that, having identified an opportunity, entrepreneurs seek to find and access the appropriate resources to exploit the perceived opportunity (Fisher, 2012). Under the causal model of entrepreneurship, the intentional exploitation of opportunities previously selected based on extensive calculations of potential returns, strategic planning, and resource acquisition are key stages of the entrepreneurial process (Fisher, 2012). Effectual entrepreneurship, on the other hand, is not directed by a clearly defined goal or an envisioned opportunity, but rather by the set of means or resources accessible to the entrepreneur (Fisher, 2012; Sarasvathy, 2001). Given this set of resources, the entrepreneur selects from a number of goals or outcomes which could be realistically achieved (Sarasvathy, 2001).

Although the theories of effectuation and bricolage have emerged independent of each other, there are important similarities between the two: a) available resources influence the enactment of opportunities; b) an inclination towards action allows the actor (entrepreneur or bricoleur) to overcome resource constraints; c) the customers, suppliers, and generally the community in which the actor operates can often be a source of valuable material resources, ideas, and knowledge; d) the resource constraints often act as catalysts for creativity and innovation (Fisher, 2012). However, while prior studies (e.g. Fisher, 2012) focused on the similarities between effectuation and bricolage, significant differences remains between the two concepts. At the inception of the effectuation process, the actor is driven only by a vague aspiration or desiderate. The actor does not have a clear objective or goal in mind. He but attempts to find out what could be achieved with the skills and resources he possesses. In contrast, the process of bricolage emerges as a result of a clearly defined problem which the bricoleur is trying to solve. Although a crucial activity preceding the bricolage process, namely the creation of the repertoire of resources, is not driven by a precise objective, the bricoleur actively engages in the process of bricolage only when he faces a problem which requires a solution. Another difference between bricolage and effectuation is that the process of bricolage ends when the solution has been found, while with effectuation the actor continues to search for new opportunities to deploy his resources.

2.1.3 Bricolage theory in organisation and management studies

Generally, organisation and management studies discussed the bricoleur and the engineer as ideal-types (Duymedjian and Ruling, 2010). In Weber’s (1997) view, an ideal-typical construct is “formed by the one-sided accentuation of one or more points of view and by the synthesis of a great many diffuse, discrete, more or less present and occasionally absent concrete individual phenomena" (p. 88). The main implication derived from treating bricoleur and the engineer as ideal-types is the acknowledgement that real-life activities are very often a mix between bricolage and engineering and that "pure bricolage" is rarely found in practice (Duymedjian and Ruling, 2010; p. 139).

According to Duymedjian and Ruling (2010), the process of bricolage can be better explained by carefully considering three elements: the repertoire (i.e. the set of resources used by the bricoleur), the dialogue (i.e. the process of assembling components), and the outcome (i.e. the nature of its results). In the original depiction of bricolage, the bricoleur's *repertoire* was finite and closed (i.e. new resources could not be added) (Levi-Strauss, 1966). However, in more recent studies of bricolage, the repertoire is seen as a dynamic construct - the bricoleur continues to acquire and use resources, cutting costs and learning new things along the way (see Baker and Nelson, 2005; Duymedjian and Ruling, 2010). Despite its potentially large volume, the bricoleur has an intimate knowledge of the repertoire based on an exhaustive inventorying of all resources (Duymedjian and Ruling, 2010; Levi-Strauss, 1966). Thus, bricolage is not an occasional activity that is performed every now and then, depending on circumstances. Bricolage is usually a continued process extending over significant periods of time as the collecting of resources and development of an intimate knowledge of what is at hand within the repertoire are complex and lengthy processes (Duymedjian and Ruling, 2010). This idea seems to be at odds with the concept of selective bricolage proposed by Baker and Nelson (2005). The two perspectives can be easily reconciled by observing that Baker and Nelson's (2005) study captured extensive firm histories, sometimes decades long, and the selective bricolage stages often lasted for significant periods of time.

The *dialogue* starts when the bricoleur faces a practical problem. It refers to the actual assembling of objects and reflects the interaction between the bricoleur and the repertoire.

During this ‘dialogue’, the bricoleur engages in a process of experimentation aiming to discover combinations or configurations of resources which could present solutions (Duymedjian and Ruling, 2010). Thus, the dialogue is aimed at identifying the possible functionalities of each resource within each performing structure. The dialogue is similar to the processes through which the aboriginal populations studied by Levi-Strauss would assign a nutritive, medicinal, or hallucinogenic use to individual or combinations of plants available in their environment. The main objective of the dialogue is to test the various arrangements and permutations of resources. Although bricoleurs generally do not focus on the transformation of resources, their improvisation attempts could very well alter some of the components of the repertoire (Duymedjian and Ruling, 2010).

The *outcomes* of bricolage are combinations of resources in which each element is assigned a new role, significantly different than its conventional usage (Duymedjian and Ruling, 2010). They are usually hybrid, imperfect artefacts which serve the intended purposes and can be improved over time (Lanzara, 1999). The outcomes of bricolage processes may not always look very elegant; some of the components can remain visible and obtrusive within the assembly (Duymedjian and Ruling, 2010). The combinations or structures obtained through bricolage can be regarded as the outcomes of what “the surrealists have felicitously called ‘objective hazard’” (Levi-Strauss, 1966; p. 140). The bricoleur always invests a part of himself in the activity of bricolage as his personality and past experiences are reflected in the combinations of resources he puts together (Duymedjian and Ruling, 2010; Levi-Strauss, 1966). Consequently, the artefacts emerging as outcomes of bricolage activities can sometimes be used only by the bricoleurs responsible for their creation (Duymedjian and Ruling, 2010). In contrast, the outcomes of engineering contain only predefined inputs which are perfectly incorporated within the artefact, offer the optimal solution for a practical problem, and can be used independently of their creator. However, it is worth stressing that, in certain situations, artefacts resulting from bricolage may be the only workable alternative despite their inherent imperfections (see Garud and Karnoe, 2003).

The bricolage literature encompasses individual activities (e.g. Weick, 1993) as well as organisational (e.g. Ciborra, 1996) and inter-organisational processes (e.g. Garud and Karnoe, 2003). When performed at organisational or inter-organisational levels, bricolage becomes a collective, collaborative process (see Duymedjian and Ruling, 2010). Collective bricolage "is more than the ex-post connection" of arrangements or solutions developed by individual bricoleurs (Duymedjian and Ruling, 2010, p. 143). It is a lengthy and complex process which involves the merger or, at least, the disclosure of separate repertoires to the point where the bricoleurs become familiar with the shared repertoire "as if it was personally constituted by each of them" (Duymedjian and Ruling, 2010, p. 143). Moreover, in order to achieve such familiarity, bricoleurs need to engage in a form of joint dialogue with the common or shared repertoire (Duymedjian and Ruling, 2010). Such extensive interactions between multiple bricoleurs are more likely to happen when the actors share a physical space and trust each other (Duymedjian and Ruling, 2010). Thus, geographical proximity may be crucial for the success of collective bricolage ventures (Duymedjian and Ruling, 2010). For instance, Garud and Karnoe (2003) demonstrated how collective bricolage processes led to the successful development of wind turbine technology in Denmark. They showed how a close-knit network of stakeholders comprising producers, users, regulators, and evaluators generated inputs which eventually contributed to the creation of a profitable technological path for the entire wind turbine industry. The network-based, incremental approach to technology development allowed resource-constrained Danish innovators to successfully outwit munificent US competitors who adopted a more expensive 'technological breakthrough' seeking strategy characterised by a high relative distance between the stakeholders of the innovation process (Garud and Karnoe, 2003). Another classic case of collective bricolage involves the development of the mountain bike. In the early 1970's, a community of riders, bike shop owners, and mechanics from the hilly area of Marin County, California started building bikes specifically designed for downhill racing. To achieve their goal, the bricoleurs used frames from the Schwinn Excelsior "newsboy" bikes of the 1930's and 1940's, motorcycle gear levers, wide motocross handlebars, and derailleur gears from newer commercial road bikes (Smith, 2015).

Implementing bricolage at an organisational level often poses problems related to the legitimacy of the bricoleur and his method (Duymedjian and Ruling, 2010). Baker (2007) argues that many contemporary entrepreneurs, businessmen, and academic researchers hold a strong bias against bricolage as a legitimate way of doing things to the point that it is regarded as a shameful activity. The bias has a self-reinforcing nature as entrepreneurs, perhaps influenced by what they have learned in business schools, are underestimating bricolage in the histories or descriptions of events that they articulate (Baker, 2007). They tend to assign the merits for the positive outcomes in their businesses to strategies centred around more "heroic" activities such as risk-taking, creativity, innovation, or engineering prowess (Baker, 2007). This bias is then transmitted to the researchers who build their studies on the histories told by the entrepreneurs and, thus, bricolage remains unnoticed and under-researched compared to the more "heroic" activities (Baker, 2007). In turn, academic research feeds into business school teaching which, closing the vicious circle, alters the mind-set of future entrepreneurs who will refuse to consider bricolage as a pre-planned strategy (Baker, 2007). Given this "anti-bricolage" bias, the imperfections of bricolage outcomes, the use of unorthodox, non-specialized resources, and the difficulty of anticipating and replicating the results of bricolage are features which are often incompatible with organisations relying mostly on standard procedures, routines, performance measures, and labour division (Duymedjian and Ruling, 2010). Thus, bricolage as organisational process requires adaptation, standardisation, and formalisation procedures to ensure the transmission of the repertoire over time and the functionality of the outcomes in the absence of the creators (Duymedjian and Ruling, 2010).

2.1.4 Bricolage and improvisation

In the scholarly literature, bricolage and improvisation are inextricably linked and they are frequently used to explain and illuminate each other (see Baker and Nelson, 2005, Di Domenico et al., 2010, Garud and Karnoe, 2003, Kamoche et al., 2003, Miner et al., 2001, Weick, 1993). Improvisation occurs when composition and performance (Weick, 1993), design and execution (Baker et al., 2003; Miner et al., 2001), conception and realisation, thought and action (Duymedjian and Ruling, 2010) converge in time to the point where they become inseparable (Miner et al., 2001). Improvisers generally rely on the recombination of memorised knowledge and skills (Miner et al., 2001) just like musicians mix previously performed riffs and bundles of notes into new songs (Hatch, 1998). Given these similarities, bricolage and improvisation are sometimes used interchangeably and, thus, the relationship and boundaries between them remain unclear (Baker and Nelson 2005). Miner et al. (2001) argue that improvisation usually precedes bricolage as improvisers often do not have the time to search for the appropriate resources and, therefore, tend to engage in bricolage. While not rejecting this perspective, Baker and Nelson (2005) suggest that the opposite is equally true as bricolage can represent the cause of improvisation. Their study illustrated cases where the ‘resources at hand’ did not perform as anticipated by the bricoleurs. This usually led the bricoleurs to improvise and attempt to fix or adapt the resources.

In an attempt to clarify the relationship and differences between improvisation and bricolage, Baker (2007) argued that bricolage as activity can be independent of improvisation. In addition to the more intuitive idea of improvised bricolage, he discussed the concept of pre-planned bricolage (Baker, 2007). Planned bricolage happens when one prepares in advance to do something exclusively with the resources that will be “at hand” at a later time (Baker, 2007).

For example, "we might plan to hike, and intend to build a campfire making use of whatever materials are at hand when we make camp" (Baker et al., 2003; p. 264).

Weick (1993) discussed bricolage in the context of organisational sense-making and resilience. Using the example of the smokejumpers involved in the 1949 Mann Gulch (Montana, USA) fire disaster, Weick (1993) argued that bricoleurs often prove highly creative by figuring out how they can use what they already know (i.e. the knowledge "at hand") to improvise and solve unexpected problems which they had not experienced before. This creativity is clearly rooted in the bricoleurs' ability to assign meaning and value to every past experience (see Levi-Strauss, 1966). Thus, creatively exploiting a background of accumulated knowledge and experiences allows individuals and organisations to establish order in seemingly chaotic circumstances and resiliently overcome crisis or strenuous situations (Weick, 1993).

Another characteristic which makes bricoleurs very well equipped to handle crisis situations is their strong sense of "self-efficacy" or confidence in their ability to perform at the highest level (Duymedjian and Ruling, 2010; Weick, 1993). In a related vein, Bechky and Okhuysen (2011) showed that organisations often rely on bricolage to deal with and respond to unexpected or surprise situations. Their study, which focused on police SWAT teams and film production crews, showed that the process of organisational bricolage often involves not only material resources but also other resources "at hand" which are social and cognitive in nature such as a *shared task knowledge* and *common work flow expectations* (Bechky and Okhuysen, 2011). Shared task knowledge refers to know-how, process knowledge held jointly by organisational members and contributes to the resilience of the organisation by allowing crew members to successfully substitute one another and ensure the completion of the task even under strange, unexpected circumstances (Bechky and Okhuysen, 2011). Common work flow expectations refer to an organisation-wide shared understanding regarding the sequence in which collective tasks are to be completed. Such shared expectations allow organisation members to seamlessly change the order in which the tasks are completed in response to unexpected developments in the external environment (Bechky and Okhuysen, 2011). Thus, the effective use of physical resources “at hand” (e.g. knowledge, materials, tools, equipment, or people) depends to a large extent on a shared understanding of the situation among the members of the organisation (Bechky and Okhuysen, 2011; Weick 1993).

Ciborra (1996) used bricolage as a metaphor to illustrate how managers of high-tech companies facing turbulent conditions and numerous technological discontinuities creatively improvise in order to respond external challenges and opportunities. To address surprises, managers not only rearrange and recombine internal resources such as the available talent-pool, technological capabilities, and supplier networks, but also redesign and redevelop more complex features such as organisational identity, culture, structures, functions and routines (Ciborra, 1996). In the face of rampant and unpredictable change, managers and organisations rely on a mix of current and discarded artefacts, archetypal technological and organisational designs, as well as cognitive structures stored in the organisational memory to make sense and cope with otherwise unmanageable situations (Ciborra, 1996).

Baker et al. (2003) investigated the improvisational nature of new business founding in highly uncertain knowledge-intensive sectors. The founders of the majority of firms in their sample had relied on impulsive and improvisational action characterised by the convergence of planning and execution rather than the more widely documented “design-precedes-execution” process (Baker et al., 2003). Since the founding process is considered to be one of fundamental strategic importance for firms, it follows that improvisation can be strategic in nature when employed in such situations (Baker et al., 2003). Supporting this argument, the study shows that improvised tactics (i.e. statements or directions of action), articulated by founders to legitimate the business in relation to prospective employees and customers, developed into fully-fledged strategies. Had the founders not improvised in the early start-up days to gain the support of various stakeholders, they may have never explored what proved to be critical, strategic lines of business (Baker et al., 2003).

Furthermore, the founders of improvising firms pursued opportunities “at hand” which had emerged during the interactions with their personal or professional network rather than actively searching new business opportunities (Baker et al., 2003). Following this observation and acknowledging that identified business opportunities could be regarded as valuable resources, Baker et al. (2003) defined “network bricolage” as the “the dependence on pre-existing contact networks as the means at hand” (p. 265). In addition, Baker et al. (2003) observed that most new firm founders from their sample relied on network bricolage in the early days after start-up even though they did not improvise during the founding process. Generally, firm founders relied heavily on their contact networks to identify potential employees or to borrow key resources such as capital, office space or equipment (Baker et al., 2003). Just like collective bricolage (Duymedjian and Ruling, 2010), network bricolage allows firms to access external resources which they could not acquire otherwise. However, despite this resemblance, the two concepts remain quite different. On the one hand, the actors involved in collective bricolage share a common problem whose solution represents the common goal. Moreover, they are actively involved in the dialogue with the resource repertoire. On the other hand, the contacts of firm founders relying on network bricolage may not have a shared interest and active involvement in the development of the start-up. Baker et al. (2003) provide examples supporting the previous argument. Although, in some cases, the contacts of the founders did provide both the start-up capital and the initial orders, thereby exhibiting a direct interest in the newly established firm, in most cases, the contacts provided (only) serendipitous entrepreneurial ideas or disinterested support.

2.1.5 Bricolage and technology

Bricolage appears to play a central role in the development and organisational implementation of information systems and technologies (Lanzara, 1999). This context is often murky, ambiguous, and has ever shifting boundaries (Lanzara, 1999). Thus, such information systems need to be "designed in action" as opposed to the more traditional design process which involves heavy planning and engineering methods insulating the developer from the vagaries of the context (Lanzara, 1999). Design in action is eminently practical, experiential, situated, and highly contextual (Lanzara, 1999). Bricolage seems central when designing in action as the process relies on pre-existent structures which are transformed and reshaped to create "transient constructs" (Lanzara, 1999). Such transient constructs are used for a while and, then, are discarded in favour of new ones until a structure proves itself sufficiently efficient and becomes stable (Lanzara, 1999). Designing in action is exploratory in nature and involves experimenting, tinkering, and testing "on the ruins and with the ruins of old systems" (Lanzara, 1999; p.346).

When discussing the outcomes of bricolage, the merits seem to outweigh the shortcomings. Despite the imperfect and transient nature of its outcomes, bricolage can sometimes render "brilliant unforeseen results" (Levi-Strauss, 1966; p. 17) and is often "the only thing we can reasonably do when we are engaged in action" (Lanzara, 1999; p. 347). Moreover, the merits of bricolage deserve to be acknowledged as even the most refined and technologically advanced systems and products are usually "far from being heavenly bodies christened with the stigma of perfection" (Lanzara, 1999; p. 347). An additional benefit of bricolage and designing in action is that they involve very low sunk costs as the resources and components can be recovered and reused in new projects (Lanzara, 1999).

Examples of web-based systems and applications created through bricolage are quite common (Fisher, 2012). The core of the Flickr photo sharing platform (which was acquired by

Yahoo in 2005) was created through the conversion of codes initially developed to provide a side option in an online game, called Game Never-Ending (Fisher, 2012). To create the consumer blogging platform Six Apart, the founding entrepreneurs used the architecture of an old enterprise blogging service they had developed (Fisher, 2012). Similarly, the founder of Bloglines used programming code from an anti-spam software to develop an online news aggregation service (Fisher, 2012).

2.2 Innovation

Broadly, "an innovation is an idea, practice, or object that is perceived as new by an individual or another unit of adoption" (Rogers, 2003; p. 12). Various forms of innovation include product, service, process, and business model innovations (Smith, 2015). This doctoral thesis focuses on technological innovations in general and on electric vehicles in particular. Technological innovation is defined as "an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention" (Garcia and Calantone, 2002). This definition captures two important ideas. First, the innovation process combines the technological development of an invention with the market introduction of that invention in the form of products and/or services (Garcia and Calantone, 2002). Second, technological innovation is an iterative process. This means that the initial introduction of the innovation incorporating a new technology is followed by subsequent releases of improved versions of the innovation (Garcia and Calantone, 2002). Technological innovations incorporate inventions from industrial arts, engineering, applied sciences, and pure science (Garcia and Calantone, 2002).

Since Vernon's (1966) product life-cycle theory, a commonly held assumption is that innovations originate and are adopted first in the US and other developed countries and trickle down to emerging and developing countries only in the later stages of the product life-cycle (i.e. maturity and decline). More recently, researchers have pointed out innovations that follow the reverse trajectory: from emerging markets to developed countries (Govindarajan, 2012; Immelt et al., 2009). Examples of such reverse innovations include Harman's low-cost infotainment system developed by the company's Indian and Chinese subsidiaries (Govindarajan, 2012) and GE's $1,000 hand-held electrocardiogram device developed in India (Immelt et al., 2009). In both cases, the parent companies transferred to developed countries products that had been developed to address the requirements of emerging market customers. These innovations were generated by emerging market subsidiaries of DMNEs. This doctoral study aims to show that companies from emerging markets too have the potential to develop cutting-edge technological innovations which could be adopted on a global scale.

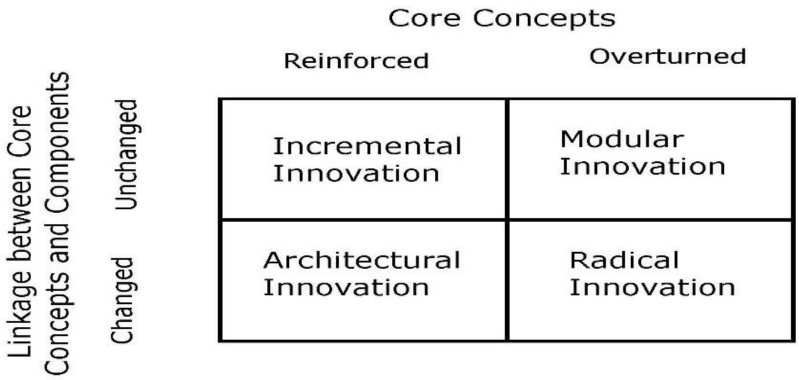
The following sub-sections review several typologies of technological innovations which provide direction and support in the analysis of the innovation process at Mahindra Reva.

2.2.1 The Henderson and Clark (1990) framework

Since innovation is increasingly touted as an important source of competitive advantage (Smith, 2015), firms all over the world are advertising their innovativeness. The degree of a firm innovativeness can be related to the degree of novelty or change incorporated in the firm's innovations (Smith, 2015). Some innovations are completely new to the world and unlike anything that has been developed before, while other innovations bring only minor, cosmetic improvements to existing products (Smith, 2015). Thus, innovations involving a great change relative to industry status quo are regarded as radical innovations, while innovations bringing on only a small or marginal change are considered incremental innovations (Freeman, 1974). Although a very useful starting point, this dichotomous categorization does not allow for a nuanced analysis and differentiation between innovations. To address this analytical limitation, more sophisticated frameworks were developed (e.g. Henderson and Clark, 1990; Garcia and Cantalone, 2002).

Henderson and Clark (1990) developed their conceptual framework around the distinction between the product in its parts (i.e. the components) and the product as a whole (i.e. a system made up of components that work together in order to carry out a particular task). A component is defined as "a physically distinct portion of the product that embodies a core design concept and performs a well-defined function", while the overall architecture of the product determines how the components are integrated together in a coherent, working system (Henderson and Clark, 1990; p. 11). Depending on their impact on the core design concept of components and on the linkages between the components (see Figure 1), innovations can be classified into four categories (Henderson and Clark, 1990).

Figure 1. Henderson and Clark's (1990) framework



Incremental innovation introduces relatively modest improvements to components and, overall, relies on and reinforces existing design concepts and architectures (Henderson and Clark, 1990). Incremental innovations build on existing knowledge and capabilities and, thus, bolster the dominance of established firms (Christensen, 1997; Henderson and Clark, 1990). Any new and improved model of an existing product (e.g. new versions of the iPhone, the iPod) can be a good illustration of incremental innovation (Smith, 2015). Incremental innovation is the most frequent type of innovation as it generally follows a "linear process of continuous change" (Smith, 2015; p.38).

Modular innovation involves the development of new design concepts for one or more components while relying on the architecture of an existing product (Henderson and Clark, 1990). Similar to incremental innovation, modular innovation tends to be the oeuvre of established firms (Henderson and Clark, 1990; Smith, 2015). Examples of modular innovations include the introduction of digital landline phones as a replacement for analogue phones (Henderson and Clark, 1990) and the clockwork radio (Smith, 2015).

Architectural innovation maintains existing components and their corresponding design concepts but introduces a new configuration of linkages between components (Henderson and Clark, 1990). This does not imply that architecture innovation excludes any improvements in the components. In fact, architectural innovation can be the result of a change in one component (e.g. miniaturization) which impacts the interactions and linkages between other components (Henderson and Clark, 1990). The Sony Walkman is an example of architectural innovation (Smith, 2015). Architectural innovations can pose unexpected problems to established firms (Henderson and Clark, 1990). Because architectural knowledge tends to be more stable than the design concepts of components, it often becomes embedded in the organisational practices, routines, and processes (Henderson and Clark, 1990). Consequently, implementing an architectural change could require numerous and profound organisational changes (Henderson and Clark, 1990).

Radical innovation is often the result of a technological breakthrough (Smith, 2015). It is non-linear (Smith, 2015) and it involves new sets of engineering and scientific knowledge (Henderson and Clark, 1990). Radical innovation relies on new design concepts for components which are connected to each other in a completely new architecture (Henderson and Clark, 1990). Radical innovations pose major problems to established firms and provide important opportunities for new entrants or even for the creation of new industries (Henderson and Clark, 1990). According to Utterback (1996), radical innovation “sweeps away much of a firm’s existing investment in technical skills and knowledge, designs, production technique, plant, and equipment” (p. 200). Examples of radical innovations include the flat-screen TV relying on the liquid crystal display (LCD) technology (Smith, 2015), the digital camera, and the electric automobile. Radical innovation is the rarest type of innovation accounting for between 10% (Smith, 2015) to maximum 20% (Garcia and Calantone, 2002) of the total number of innovations.

2.2.2 Closed vs open innovation

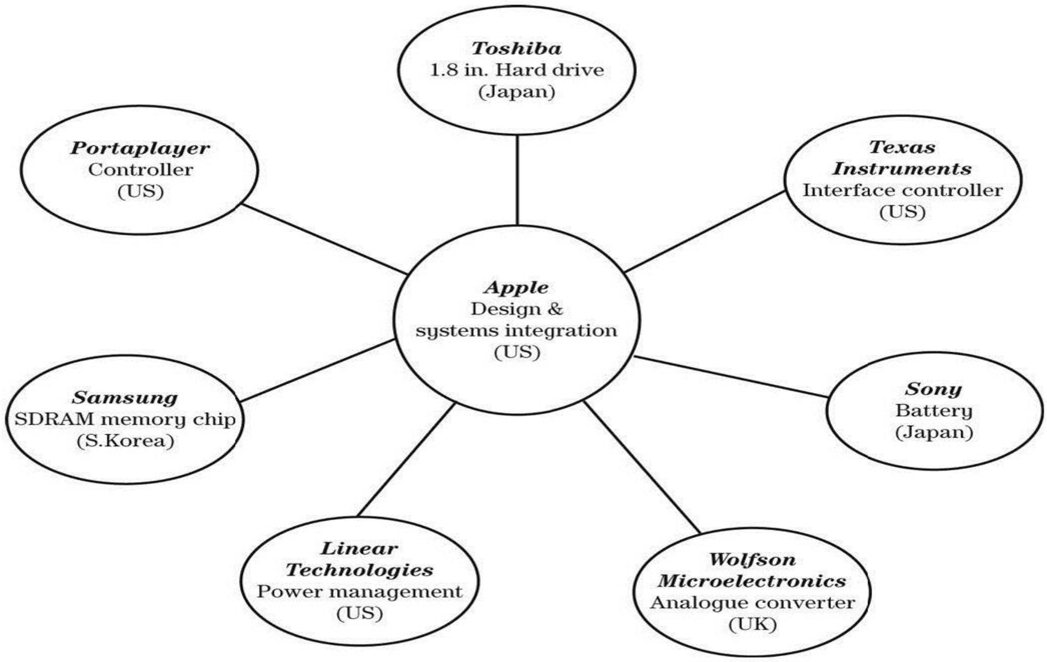
For most of the twentieth century, technological innovation was the prerogative of large corporations which had substantial physical, financial, and human resources allowing them to undertake all the activities related to the process of innovation within the corporate boundaries (Chesbrough, 2006; Smith, 2015). The archetype of yesteryear's corporate giants engaging in highly expensive, large-scale R&D is epitomized by companies such as AT&T, Xerox, IBM, and General Electric. AT&T's famous Bell Labs are responsible for developing the transistor, the laser, and the first mobile phone system, while at Xerox's Palo Alto Research Centre (PARC) have seen the light of day the first laser printers, the Ethernet network protocol, the computer mouse, and the graphical user interface with overlapping windows and point and click commands available on modern computers (Gladwell, 2011; Smith, 2015). This classic type of innovation where all the R&D and new product development (NPD) related activities are performed in-house by a single organisation was labelled as "closed innovation" (Chesbrough, 2006).

However, in recent years a more open model of innovation, which involves extensive interactions among multiple organisations, has gained momentum and attracted interest from academic and practitioner communities (Chesbrough et al., 2006; Lakhani et al., 2013; Laursen and Salter, 2006; van de Vrande et al., 2009). Open innovation was defined as "the distributed innovation process based on purposively managed knowledge flows across organisational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organisation's business model" (Chesbrough and Bogers, 2014; p. 24). Unlike typical component outsourcing relationships where the suppliers produce the components according to the designs and blueprints provided by their clients, in the case of open innovation the suppliers design and develop the components using their own knowledge and capabilities (Smith, 2015). Differentiating between closed and open innovation implies the existence of a closed-to-open organisational boundary continuum on which the locus of innovation can be positioned, rather than a dichotomous categorization of innovations (Lakhani et al., 2013). As the notion of organisational boundaries becomes increasingly complex, companies tend to engage in assorted innovation strategies which may incorporate closed vertical integration, strategic alliances, joint ventures, and open innovation (Lakhani et al., 2013). The positioning of a firm's innovation process along the closed-to-open boundary continuum depends on the extent to which critical tasks can be decomposed and the degree to which the knowledge required by those tasks is distributed among multiple actors (Lakhani et al., 2013).

Factors favouring the rise of open innovation include: (i) the fast changing markets, technologies, and consumer demands (Smith, 2015), (ii) the increasing competition which imposes shorter lead times on innovating firms (Smith, 2015), (iii) the increasing complexity of new technologies and products which makes it unlikely (if not impossible) for a single organisation to possess all the knowledge required in the innovation process (Smith, 2015), (iv) a greater mobility of knowledge caused by staff members who are less willing to spend long periods with the same company (Chesbrough, 2006), (v) the pervasiveness of digitization (i.e. codifying knowledge and physical products in binary computer language) which allows material objects to be created, examined, and transformed based on their "information shadow" (Lakhani et al., 2013), and (vi) the reductions in communication and knowledge dissemination costs enabled by the internet and other ICT innovations (Lakhani et al., 2013).

Two of the most widely cited examples of open innovation involve Apple and Boeing, companies regarded in the past as rather closed innovators, which usually relied on internal knowledge for the development of most of their products. Apple's iPod incorporates components designed and developed by seven companies (see Figure 2 below): Toshiba, Texas Instruments, Sony, Wolfson Electronics, Linear Technologies, Samsung, and PortalPlayer (Kahney, 2013; Levy, 2006). Although it retained a central position in the innovation network, Apple handled only the overall design and the system integration (Smith, 2015).

Figure 2. Global innovation network for the Apple iPod

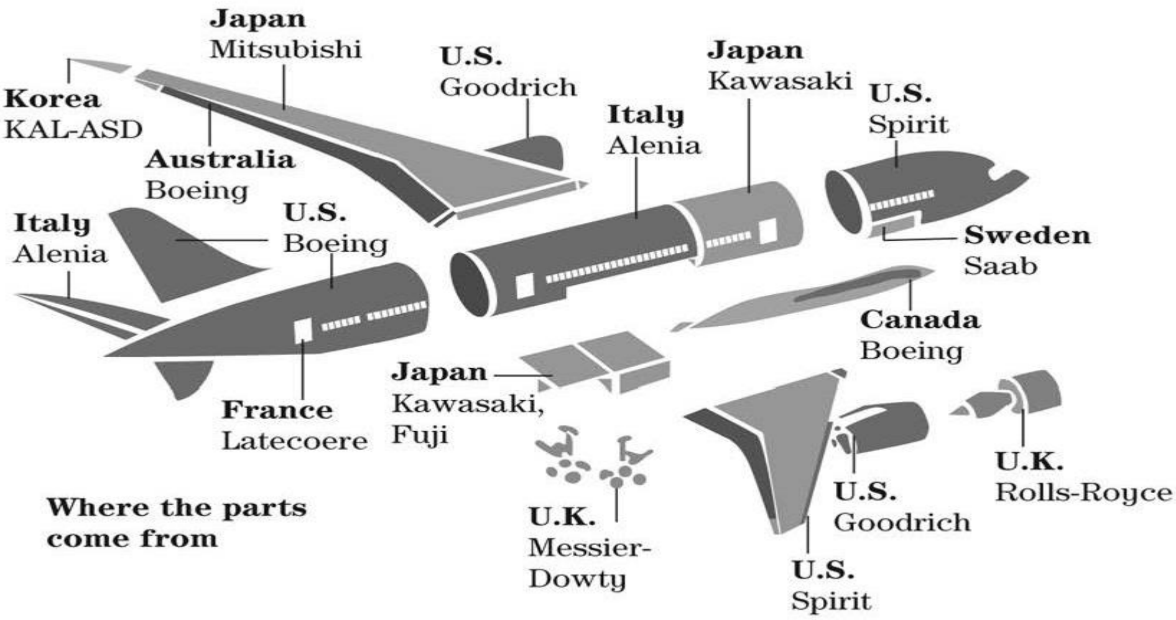


Source: Smith (2015)

Similarly, Boeing relied on a vast network of international partners (see Figure 3) for the development of the new 787 Dreamliner. Companies such as Mitsubishi, Kawasaki, Rolls-Royce, Goodrich, Saab, Alenia, and Fuji have contributed with original designs of critical components to the development of the Dreamliner (Norris and Wagner, 2009).

These examples support the claim the open innovation is more common in turbulent, high-technology sectors characterised by high product complexity and rapid technological change (Chesbrough et al., 2006; Miotti and Sachwald, 2003). Firms operating in industries such as consumer electronics and aerospace have to balance conflicting requirements for extensive R&D efforts, on the one hand, and short lead times and rapid new product development, on the other. Consequently, firms in high-technology are increasingly turning towards (more) open innovation strategies in order to stay competitive.

Figure 3. Global innovation network for the Boeing 787 Dreamliner



Source: Smith (2015)

Prior studies have not reached consensus regarding the type of companies that are more likely to engage in open innovation. On the one hand, large companies such as Apple and Boeing tend to have a higher absorptive capacity (see Cohen and Levinthal, 1990) which allows them to internalize faster the external knowledge. On the other hand, the greater mobility of capital has determined an increase in technology-intensive start-ups and spin-offs which incline towards an open model of innovation in order to overcome their liability to newness and resource constraints (Chesbrough, 2006; Brunswicker and Van de Vrande, 2014).

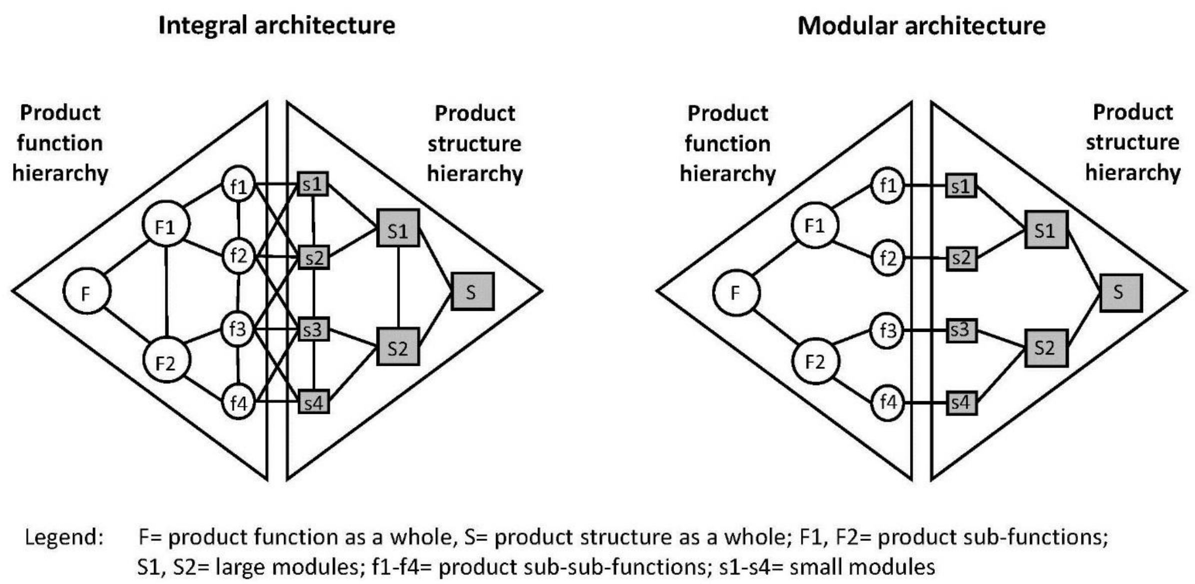
Three types of open innovation have been documented thus far (i.e. inbound, outbound, and coupled). Inbound open innovation refers to instances where companies incorporate external knowledge in their R&D and NPD efforts (Chesbrough and Bogers, 2014). Sources of such external resources include but are not limited to universities, suppliers, competitors, and customers (Chesbrough and Bogers, 2014). Outbound open innovation refers to situations where firms release internal knowledge that may not be related to firm's business model

(Chesbrough and Bogers, 2014). Such non-core internal knowledge can be monetized through spin-offs, spin-outs, sale or licencing out of intellectual property (Chesbrough and Bogers, 2014). Finally, coupled open innovation refers to firms combining external knowledge and external monetization routes for their innovative efforts (Chesbrough and Bogers, 2014). Coupled open innovation can be observed in joint-ventures, collaborations, alliances, co-creation, and co-patenting (Chesbrough and Bogers, 2014; West and Bogers, 2014).

2.2.3 Fujimoto's framework

Drawing on the work of Henderson and Clark (1995), Ulrich (1995) argued that product architecture incorporates three interrelated aspects: (i) the arrangement of functional elements, (ii) the relationship between functional elements and physical components, and (iii) the interfaces connecting interrelated physical components. Based on this definition, Ulrich (1995) identified two types of product architecture: modular and integral (see Figure 4 below).

Figure 4. Integral and modular architectures (Fujimoto, 2007)

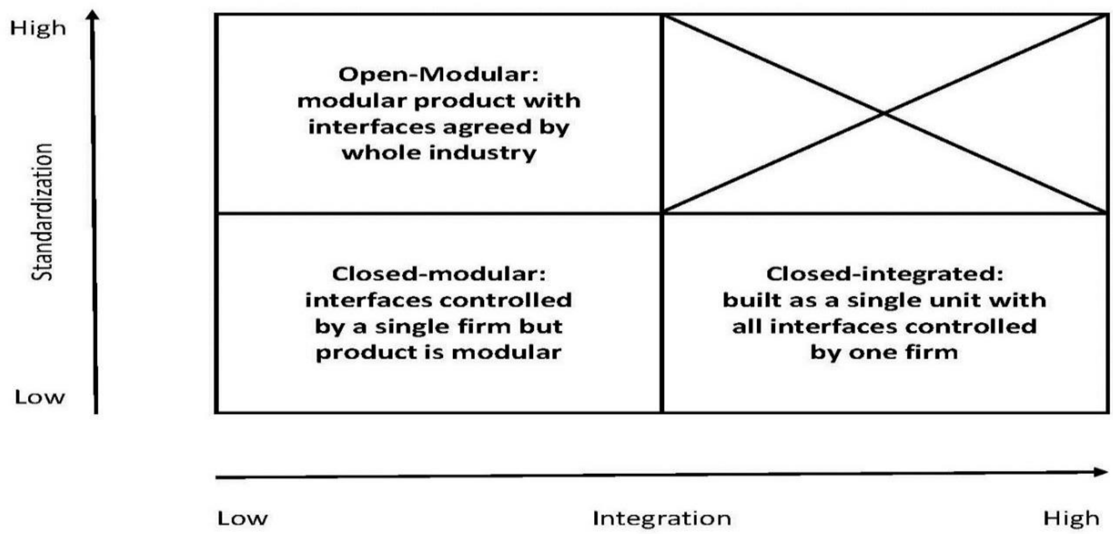


Modular architecture is characterised by a one-to-one correspondence between functions and physical components and a standardised interface that enables the interaction and connections between components (Ulrich, 1995). A crucial implication of the standardized interface is that the physical components can be designed and developed independently by multiple actors (Ulrich, 1995).

Integral architecture involves a highly complex (many-to-many) mapping between functions and physical components (Ulrich, 1995). The interfaces are not standardized and are closely coupled with the physical components (Ulrich, 1995). Consequently, the physical components cannot be designed and developed independently (Ulrich, 1995).

Fujimoto (2007) placed Ulrich's (1995) ideas on product architecture in the open innovation context discussed previously and produced a bi-dimensional framework focusing on the degree of openness and the level of integration (see Figure 5 below).

Figure 5. Fujimoto's (2007) product architecture framework



On the horizontal axis, high levels of integration imply that the product design cannot be broken down into modules or subsystems and must be produced as a single integrated unit, while low levels of integration suggest that the product design can be separated into discrete module or subsystems (Fujimoto, 2007). On the vertical, high levels of standardization indicate the existence of industry-wide standards and, consequently, that the development of components and modules can be easily outsourced (Fujimoto, 2007). Conversely, low levels of standardization imply that there are no industry-wide standards and that each producer uses unique interfaces (Fujimoto, 2007). Products with open-modular architectures include the personal computer (PC), the bicycle, PC software, and the Internet (Fujimoto, 2007). Closed modular architectures can be found in mainframe computers and machine tools, while closed-integrated products include small cars, motorcycles, and compact consumer electronics (Fujimoto, 2007).

Fujimoto's (2007) framework provides valuable insights regarding the design and architecture of products. However, important limitations become apparent when trying to integrate products such as the Apple iPod and the Boeing 787 Dreamliner (discussed previously) in Fujimoto's (2007) framework. According to Fujimoto (2007), an open-integrated architecture cannot exist for two reasons: (i) high integration implies that the product must be designed and developed as a whole, which cannot be achieved by multiple actors working independently and (ii) high standardization (modularity) and high integration are conceptual opposites and cannot coexist. Yet, the iPod and the Dreamliner undoubtedly have open-integrated architectures. In both cases, wide networks of innovators designed and developed the components (modules) independently, while the flagship companies (i.e. Apple and Boeing) handled the overall design and very complex system integration efforts (see Smith, 2015). System integration for products with open-integrated architectures can be a daunting task, yet not an impossible one. Chesbrough (2011) stated:

> *"Boeing is a good example of the problem of interdependencies in systems design. When the company developed its Dreamliner 787 project, it broke the design into major subsystems and contracted with design partners for those major subsystems. However, when the subcontractors came back with their proffered designs, Boeing couldn't get all the pieces to work together. Between the new materials, the new engines, the new avionics, etc., there were too many new and poorly understood aspects of the design to make a working aircraft. The 787 is now years behind schedule as a result."*

Roughly five months after Chesbrough's observation, the Dreamliner was launched (albeit with a three-year delay) and remains one of the most innovative commercial aircrafts to date (Smith 2015). On the other hand, Apple did not face similar problems with the integration of systems and the first iPod model was launched less than ten months after the inception of the product design and development.

The limitation of Fujimoto's framework can be easily overcome by acknowledging that the modular and integral architectures do not represent discrete, dichotomous, and mutually exclusive typologies, but rather a modular-to-integral continuum that can accommodate open-integrated architectures. An open-integrated architecture is likely to involve extensive collaborations and negotiations between the members of the innovation network regarding the design and development of modules, subsystems, and interfaces.

2.2.4 Disruptive vs sustaining innovations

The theory of disruptive technologies is based on the observation of an anomaly contradicting the rather intuitive expectation that superior technologies should displace inferior technologies. In some cases, technology development takes an unexpected path and inferior technologies manage to displace superior technologies (Bower and Christensen, 1995; Christensen and Bower, 1996; Christensen, 1997). This surprising trajectory was first observed in the context of hard-disk drives, earth-moving equipment (i.e. excavators), and motor controls (Christensen, 1997). Subsequently, the idea of disruptive innovations was introduced to include service and business model innovations such discount department stores and low-cost, no-frills airlines (Christensen and Raynor, 2003), while "the Christensen effect" was proposed as an alternative label for the phenomenon in order to avoid the confusion of disruptive innovation with radical or destructive innovation (Christensen, 2006).

Despite being inferior to the dominant technologies along performance attributes valued by mainstream customers, disruptive technologies provide value along other attributes, which are not valued or are valued less by mainstream customers (Christensen, 1997). Consequently, the disruptive technology is initially adopted by niche market segments, which appreciate the non-mainstream performance attributes (Christensen, 1997). In time, further developments improve the performance of disruptive technologies on standard attributes to levels considered acceptable by mainstream customers. The improved performance together with the alternative attributes and the cost benefits of disruptive technologies provide a new value proposition which convinces mainstream customers to adopt the new technology on a wide scale. This adoption usually happens despite the fact that the overall performance of disruptive technologies on mainstream attributes remains inferior to that provided by established technologies, which are improving as well (Christensen, 1997). For example, the 3.5-inch hard-disk drives, which were smaller and provided less storage capacity than the 5.25-inch disks, were initially used for portable computers as the size benefits and low power consumption outweighed the storage capacity limitations. The 3.5-inch disks were eventually introduced on desktop computers once their storage capacity improved sufficiently (Christensen, 1997). The switch from superior to inferior, yet disruptive technologies is more probable in the case of "performance oversupply"; that is when the performance of the mainstream technologies exceeds or "overshoots" the needs of the customers (Christensen, 1997). By this logic, when customers' performance requirements on prominent, primary attributes are met, the focus of evaluation shifts to secondary or tertiary attributes which initially were considered less important (Adner, 2002; Christensen, 1997). Thus, disruptive technologies and innovations are: (i) inferior on performance attributes valued by mainstream customers, (ii) offering new value propositions that attract new customers or price sensitive mainstream customers, (iii) more affordable than mainstream technologies, (iv) initially adopted by niche customers but eventually penetrate mainstream markets (Govindarajan and Kopalle, 2006).

Disruptive innovations pose a resource allocation dilemma for many successful incumbents as it often seems unreasonable, if not irrational, to divert resources from existing mainstream customers to small, even inexistent markets (Bower and Christensen, 1995; Christensen, 1997). For this reason, many disruptive innovations are introduced by new entrants as established firms choose to focus on "sustaining" and improving the technologies demanded by their current customers (Christensen, 1997). Moreover, successful incumbents are inclined to ignore inferior technologies because, given their low performance, these technologies initially appeal to low-end, low-profit market segments (Adner, 2002). Consequently, successful incumbents may be caught unprepared when disruption happens and may lose their dominant positions in favour of new entrant disruptors (Christensen, 1997). Examples of companies that lost their dominant positions to disruptors include Xerox losing ground to Canon once the latter developed the small copiers, Bucyrus-Erie giving way to Caterpillar and their hydraulic excavators, and Sears losing out to Wal-Mart (Bower and Christensen, 1995). Some clarifications regarding this last point were provided by Christensen himself and by other advocates of the disruptive innovation theory (Christensen, 2006; Yu and Hang, 2010). First, when disruption happens, new entrant disruptors rarely drive the incumbents out of business and replace them completely. The sustaining improvements of the superior technology often allow the incumbents to survive by addressing the demands of affluent, high-end customers (Yu and Hang, 2010). Second, there are cases where incumbents, who are willing to cannibalize their own products, play the role of disruptors themselves. Examples of such disrupting incumbents include IBM in personal computers, Fuji in digital imaging, and HP in inkjet printing (Yu and Hang, 2010).

Govindarajan and Kopalle (2006) argued that the theory of disruptive innovation can be extended beyond the case of low performance/low price products. They claimed that even technologies that provide inferior performance and have a higher price (e.g. electric vehicles) compared to the established technologies are susceptible to cause market disruptions (see Govindarajan and Kopalle, 2006). The cellular phones are the most relevant example of this argument. When first introduced, cellular phones provided poor quality and reliability compared to landline phones (Govindarajan and Kopalle, 2006). In addition, the cost of cellular phone calls was significantly higher than the cost of landline calls. Consequently, cellular phones were initially adopted by high-level executives who valued the portability of cell phones, despite their shortcomings (Govindarajan and Kopalle, 2006). However, disruption happened once the technology improved sufficiently to offer reliable coverage at prices that satisfied the needs of mainstream consumers (Govindarajan and Kopalle, 2006).

2.2.5 Continuous vs discontinuous innovations

The continuous-discontinuous typology is, by far, the murkiest and most confusing attempt to categorize innovations. There seems to be significant overlap between the incremental-radical typology as originally proposed by Freeman (1974) and the continuous-discontinuous categorization as employed by scholars such as Lynn et al. (1996) and Veryzer (1998). Radical or discontinuous innovations cause massive and critical changes to industry status quo, while incremental or continuous innovations involve small, less dramatic, sometimes merely "cosmetic" changes relative to an existing design (see Freeman, 1974; Lynn et al., 1996).

Rice et al. (1998) define discontinuous innovations as "game changers which have potential for (i) for a 5-10 times improvement in performance compared to existing products, (ii) to create the basis for a 30-50% reduction in cost, or (iii) to have new-to-the-world performance features" (p. 52). However, this definition seems rather narrow and arbitrary.

A more accommodating perspective shared by many researchers holds that discontinuous innovations create technology and/or market changes/discontinuities (see Garcia and Calantone, 2002; Lynn et al., 1996; Veryzer, 1998). Nevertheless, this approach too is far from perfect. Confusion arises when examining some of the examples provided by extant literature. Birkinshaw et al. (2007) suggested that digital cameras and mobile phones created market discontinuities. Upon reflection, one could argue that the transition from chemical imaging to digital imaging represents first and foremost a technological discontinuity. Similarly, although it could be claimed that, in the early stages, mobile phones have created a niche market consisting mainly of high-level executives who adopted mobile phones despite their poor performance and high costs, changing from land-line phones to mobile phones involves an important technological discontinuity. This poses difficulties in positioning EVs within the continuous-discontinuous classification. Arguably, EVs create both technological and market discontinuities. First, the EV technology is completely different from the prevalent internal combustion (IC) technology and, thus, it creates a technological discontinuity. Second, technical specifications and limitations (lower top-speeds and driving ranges) imply that EV adopters tend to have different commuting patterns and use automobiles differently than drivers of IC cars. Such differences suggest that EVs create a market discontinuity.

Discontinuous innovations pose significant challenges to managers. Discontinuous innovations are highly uncertain, very costly and time-consuming to develop (Birkinshaw et al., 2007; Lynn et al., 1996). Because discontinuous innovations do not "emerge perfectly formed like Venus from the sea" (Birkinshaw et al., 2007; p. 68), companies have to face uncertainties related to the development of technology, the customers who will adopt the innovation, and possible government regulations over which firms have hardly any control (Lynn et al., 1996). To address such uncertainties firms have limited strategic options and, more often than not, they have to engage in a costly and lengthy "probing and learning" iterative process, whereby the innovating firms develop successive versions of new products and release them on the market to gauge the customers' reaction (Lynn et al., 1996). Firms then learn from the customers' reaction and try to incorporate the acquired knowledge in the next versions of the product (Lynn et al., 1996). The "probing and learning" process is repeated until the innovating firms manage to align the technology with the customers' requirements, thereby ensuring the wide-scale adoption of the innovation (Lynn et al., 1996).

Generally, very few firms are willing to undertake the "probing and learning" process. On the one hand, small new entrants rarely have the deep pockets required to carry out the probing and learning. On the other, successful incumbents, who may have the required resources, usually lack the incentive. They often prefer continuous/incremental innovations with results reflected in the firms' short-term profitability rather than discontinuous innovations which hurt the bottom line in the short-run and may not yield much in the long-run either (Lynn et al., 1996).

2.3 Technological innovation in emerging markets and bricolage

Concepts such as jugaad innovation (e.g. Radjou et al., 2012), frugal innovation (e.g. Kumar and Puranam, 2012; Leadbeater, 2014), and cost innovation (e.g. Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007) have been used to explain technological innovation in emerging markets. As there are both significant overlaps and critical differences between the three concepts, caution needs to be exercised when using and interpreting them. Perhaps attempting to gain traction for the terms they have coined or popularized, researchers often forcefully stretch the boundaries of the terms jugaad innovation and frugal innovation, and use them in the broadest sense possible (see Leadbeater, 2014; Radjou et al., 2012). Consequently, jugaad innovation and frugal innovation may become meta-concepts with little explanatory power.

Each of the three concepts is discussed next, in an attempt to identify the differences and similarities between them, as well as the relationship between these concepts and bricolage. Prior studies (e.g. Kumar and Puranam, 2012; Radjou et al., 2012; Zeng and Williamson, 2007) present jugaad innovation, frugal innovation, and cost innovation as more affordable and democratic alternatives to the traditional, structured, R&D intensive approach to innovation.

The traditional innovation process seems to possess several shortcomings which are irreconcilable with the realities of emerging markets and, thus, make it ill-suited for such resource-poor environments: (i) the traditional innovation process is expensive, resource intensive, and very risky as there is a weak correlation between R&D budgets and the development of commercially successful products; (ii) because it often entails a structured process, traditional innovation lacks the flexibility required in turbulent emerging market environments where socioeconomic, technological, and competitive changes are very frequent; (iii) traditional innovation is "elitist and insular", that is top scientists and engineers develop highly expensive and complex products which target affluent customers and remain outside the reach of the masses (Radjou et al., 2012). Therefore, understanding the processes underlying concepts such as jugaad innovation, frugal innovation, and cost innovation can provide valuable insights for managers in both emerging markets and developed countries.

2.3.1 Jugaad innovation

Originally, the Hindi and Punjabi word "jugaad" described a jury-rigged, make-shift vehicle cobbled together by mounting a diesel engine on a cart (Birtchnell, 2011; Radjou et al., 2012). In its original acceptation, jugaad was rooted in India's wide-spread poverty, unsafe transport practices, and infrastructure deficit (Birtchnell, 2011). More recently, however, the negative connotation of the word has faded away, the scope has expanded, and jugaad currently denotes "an innovative fix; an improvised solution born from ingenuity and cleverness" (Radjou et al., 2012; p. 4). Moreover, the underlying idea of jugaad is no longer limited to the Indian context. The Brazilians convey the idea of jugaadist innovation through the word "gambiarra", the Chinese refer to it as "zizhu chuangxin", while the Kenyans use the phrase "jua kali" (Radjou et al., 2012). These countries and others share similar difficult, turbulent conditions and resource constraints. Consequently, they show the same inclination towards an improvisational approach to innovation (Radjou et al., 2012).

Jugaad is not a structured process or a scientific method for innovation, rather it is assimilated to an art form, mind-set, or culture conducive to improvised ingenuity and it is based on several principles (Radjou et al., 2012) which hint at bricolage. First, jugaad innovators *seek opportunity in adversity* (Radjou et al., 2012). They do not find opportunities in spite of resource constraints and adverse conditions, rather jugaad innovators view adversity itself as an opportunity (Radjou et al., 2012). Jugaad innovators have the unique cognitive ability to reframe debilitating circumstances into opportunities to experiment and innovate (Radjou et al., 2012).

Second, jugaad implies *doing more with less* (Radjou et al., 2012). Jugaadists have developed this frugal mind-set as a consequence of the constraints they constantly face such as the scarcity of capital, material resources, and quality infrastructure (Radjou et al., 2012). Jugaad innovators are cost-oriented at all stages of the product development process, from concept development and design to manufacturing and delivery (Radjou et al., 2012). They use mostly light assets and try to leverage the capabilities of partners to scale up their innovations (Radjou et al., 2012).

Third, jugaad innovators *think and act flexibly* in order to survive in unpredictable and turbulent emerging markets (Radjou et al., 2012). Just like bricoleurs, jugaad innovators often challenge conventional wisdom and rely on extensive experimentation and trial-and-error to find new and surprising solutions (Radjou et al., 2012). Moreover, jugaadists often improvise their course of action rather than making mid- or long-term plans which are very likely to be disrupted by the volatile environment (Radjou et al., 2012).

Fourth, a key feature of jugaad innovations is *simplicity* (Radjou et al., 2012). Jugaad innovations are rarely high-tech, complex products. They are rather low-tech, “good-enough” solutions (Radjou et al., 2012). However, although they are simple, jugaad innovations are not simplistic. Jugaadists do not oversimplify the problem at hand. Instead, they try to address the full complexity of the problem in the simplest way possible (Radjou et al., 2012).

Fifth, jugaad innovators always *include the margin* (Radjou et al., 2012). They focus on and try to address the needs and aspirations of marginal individuals and groups which are often considered unattractive due to their low incomes and, thus, ignored by mainstream corporations (Radjou et al., 2012). Jugaadists not only develop innovative products and business models targeting bottom-of-the-pyramid, underserved customers, but also integrate these customers in the product development, manufacturing, or delivery (Radjou et al., 2012).

Sixth, jugaad innovators *follow their hearts* in the decision-making process (Radjou et al., 2012). They are intelligent and passionate entrepreneurs and often rely on intuition rather than on rational analysis to manoeuvre in the complex and unpredictable emerging market environment (Radjou et al., 2012). Jugaad innovators are very close to the targeted customers, often sharing a similar background. Thus, "empathy forms the cornerstone of jugaad innovators' practice of an altruistic form of capitalism that is shaped by enlightened self-interest" (Radjou et al., 2012; p. 161).

Examples of jugaad innovations include the terra-cotta refrigerator called Mitticool and the solar bottle bulb (Radjou et al., 2012). The Mitticool, which was developed by a Gujarati rural entrepreneur, consisted of a pot-like body made of clay, a glass door and a plastic faucet at the bottom and cost only US$ 50 (Radjou et al., 2012). The Mitticool did not use any electricity which was unreliable in the rural parts of India. Instead, it used water from an upper chamber which trickled into the side walls and cooled the main food chamber through evaporation (Radjou et al., 2012). The solar bottle bulb was developed by a local entrepreneur to illuminate during day-time the otherwise dark shanties in the Filipino slums (Radjou et al., 2012). The solar bottle bulb consisted of a recycled plastic bottle containing water treated against the formation of mould which was fitted through a hole in the roof of the shanty (Radjou et al., 2012). The water in the bottle reflected the sunlight and produced the equivalent of a 55-watt electric light bulb (Radjou et al., 2012). The solar bottle bulb was more efficient than a window cut in the roof and was less likely to leak during the typhoon season (Radjou et al., 2012). The solar bottle bulb and its installation cost only US$ 1 (Radjou et al., 2012).

2.3.2 Frugal Innovation

The origins of the frugal innovation concept are attributed to Renault-Nissan's CEO, Carlos Ghosn, who coined the phrase "frugal engineering" to suggest the idea of achieving more with fewer resources (Kumar and Puranam, 2012; Radjou and Prabhu, 2013). Frugal innovations or products are highly affordable, robust and resistant, easy to use, and incorporate minimal resources (Economist, 2010). As the concept gained traction, frugal innovation has come to denote a new economic paradigm which involved attaining the challenging goal of "providing better solutions for more people by using fewer resources by doing things completely differently" (Leadbeater, 2014; p. x). This core tenet of frugal innovation is central to other concepts such as Gandhian innovation (Prahalad and Mashelkar, 2010) and resource constrained product development (Sharma and Iyer, 2012).

Frugal innovations are targeting mainly BOP-MOP market segments. As these consumers have limited incomes, they can afford only basic, low-cost, often outdated technologies which are easy to use and cheap to buy and maintain (Leadbeater, 2014). Consequently, frugal innovators develop new products by leveraging, updating, and scaling up older and proven technologies which are more affordable and familiar to the consumers (Leadbeater, 2014). In this sense, frugal innovators re-think extant ideas, inventions, technologies and recycle, reuse, repurpose resources (Leadbeater, 2014).

Frugal innovations were initially observed, recognised, and studied in India in the form of jugaad. The explanation for the link between frugal innovations and India is most likely related to the particularities of the Indian market which, according to Guillermo Wille, former managing director of GE India, "pushes you into a corner… it demands everything in the world, but cheaper and smaller" (Kumar and Puranam, 2012). Consequently, there are important overlaps between the two concepts. Frugal innovations are based on four design principles which are somewhat similar to the principles driving jugaad innovation discussed above (see Leadbeater, 2014).

First, frugal innovations are *"lean"*. Lean thinking is a business methodology developed by Toyota to increase value and eliminate any form of waste. Lean thinking implies eliminating the extraneous and focusing exclusively on value-creating activities (Leadbeater, 2014; Womack et al., 2007). Lean thinking is a continuous, incremental process of eliminating waste and defects as soon as they are detected (Womack et al., 2007). Being "lean" is crucial in resource-poor environments such as Japan in the years following the Second World War and the emerging markets in current times (Leadbeater, 2014).

Second, drawing on their jugaadist background, frugal innovations must be characterised by *simplicity* to ensure affordability and ease of use (Leadbeater, 2014). The design of frugal innovations involves a process of "defeaturing" or feature rationalization (Kumar and Puranam, 2012) which means that designers avoid all the unnecessary bells and whistles. Thus, frugal innovators focus only on what matters most for the consumers, proving the "20% of the features that create 80% of the value" (Leadbeater, 2014; p. 81).

Third, frugal innovations are *social* in nature. On the one hand, frugal innovations are highly relational, participative, and cooperative. Frugal innovators are rarely isolated visionaries. Instead, they are entrepreneurs living and operating among targeted customers, often coming from a similar background (Leadbeater, 2014). Frugal innovators bring together communities and social movements by engaging consumers in the development, adoption, and spreading of innovations (Leadbeater, 2014). On the other hand, frugal innovators have a social mission to meet the needs and improve the lives of marginal, overlooked consumers who are either too poor or located in remote areas to be attractive for mainstream corporations (Leadbeater, 2014).

Fourth, frugal innovations are usually *clean* and environmentally friendly (Leadbeater, 2014; Radjou and Prabhu, 2013; Sharma and Iyer, 2012). The argument is very straightforward. Frugal innovations ensure environmental sustainability by using minimal or fewer resources compared to traditional innovations which tend to be resource intensive (Sharma and Iyer, 2012). Moreover, because they are cost-driven, frugal innovations tend to rely on discarded, recycled, or non-conventional resources rather than more polluting, mainstream resources which are increasingly in short supply and, thus, more expensive (Leadbeater, 2014; Sharma and Iyer, 2012).

Frugal innovations can be achieved in three ways: new product design, new process design, and by leveraging economies of scale (Sharma and Iyer, 2012). Regarding the product design, as mentioned before, frugal innovators try to keep costs down by focusing on simple, basic functionality, often achieved by using open sourced components and systems (Leadbeater, 2014; Sharma and Iyer, 2012). A relevant example in this sense is Aakash, the $60 tablet launched in India in 2011 by several leading technical universities in collaboration with Data Wind, an UK technology start-up (Leadbeater, 2014; Radjou et al., 2012). The Aakash, which was targeting mainly Indian students, had a simplified interface and a number of preloaded educational software in local languages (Radjou et al., 2012). The Aakash used the open source Android operating system and, although it had limited computing power compared to the iPad or other mainstream tablets, it offered students capabilities such as Wi-Fi, internet browsing, and word processing software (Radjou et al., 2012).

In terms of new process design, frugal innovations generally involve the improvement or rethinking of extant processes (Sharma and Iyer, 2012). For example, Husk Power Systems (HPS) sets up mini power plants delivering electricity to hundreds of homes in the poorest

Indian villages (Leadbeater, 2014). The HPS power plants rely on biomass gasification, a technology considered obsolete. The HPS power plants convert discarded husks resulting from rice production into a synthetic gas through a controlled process using oxygen and steam (Leadbeater, 2014). The synthetic gas subsequently fuels the power plants to produce electricity (Leadbeater, 2014). Since it uses the waste resulting from rice production, the HPS gasification system is significantly cheaper than the traditional power plants using coal or natural gas. Moreover, the HPS system is much cleaner than traditional alternatives because much of the carbon dioxide which otherwise would be eliminated in the atmosphere is removed in the gasification process (Leadbeater, 2014).

The third method to frugally innovate is to leverage economies of scale by creating and delivering products and services to the masses, including BOP non-consumers which are overlooked by political systems and mainstream corporations (Sharma and Iyer, 2012). A classic example in this sense involves the Narayana Hrudayalaya (NH) Heart Hospital in Banglore, India (Leadbeater, 2014; Khanna and Bijlani, 2011; Sharma and Iyer, 2012). Doctors at NH successfully perform complicated coronary artery bypass graft surgeries for about $1,800. In addition, patients pay according to their possibilities and, thus, very poor patients are subsidised and receive heart treatment for free (Leadbeater, 2014; Khanna and Bijlani, 2011; Sharma and Iyer, 2012). A similar operation can cost over $100,000 in the US as it normally involves the use of an expensive heart-lung machine which redirects the blood flow to immobilise the heart for the duration of the operation (see Khanna and Bijlani, 2011). Doctors at NH have achieved their very low cost-point by eliminating the use of the heart-lung machine. Instead, they used manufacturing strategies, which involved setting up very large operation theatres allowing surgeons to quickly move from one patient to another, to scale up operations and achieve a labour substitution innovation (Khanna and Bijlani, 2011). Because doctors at NH perform in one day about the same number of open heart surgeries that a doctor in the US performs in a month, they have become highly experienced and proficient at operating directly on the beating heart (Khanna and Bijlani, 2011). In fact, the success rates of the NH doctors are comparable if not better than those of doctors in US hospitals (Khanna and Bijlani, 2011).

Although frugal innovations are often associated with Indian entrepreneurs and the notion of jugaad innovations, the latter remain only a facet or subcategory of the frugal wave (Leadbeater, 2014). It is apparent from the previous examples, that frugal innovations do not necessarily share the improvisational nature of jugaad innovations. Frugal innovations are very often optimal solutions for the targeted customers rather than the improvised yet functional quick fixes implied by the more conservative definition of jugaad innovation.

Moreover, frugal innovations are often developed by multinational companies which set up their own R&D facilities or find partners in emerging markets (Leadbeater, 2014; Prahalad and Mashelkar, 2010; Zeschky et al. 2014). For example, GE Healthcare's R&D unit in India developed the MAC 400, a portable electrocardiogram (ECG) device priced at only $1,000 (compared to about $10,000, the price of an ECG sold in developed countries) (Leadbeater, 2014; Sharma and Iyer, 2012). The MAC 400 used several off-the-shelf components and incorporated a printer adapted from the portable ticket machine used in Indian bus kiosks (Radjou et al., 2012). The MAC 400 was designed to address local requirements: it was light allowing local doctors to carry it on the motorcycles or bicycles, it had long battery life, and it was solid and resistant to dust (Leadbeater, 2014; Prahalad and Mashelkar, 2010; Radjou et al., 2012). Similarly, Harman, an American company producing among others high-end audio equipment for the automotive sector, set up small R&D facilities in India and China to develop a more affordable infotainment system called Saras for vehicles sold in the fast-growing Indian and Chinese markets (Govindarajan and Ramamurti, 2011; Leadbeater, 2014). The resulting Saras infotainment unit had fewer features, used open source software, and relied on off-the-shelf chips generally used for smartphones.

Some frugal innovations that were developed in and for emerging markets, such as GE's MAC 400 and Harman's Saras infotainment, traveled to developed countries in the form of reverse innovations (Govindarajan and Ramamurti, 2011).

2.3.3 Cost innovation

Cost innovation (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007) is the third concept developed to capture the nature of innovation emerging markets, particularly in China. Cost innovation refers to the strategies employed by leading Chinese companies or "dragons" (Zeng and Williamson, 2007) to aggressively cut costs and offer similar product functionality at much better value-for-money to customers worldwide (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007). The concept of cost innovation refers to cost reductions far exceeding the wage differential between developed countries and emerging markets such as China (Zeng and Williamson, 2007). Thus, the Chinese dragons deploying cost innovation strategies can successfully defend their cost advantage even when developed country competitors outsource their manufacturing operations to emerging markets to benefit from low labour costs (Zeng and Williamson, 2007).

Like jugaad and frugal innovators, the Chinese dragons relying on cost innovation do not pursue the same routes for innovation as the incumbent industry leaders (Zeng and Williamson, 2007). The strategies of the Chinese dragons challenge some of the entrenched assumptions of top multinationals from developed countries which held that cutting-edge high technology, product variety and customization, as well as specialist, niche products demand a price premium allowing producers to reap hefty profits (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007). In fact, cost innovation has three facets: (i) providing high technology at low prices; (ii) offering a wide choice of products in otherwise standardised, mass-market segments; (iii) delivering specialized products at significantly lower costs, thereby transforming niche segments into volume businesses (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007). Thus, market segments such as high-tech products, highly customised, and niche/specialist products, which were previously perceived as havens for companies from developed countries, come increasingly under attack by emerging Chinese dragons (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007).

First, the Chinese cost innovators manage to sell at low prices products that incorporate high technology by relying on cheap yet effective R&D staff, recombining low-cost, mature technologies, and using open architectures (Zeng and Williamson, 2007). For example, the Chinese firm Dawning produced one of its first high-performance supercomputers by clustering together 32 basic, standard Intel i860 chips (Zeng and Williamson, 2007). While industry leaders from developed countries were focusing their R&D efforts on improving the individual performance of new chips and state-of-the-art operating systems, Dawning's supercomputers achieved similar performance using a technology called "parallel computing" which involved standard hardware modules working in unison and a modified UNIX operating system (Zeng and Williamson, 2007). Although Dawning's approach was not highly revolutionary, it was certainly challenging the status quo in the supercomputer industry.

Second, the Chinese dragons offer a wide variety of products and a high degree of customization at mass-market prices by developing flexible production processes (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007). When BYD, the Chinese producer of rechargeable batteries, first entered the international market in 1995, they replaced the typical, fully automated Japanese and Korean production lines for nickel cadmium (NiCad) batteries with labour intensive production lines where many operations were completed using manual procedures instead of expensive machinery (Zeng and Williamson, 2007). Thus, BYD addressed their lack of resources by developing a labour substituting innovation (i.e. substituting labour for automation). The BYD NiCad production lines employed roughly 10 times more workers than those of Japanese and Korean competitors, but they were about 8 times less costly to set up, while the production costs of BYD NiCad batteries were about 5 or 6 times lower than those incurred by competitors (Zeng and Williamson, 2007). In addition, the BYD production lines were significantly more flexible than those of established competitors (Zeng and Williamson, 2007). The fully automated production lines of incumbents proved inefficient when handling small batch production, especially if some customisation was required (Zeng and Williamson, 2007). The Japanese production lines could produce only one product at a time and the expensive retooling required to move to a new product could take up to three months (Zeng and Williamson, 2007). In contrast, BYD was able to change to new products in only a few weeks by adjusting key equipment and retraining workers (Zeng and Williamson, 2007). By 1999, the simple labour intensive production strategy made BYD the world's largest producer of batteries for toys, cordless phones, and power tools (Zeng and Williamson, 2007).

Third, the Chinese dragons use their cost advantages to turn premium niches into large mass-markets (Williamson and Zeng, 2009; Zeng and Williamson, 2007). For example, Shinco, the Chinese DVD player producer, chose not to attack global incumbents such as Sony, Panasonic, and Samsung on their main market for table-top DVD players (Williamson and Zeng, 2009; Zeng and Williamson, 2007). Instead, Shinco focused on portable DVD players which, by 2002, had failed to penetrate mainstream markets given their high relative price (Williamson and Zeng, 2009; Zeng and Williamson, 2007). Shinco engineers relied on an older error-correction technology, which they had developed initially to allow Chinese users to watch low quality pirated DVDs, to compensate for the inherent jumps and shakes that happen when watching a DVD in motion (e.g. in a car or a train) (Williamson and Zeng, 2009; Zeng and

Williamson, 2007). Given that the Chinese portable DVD player was sold at roughly 50% of the price of competitor products, Shinco successfully unlocked the latent potential of portable DVD players (Williamson and Zeng, 2009; Zeng and Williamson, 2007). Shinco soon became the leader on the portable DVD player market which increased significantly in the following years (Williamson and Zeng, 2009; Zeng and Williamson, 2007).

Chinese cost-innovators often follow a similar development path by first establishing a solid position in their home market. This means that they develop the cost-cutting ability required to service highly price-sensitive local customers (Zeng and Williamson, 2007). The sheer size of the Chinese market allows the emerging dragons to achieve economies of scale and, thereby, to slash prices even more (Zeng and Williamson, 2007). By the time they internationalize, Chinese dragons have a significant cost advantage compared to established competitors while providing similar product functionalities (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007). This allows them to win market share at a very fast pace, forcing incumbents to move to higher-end segments of the market (Zeng and Williamson, 2007). However, this retreat to “the sunlit uplands” is usually unsustainable in the long-run for incumbents from developed countries (Zeng and Williamson, 2007; p. 11). On the one hand, the volumes in the high-end segments are insufficient to support high fixed costs of R&D over the long term and, thus, the incumbents’ will face difficulties in keeping up with the demands of high-end customers (Zeng and Williamson, 2007). On the other hand, the Chinese companies often use part of their substantial profits derived from selling large volumes in low-end segments for R&D activities or to license state-of-the-art technology (Zeng and Williamson, 2007). This newly acquired high technology allows the dragons to target high-end segments and enter completely new markets (Zeng and Williamson, 2007). For example, Dawning successfully developed and commercialized 64-bit computer chips one year ahead of Intel (Zeng and Williamson, 2007). Dawning also transferred its technological capability and cost advantage to the market for low-end servers (Zeng and Williamson, 2007). Similarly, BYD invested significant resources in the development of lithium-ion (Li-ion) technology and gained important shares in the markets for mobile telephones, portable computers, and electric vehicles (Zeng and Williamson, 2007). Lastly, Shinco leveraged its past DVD player success to enter the markets for LED-screen TV-sets and tablets[2].

2.3.4 Comparing jugaad, frugal, and cost innovations

Undoubtedly, jugaad innovation, frugal innovation, and cost-innovation provide valuable insights regarding the process of innovation in emerging markets. However, there are important similarities and differences between these concepts which can cause a fair amount of confusion. Consequently, the following subsections will describe the relationship between the three concepts and discuss why the idea of bricolage is central for fully understanding these concepts (see table 1 below).

It is apparent that the core tenet of all three concepts is doing (or achieving) more with fewer resources. The reason for adopting this mantra is that emerging market innovations often target BOP-MOP customers who have limited disposable incomes and cannot afford mainstream products offered by developed country multinationals. In addition, emerging market innovators have to work around serious resource constraints (e.g. Govindarajan and Ramamurti, 2011). However, while this usually true for jugaadist and frugal innovators, not all cost-innovators are resource constrained, at least not to the same extreme extent as their jugaadist and frugal counterparts. In fact, many Chinese innovating companies enjoy the generous support of the local and central governments (Zeng and Williamson, 2007).

[2] Information available on the Shico company website: http://www.shinco.com/.

Another feature shared by all three concepts is that emerging market innovators usually challenge conventional wisdom, disregard established methodologies, and adopt unusual innovation practices in order to overcome the contextual constraints that they face. Moreover, jugaadist, frugal, and cost innovators often rely on labour substituting innovations (i.e. substituting labour for automation) to achieve highly flexible production systems.

Jugaadist, frugal, and cost innovators tend to take an open approach to innovation. While jugaad and frugal innovators often rely on the involvement of targeted customers and on the recombination of low-cost, older (often obsolete) technologies imported from various sources, cost innovators usually buy, licence, or co-develop with third-parties technologies, components, and production systems.

A final yet important feature shared by the three types of emerging market innovation is their disruptive potential (e.g. Markides, 2012; Zeng and Williamson, 2007). Once jugaadist, frugal, and cost innovators establish themselves in their local markets and gain sufficient market share either by attracting value conscious customers from competing DMNEs or by tapping into the vast pool of BOP non-consumers, these emerging market innovators become able to invest in R&D activities and improve the performance and quality of their products, while maintaining their cost advantage (Markides, 2012; Zeng and Williamson, 2007). This evolutionary trajectory, which resembles a lot to the one of the Japanese automakers after the Second World War, often continues with gradual moves to higher-end market segments (Markides, 2012; Zeng and Williamson, 2007). As products from emerging markets become competitive performance-wise, developed country incumbents are cornered into small-volume niches (Markides, 2012; Zeng and Williamson, 2007).

In terms of differences, jugaad innovation stands apart due to its improvisational nature. Although jugaad innovations can be regarded as a subcategory of frugal innovations, the latter are often optimal solutions for the medium or even long term. Moreover, cost innovations are not only optimal solutions but they are also competitive performance-wise with the products of multinationals from developed countries. While jugaadist and frugal innovations involve the paring down or “defeaturing” of mature technologies and products to ensure affordability, cost innovations usually provide similar features and functionalities as the products of developed-country competitors. Cost innovations also differ from jugaad and frugal innovation by being exclusively profit driven and lacking an explicit social mission of improving the lives of BOP consumers.

Most importantly, the concepts of jugaad innovation, frugal innovation, and cost innovation differ in the nature of their meaning. Jugaad innovation can be interpreted as an art form, mind-set, or culture conducive to the development of low-cost, improvised outcomes (i.e. a solution, product, or service). Given this nature of the concept, jugaad innovation seems to remain the attribute of innovator heroes who are artistic, creative, emphatic, and grounded enough to achieve ingenious outcomes despite their challenging environment. Thus, all that organisations can do in practice to achieve jugaad innovations is to attempt to cultivate the creative, jugaadist spirt of employees. The concept of frugal innovation generally designates an outcome and, although relevant, the four characteristics of frugal outcomes (i.e. lean, simple, clean, and social) provide only limited insight into how such outcomes can be achieved. Finally, although cost innovation can also be viewed as an outcome, the concept refers mainly to a strategy of offering more value-for-money to customers by leveraging the cost advantage of firms from emerging markets. While prior studies on cost innovation (Williamson, 2010; Williamson and Zeng, 2008; Williamson and Zeng, 2009; Zeng and Williamson, 2007) provide some broad indications on how companies from emerging markets derive their cost advantage, they offer little detail into the process of cost innovating which remains a black-box.

Paradoxically, despite their different nature, the three types of emerging market innovations share a common shortcoming as it is unclear how they can be achieved in a consisted, systematic, replicable manner. Although it is true that creativity cannot be systemised, structured, or formalised (Radjou et al., 2012), the practical value of concepts such as jugaad innovation, frugal innovation, and cost innovation remains limited in the absence of some insights or guidelines regarding replicable activities that managers can undertake to achieve cost-driven, innovative outcomes.

2.3.5 The bricolage underpinnings of jugaad, frugal, and cost innovation

In general, emerging market companies are perceived as "technological followers" that are recently catching up with competitors from developed countries in terms of manufacturing capabilities (Awate et al., 2012; Subramaniam et al., 2015). These emerging market companies, which develop jugaad and frugal innovations, typically pare down mature technologies to meet the cost requirements of emerging market customers. Two recent empirical studies of emerging market innovations provide good illustrations of this argument: Tata Motors' development of Nano, the world's cheapest car (Ray and Ray, 2011) and Godrej & Boyce's development of a small portable cooling unit to meet the needs of customers in rural India (Eyring et al., 2011). Tata Motors used an adapted motorcycle starter motor and a two-cylinder engine, also specific to motorcycles, to cut the cost of its Nano car (Ray and Ray, 2011). Similarly, Godrej & Boyce replaced the compressor, cooling tubes and refrigerant of a conventional refrigerator with a fan resembling those which prevent computers from overheating and a chip that cools when electricity is applied (Eyring et al. 2011).

However, not all innovations from emerging markets involve the paring down of mature technologies. The Chinese cost innovations offer similar functionalities and performance as high-end products from developed countries. For example, Dawning's supercomputers developed in mid-1990's on an open architecture involving the clustering together of standard, off-the-shelf hardware modules (i.e. chips) were not inferior performance-wise to foreign supercomputers using state-of-the-art chips (Zeng and Williamson, 2007). Similarly, the Eka supercomputer developed in 2007 by Computational Research Laboratories, belonging to the Tata Group, was considered the fourth-fastest supercomputer in the world (Prahalad and Mashelkar, 2010). The Eka also involved an open architecture incorporating exclusively off-the-shelf servers and relied on the open-source Linux operating system (Prahalad and Mashelkar, 2010). These examples suggest that low-cost, frugal innovations achieved through the paring down of mature technologies as well as highly performant cost innovations are often developed through bricolage activities and processes such as the creative recombination of technologies and non-specialized components.

Concepts such as jugaadist, frugal, and cost innovation do not account for the development of radical technologies and products. The three established types of emerging market innovation seem to assume that technologies (older or newer) are imported, assimilated, and then improved incrementally as the emerging market companies close the technological gap and move towards higher-end segments. However, bricolage processes appear to be central for emerging market companies engaging in the development of more radical, cutting-edge technological products. The case of relatively nascent industries such as regenerative medicine (see McMahon and Thorsteinsdottir, 2013) and electric vehicles (which are the focus of this thesis) offer good illustrations. In a recent study, McMahon and Thorsteinsdottir (2013) showed how emerging market innovators in the regenerative medicine industry developed systemic innovation capabilities and products through contributions from multiple entities such as firms, governmental bodies, universities and research centres, hospitals, cord blood banks, and in vitro fertilization clinics. It seems that at least some emerging market companies are poised to become "technological leaders" through strategies involving distributed agency, innovative collaborations, and recombination of resources (often belonging to multiple actors), which chime with prior studies on bricolage (see Garud and Karnoe, 2005). This reliance on networking and relationship-based strategies is obviously closely linked to institutional voids such as the lack of intermediary and support services, poorly enforced regulations, and poor infrastructure (Dhanaraj and Khanna, 2011), which arguably weigh heavier for companies pursuing radical innovations than for those targeting incremental innovations. Although this body of literature may not explicitly use the term, it hints at a conscious managerial deployment of bricolage-based approaches in the new technology development process.

Just like jugaad innovation, frugal innovation, and cost innovation, bricolage seems to thrive in harsh, turbulent, resource-poor environments characteristic for emerging markets. In addition, the notion of bricolage describes and explains the activities and processes underlying jugaadist, frugal, cost, and more radical innovations originating from emerging markets. For a detailed comparison of the scopes of each of the four concepts (i.e. jugaad, frugal innovation, cost innovation, and bricolage), please see Table 1 below.

Table 1. Comparison between the scopes of concepts

	Jugaad Innov.	Frugal Innov.	Cost Innov.	Bricolage
… achieving "more with less"	√√	√√	√√	√√
Resource constraints	√√	√√	√	√√
Improvised solution	√√	√	X	√
Challenging status quo	√√	√√	√√	√√
Open innovation approach	√	√√	√√	√√
Disruptive potential	√√	√√	√√	√√
Optimal solution	X	√	√√	√
Paring down of mature technologies	√√	√√	X	√√
Incremental innovation	√√	√√	√√	√√
Radical innovation	X	X	X	√√
Designates an art form or mind-set	√√	√	X	√
Designates a product	√	√√	√	X
Designates a strategy	X	X	√√	√√
Designates a process or an activity	X	X	X	√√

In this last section of the literature review chapter, we argued that extant literature on emerging market innovation lacks clear categorisations and, consequently, can generate a fair amount of confusion. As jugaad and frugal innovation face the danger of becoming meta-concepts with very broad scopes and little explanatory power, there is significant overlap between the three main concepts developed to capture and explain emerging market innovation (i.e. jugaad innovation, frugal innovation, and cost innovation). Another shortcoming of the extant literature on emerging market innovation is that it provides very few insights regarding the organisational processes underpinning the development of jugaad, frugal, and cost innovations. In the absence of a clear understanding of the underlying processes, it remains unclear how such innovative outcomes can be achieved in consistent and replicable fashion. To address these shortcomings, we provided a critical evaluation of the extant literature and tried to untangle the three main concepts (i.e. jugaad innovation, frugal innovation, and cost innovation) by clearly identifying the unique characteristics of each concept, as well as the similarities and differences between them (see Table 1 above). Moreover, we gathered compelling evidence from extant literature suggesting that bricolage processes such as creative recombinations of accessible, non-specialised resources are in fact supporting the development of jugaad, frugal, and cost innovations in emerging markets. We have also drawn critical comparisons between bricolage, on the on hand, and jugaad, frugal, and cost innovations, on the other (see Table 1 above). In the next chapters of this thesis, we develop these arguments further through an in-depth qualitative case study of an Indian electric vehicle (EV) manufacturing company.

Chapter 3: Research Methodology

This chapter conveys the philosophical assumptions underpinning this study and outlines the research methodology. In addition, this chapter explains the relevance of the chosen methodology for our inquiry and helps guide the readers' assessment of the overall quality or "goodness" (Guba and Lincoln, 2005) of this doctoral study.

Interpretivism is the inquiry paradigm informing this research (Cohen and Ravishankar, 2012; Lincoln et al., 2011). The inquiry strategy was designed to capture knowledge about a socially constructed organisational reality and, therefore, the qualitative case approach was employed. The methods used for data collection and analysis were also commensurate with the interpretivist paradigm. In this sense, hermeneutics (Gadamer, 1975; Myers, 1997) was the main mode of analysis for our interviews, field observations and company documents. The present study employs a retrospective approach. The interviews and documents analysed throughout this study trace events and outcomes spanning over a period of about two decades.

Bangalore-based Mahindra Reva, India's sole EV maker, was selected as a case of a distinctive organisation attempting to develop disruptive technologies. The fieldwork was conducted between June and September 2013. However, secondary data about the company was collected throughout 2013 and the spring of 2014.

This chapter is divided into six sections. The first section focuses on the philosophical assumptions informing this study, provides definitions, and discusses how these assumptions are reflected in the study. The second section describes the rationale based on which the methodology was chosen and provides an overview of case study research as means to develop in-depth understanding regarding context-bound phenomena. The third section briefly discusses how the case on which this doctoral thesis focuses was selected and how access was negotiated. The fourth section provides background information on Mahindra Reva, presents their main products, and discusses how the company plans to expand its product range. The fifth section presents the methods used for data collection. The last section discusses the role of theory in our analysis and the procedures used to analyse the data.

3.1 Underlying philosophical assumptions

Given the nature and aim of this doctoral study, we adopted interpretivism (also labelled as constructivism; see Cohen and Ravishankar, 2012; Creswell, 2013; Lincoln et al., 2011) as inquiry paradigm. Paradigms represent sets of beliefs and assumptions which inform the choice of research questions and theories, shape the methods of accessing and collecting information, and generally guide the researcher's actions (Creswell, 2013; Guba, 1990). These assumptions relate to the nature of reality (ontology), the nature of knowledge and how knowledge claims can be justified (epistemology), the role of values in research (axiology) and the process of research (methodology) (Creswell, 2013; Lincoln et al., 2011).

In this thesis, we share the stance which views interpretivism and constructivism as equivalent concepts (e.g. Lincoln et al., 2011; Creswell, 2013). In other words, interpretivism and constructivism are different labels for the same inquiry paradigm. According to Lincoln et al. (2011), there are five such inquiry paradigms: positivism, postpositivism, critical theory, interpretivism (or constructivism), and postmodernism. Their stance posits that these paradigms rest on two main ontological assumptions (based on which several variations can be derived), namely realism and relativism corresponding to the two groups of compatible inquiry paradigms – positivism/postpositivism and interpretivism/postmodernism respectively. Furthermore, Lincoln et al. (2011) also argue that there are two main epistemological assumptions (again with variations), namely objectivism corresponding to the positivist and postpositivist paradigms, and subjectivism corresponding to the interpretivist, critical and postmodern paradigms.

Lincoln et al.'s (2011) stance departs significantly from other perspectives regarding philosophical underpinnings in social sciences such as Bryman (2012) and Orlikowski and

Baroudi (1991). Bryman (2012) draws a clear demarcation line between constructivism and interpretivism by claiming that the former represents an ontological assumption, while the latter is an epistemological one. Orlikowsli and Baroudi (1991) chose to discuss positivism, interpretivism, and critical theory only as epistemological perspectives. In this thesis, we adopted Lincoln et al.'s (2011) perspective as it seemed more comprehensive and logically sound.

3.1.1 Ontology

Ontology is defined as the nature of reality (Creswell, 2013) or "the worldviews and assumptions in which researchers operate in their search for new knowledge" (Schwandt, 2007; p. 190). The interpretivist ontology posits that there are multiple realities depending for their form and content on each individual (Guba, 1996). In this sense, reality is a mental model socially constructed through interactions and lived experiences (Lincoln et al., 2011). According to Guba and Lincoln (1985), interpretivists develop their own personal realities as "the way we think life is and the part we are to play in it is self-created" (p. 73).

Drawing on this ontological foundation and considering that technology development itself is a social process, we relied on the participants' subjective perspectives and interpretations in our endeavour to capture the complexity of the investigated phenomenon. We also paid attention to possible historical and cultural factors influencing the interpretations and sense-making of the participants. Moreover, we used secondary data from various independent sources (e.g. media reports, customer reviews) to triangulate the reality about technology development we constructed in this study based on our own lived experience in the field, at Mahindra Reva, and on the face-to-face interactions with the informants.

3.1.2 Epistemology

Epistemology refers to the nature of knowledge claims (Walsham, 1995), the relationship between the researcher and that being researched (Creswell, 2013) and the relationship between "what we know and what we see" (Lincoln et al., 2011). The interpretivist epistemological stance is viewed as transactional or subjective in the sense that knowledge is co-created in the process of interaction between researcher and subjects (Guba and Lincoln, 2005). Moreover, interpretivists consider that the researcher and the object of inquiry are merged into a single entity (Guba and Lincoln, 2005) because "we cannot know the real without recognizing our own role as knowers" (Flax, 1990) and "we are studying ourselves studying ourselves and others" (Preissle, 2006; p. 691). Therefore, the interpretivist epistemology posits that the researchers' background will always transpire in the knowledge they generate (Lincoln et al., 2011).

Relating these assumptions to the present study, our role in the creation of knowledge was threefold. First, we initiated the dialog with the informants and elicited their views and experiences related to the process of technology development at Mahindra Reva. E.M. Forster's reflection "How can I tell what I think till I see what I say?"[3] suggests that individuals become aware of their own ideas and opinions only when these mental constructs are verbalized (see Tsoukas and Chia, 2002). In this sense, it could be claimed that the informants' views and interpretations did not exist until they were articulated during the interaction with the researcher. Second, the informants' interpretations were guided by our questions which were formulated based on our perspective on the phenomenon. Third, the study reflects our own analysis and understanding of the informants' words and interpretations. Moreover, the choice of theoretical lenses and the framing of the study were influenced by our background, interests and prior knowledge (see Creswell, 2013).

[3] E.M. Forster (1927) *Aspects of the novel*. Edward Arnold, Cambridge, UK.

3.1.3 Axiology

Axiology refers to the philosophical theory of value (Merriam-Webster Online Dictionary), the role of values (Creswell, 2013) and "how researchers act based on the research they produce" (Lincoln et al., 2011; p. 111). Because its scope includes religion, it was considered that axiology does not belong in the realm of scientific inquiry. However, Lincoln et al. (2011) argue that axiology should be included among the foundations of inquiry paradigms. According to them, values influence the inquiry process in multiple ways such as the choice of research topic, choice of theoretical lenses, choice of methods, or choice of context (Lincoln et al., 2011). From an axiological perspective, positivists and postpositivists aim to gain an understanding of reality which is as close as possible to the "truth". Critical theorists seek to address social injustice and determine positive change through their research (Lincoln et al., 2011). Similarly to critical theorists, interpretivists see themselves as generating knowledge which could contribute to social and technological progress (Lincoln and Guba, 1985). However, while critical theorists aim for immediate change, the goal of interpretivists is more reflective and long-term oriented (Lincoln et al., 2011).

The present study aims to provide context-dependent information on technology development in emerging markets. Such context-specific information can help entrepreneurs and managers develop expert or virtuoso knowledge on technology development (see Flyvbjerg, 2006), thereby contributing to technological progress. This study also focuses on the development of environmentally friendly, sustainable mobility solutions which could address important social concerns such as pollution and global warming if adopted. Moreover, the insights provided in this thesis may help firms address the cost requirements of BOP-MOP consumers and turn these previous non-consumers into consumers, thereby improving the quality of life of this marginalised segment.

3.2 Methodology

Methodology refers to the process of seeking out new knowledge and the principles of inquiry (Schwandt, 2007). Generally, the interpretivist methodology is hermeneutic[4] and dialectic (Lincoln et al., 2011). Interpretivists rely on naturalistic methods such as observation, interviewing and analysis of texts, which allow researchers and participants to "collaboratively construct a meaningful reality" (Lincoln et al., 2011; p. 105).

For this study, primary data was collected through face-to-face interviews and field observations. Secondary data was gathered from written materials produced by Mahindra Reva and independent reports published in Indian and international media. The primary and secondary data reflecting the perspectives of informants and other independent observers were interpreted hermeneutically (i.e. the meaning of a complex whole is understood by recognising the meaning of individual parts and vice versa, see Gadamer, 1975) and then compared and contrasted dialectically until a coherent perspective on the phenomenon of interest finally emerged (see Lincoln et al., 2011).

3.2.1 Rationale for choice of methodology

Sjoberg et al. (1991) defined methodology as "the analysis of the intersection (and interaction) between theory and research methods and data" (p. 29). Van Maanen (1979) suggested that methodology should be viewed as a map which helps the researchers interpret the 'slice' of social reality chosen for investigation. In a similar vein, Miles and Huberman (1994) argued that the choice of methodology should be driven by the aim and the nature of the research endeavour and the context of the phenomenon of interest (also see Cohen and Ravishankar, 2012; Lincoln et al., 2011). Accordingly, the methodology choice for the present doctoral thesis was determined by the objective and characteristics of the research questions.

[4] Hermeneutics can be viewed both as an underlying philosophy and as a mode of analysis (Myers 1997). Hermeneutics as mode of analysis will be discussed in the Data Analysis section.

Since the aim of this study was to understand the mechanisms underpinning the process of technology innovation in emerging markets, we chose a qualitative approach. The qualitative methodology was not only very useful and appropriate but, in fact, was the *only* viable path for two reasons. First, illustrating how a certain organisation approached technology development and explaining why it has done so does not lend itself to measurement or experimental examination, thus making quantitative approaches unfeasible for the purpose of this research topic. In contrast, qualitative methods allow researchers to understand human agency and "interpret phenomena in terms of the meanings people bring to them" (Lincoln et al., 2011; p. 3). Second, we expected the socio-economic context to play a central role in our research. Unlike quantitative studies which generally try to establish rules or causal relationships generally applicable (i.e. context-independent), qualitative research involves studying phenomena in their natural setting or context (Cohen and Ravishankar, 2012; Lincoln et al., 2011). In other words, qualitative studies allow researchers to provide a naturalistic perspective on human experience (see Cohen and Ravishankar, 2012; Mayasandra et al., 2006; Nelson et al., 1992; Sandeep and Ravishankar, 2016).

Qualitative research is associated with various means of inquiry such as case studies, ethnographies, participant observations, grounded theory, or phenomenology (Cohen and Ravishankar, 2012; Lincoln et al., 2011). In social sciences, the use of the case study is now "solidly ensconced, and, perhaps, even thriving" (Gerring, 2004; p. 341). We chose the case study as mode of inquiry for several reasons. First, the interpretive case study relies on naturalistic methods such as observation and interviewing, which allowed us to understand the innovation process within its contextual setting from the perspective of the informants (see Cohen and Ravishankar, 2012; Lincoln et al., 2011; Mayasandra et al., 2006; Sandeep and Ravishankar, 2016). Second, bricolage is generally used as an analogy in social sciences and, as such, it is dependent on the meanings assigned to it by informants and researchers. Thus, the notion of bricolage lends itself particularly well to interpretive research (e.g. Baker and Nelson, 2005; Di Domenico et al., 2010; Levi-Strauss, 1966; Weick, 1993). Third, the case study allows researchers to access a variety of evidence (e.g. documents, interviews, observations) reflecting the social complexity of emergent, locally specific realities (see Cohen and Ravishankar, 2012; Mayasandra et al., 2006; Sandeep and Ravishankar, 2016). Fourth, it is often easier for researchers without an established reputation to negotiate access to an organisation for a rather short timeframe (i.e. a few months) which would be inappropriate for an ethnographical study, for example.

3.2.2 Definition and main characteristics of the case study

There are multiple definitions available for the term "case study" (see Eisenhardt, 1989; Yin, 2003). All definitions have their individual strengths and limitations as they depend on the priorities and epistemological stances (i.e. positivist/postpositivist vs. interpretivist/critical) of authors employing the case study as strategy of inquiry (Thomas, 2011). For the purpose of this doctoral thesis, we adhere to Simons' (2009) definition which takes an interpretivist perspective and states that a "case study is an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, program or system in a 'real life' context" (p. 21).

However, the debate about what a case study actually is does not end here as there can multiple interpretations of this definition. On the one hand, some see the case study as a choice of what is to be studied rather than a methodological or method choice (Simons, 2009; Stake, 2005). Adepts of this view argue that the case study can integrate a number of methods, thereby suggesting that "analytical eclecticism" is central to the case study debate (Thomas, 2011; p. 512). On the other hand, Creswell (2013) considers the case study to be "a methodology: a type of design in qualitative research that may be an object of study, as well as a product of the inquiry" (p. 97). The main difference between these two interpretations is that the former views the 'case' as the subject of the inquiry or the unit of analysis, while the latter views the 'case' as the object of the inquiry or the analytical framework. In this doctoral study, we take the first perspective.

Drawing on extant literature, it can be argued that the case study has five distinctive features. These are:

- The *subject* of the inquiry which is represented by a practical, historical unit (Thomas, 2011). As suggested by Simons' (2009) definition, this unit of analysis can be a person, event, project, policy, organisation or some other system bounded by place and time (Stake, 2005). The unit of analysis to be studied provides an opportunity to relate facts and concepts, but it has little meaning in itself and it should not be confused with a concept (Wieviorka, 1992). In this doctoral thesis, the subject of the inquiry is represented by the Indian EV-maker Mahindra Reva.
- The *object* of the inquiry which is represented by an analytical or theoretical framework based on which the unit of analysis or the subject is studied and which the subject exemplifies (Thomas, 2011). Typically, the object can be identified as the answer to the question "What is this a case of?" (Thomas, 2011). The analytical framework can be chosen at the beginning of the study or it can emerge as the inquiry advances. However, the way the object crystallizes and develops is always "at the heart of the study" (Thomas, 2011, p. 514). The analytical framework allows the researcher to investigate and assign meaning to the subject or the case (Wieviorka, 1992). In this study, the object of inquiry is represented by a bricolage-based perspective on technology development.
- An *in-depth understanding* of the relationship between the subject and the object, which is considered to represent the "hallmark of a good qualitative case study" (Creswell, 2013; p. 98). Such in-depth understanding can be achieved by

investigating the subject in its natural setting where the researcher has little control over behaviour, events, and organisation (VanWynsberghe and Khan, 2007; Yin, 2003). In addition, case study researchers aim to provide an abundance of contextual detail which contributes to the richness and completeness of the analysis (Flyvbjerg, 2006; VanWynsberghe and Khan, 2007). For the purpose of this doctoral study, we developed an in-depth understanding of Mahindra Reva's approach to disruptive technology development by conducting extensive fieldwork within the company's ranks and by paying attention to the company's general context as well as to the participants' individual background.

- *Multiple data sources* which facilitate the triangulation of information, thereby providing more credibility to the findings (VanWynsberghe and Khan, 2007; Yin, 2003). In this study, the data was provided by 45 informants representing various hierarchical levels at Mahindra Reva such as lower-level managers, middle managers, and top-level managers. In addition, interviews were conducted with 5 mid-level managers employed by the PR and advertisement agencies contracted by Mahindra Reva. Furthermore, articles referring to Mahindra Reva and published in independent online business media were collected for a period of 15 months and analysed in order to grasp the perspective of independent observers.
- *Multiple methods* for gathering evidence and collecting data are often employed by case study researchers (Stake, 2005; Thomas, 2011). As case studies do not require specific data collection procedures (Eisenhardt, 1989; VanWynsberghe and Khan, 2007), researchers tend to employ multiple methods in an attempt to provide as much contextual detail as possible and to capture interpretations from different sources. For this study, data was collected through face-to-face interviews, field observations, and document analysis.

3.2.3 Case study typologies

Arguably as a consequence of the multitude of case study definitions, there are numerous case study typologies available in the extant literature. We review below two of these typologies and discuss how this doctoral study fits in each classification. First, Stake (2005) identified three types of case studies:

- The instrumental case study, where the researcher aims to understand a certain phenomenon and identifies a case which exemplifies that respective issue;
- The collective case study (or multiple case study), where the researcher selects multiple cases to illustrate the phenomenon of interest;
- The intrinsic case study, where the researcher focuses on a unique or unusual case which needs to be investigated and explained.

The Mahindra Reva case falls in the instrumental case study category as it aptly exemplifies the process of technology development in emerging markets. However, given the company's local context and unusual approach to innovation, it could be argued that the case is rather unique and warrants in-depth investigation.

Second, drawing on the work of Eckstein (1975), George and Bennett (2005) developed a more comprehensive typology of case studies:

- Atheoretical/configurative idiographic case studies, namely illustrative studies which do not make any theoretical contributions;
- Disciplined configurative case studies, where theory is used to explain the phenomenon of interest;
- Heuristic case studies, where causal relationships are identified;
- Theory testing case studies, where the scope and validity of a theory are assessed;
- Plausible probes, where a preliminary study is undertaken to determine whether further investigation is warranted;

- “Building block” case studies of particular types or subtypes of a phenomenon, where common patterns or some sort of heuristic is identified.

This doctoral study represents a disciplined configurative case study as we employ the theories of bricolage and disruptive innovation to explain Mahindra Reva’s approach to technology development.

3.2.4 Generalisation from case studies

The case study approach is often criticised by researchers taking a positivist or postpositivist stance because the conclusions drawn from a single case study cannot be widely generalised (Flyvbjerg, 2006). However, case study research can produce mid-range theories which could be used in similar contexts (Eisenhardt, 1989). Moreover, the conclusions and explanations derived from a case study should be viewed as ‘tendencies’ which provide valuable insights on past events and behaviours, but do not offer predictions (Walsham, 1995). Such explanations emerging from in-depth case studies may help managers and organisations make sense of future situations and contexts.

Moreover, Walsham (1995) proposed four types of generalisation from case studies: the development of concepts, the generation of theory, the drawing of specific implications, and the contribution of rich insight.

This doctoral study draws important implications regarding the organisational processes underpinning the development of frugal and cost innovations in emerging markets. The findings of present study also draw specific implications concerning the relationship between bricolage-based processes and the development of disruptive (Christensen, 1997) and discontinuous (Lynn et al., 1996) technologies which may be extended beyond the emerging-market context of our case study. The implications drawn from this study can also offer organisations a novel perspective on the marketing of disruptive technologies.

3.3 Case selection and access negotiation

Identifying a relevant 'case' or site to conduct the research is a vital issue for all qualitative case studies. The conventional wisdom regarding the case (organisation) selection is based on Yin's (2003) guidelines which suggest that the case selection process should start with a shortlist of some 20 candidate organisations. The viability of each candidate should be assessed against the theoretical framework informing the study. If the field reality does not match "the study's original theoretical propositions", then the case should be abandoned and the researcher should move on to the next shortlisted organisation (Yin 2003, p. 50). However, Pan and Tan (2011) criticized Yin's perspective for holding "idealised" and unrealistic assumptions about access availability making it unfeasible for most "aspiring case researchers" (p. 162). As an alternative Pan and Tan (2011) proposed a "planned opportunism" approach to case selection which allows "research interests, funding strategies, and explicit opportunities for network-building [to] shape the long-term plan for case selection" (p. 165).

Consequently, for this doctoral thesis we employed the more pragmatic and opportunistic strategy suggested by Pan and Tan (2011). While the objectives of this doctoral study were driven by our interest in companies developing frugal and cost innovations, the choice of the research site was decisively influenced by a friend who held a lower-level managerial position at Mahindra Reva and offered to intermediate the access negotiation with the company's Chief of Technology and Strategy. An additional element which may have influenced the Chief of Technology and Strategy's approval for our access request was the fortunate coincidence that his father, also the company's founder, was a Loughborough University alumnus and honorary doctorate holder.

3.4 Case background[5]

3.4.1 Company origins

The origins of the current Mahindra Reva Company trace back to December 1994 when Indian Maini Group and US-based Amerigon Inc. set up the basis of a joint-venture named Maini-Amerigon Car Company with the goal to develop and manufacture EVs targeting primarily the Indian market.

The Maini Group is a Bangalore-based family owned business established by Dr. Sudarshan Maini in 1973, and currently comprises, among others, Maini Precision Products (MPP), Maini Materials Movement (MMM), and Maini Plastics and Composites (MPC). MPP, the Group's first company, currently supplies high-precision automotive components and assemblies to customers such as GM, Bosch, Volvo, Honeywell, and Renault. MMM was established in 1986 and, following a collaboration with the Danish company Vestergaard, became the first Indian company to manufacture electrically-operated material handling equipment. MPC became a fully-fledged company within the Maini Group in 2010. However, the MPC predecessor was a plastics division operating within the Group for about a decade. Initially, the plastics division had been set up to provide ABS (Acrylonitrile Butadiene Styrene) body parts for Group's EVs, electric stackers and forklifts. Currently, MPC provides plastic components for companies such as Volvo, GE Medical, Toyota, the Indian Railways, Caterpillar, Bosch or Ashok Leyland.

Amerigon Inc. was established in 1991 in California, by Dr. Lon Bell, as a systems engineering and component supplier for the automotive industry. In 2012, after acquiring German-based W.E.T. Automotive Systems AG, Amerigon Inc. changed its name to Gentherm

[5] An important part of this subsection is based on the book "Reva EV – India's Green Gift to the World" written by Dr. Sudarshan K. Maini and published in 2013.

Inc. to reflect their new capabilities. Currently, Gentherm is a major designer and manufacturer of heating, cooling, and ventilating devices for the automotive industry.

The two companies came together after Sudarshan Maini’s son, Chetan (Mahindra Reva’s former CEO), started working for Amerigon in January 1994. At the time, Amerigon had a keen interest in the electrification of vehicles and appointed Chetan Maini as head of its EV project. Soon, Amerigon realised that the US was not an appropriate market for EVs for two reasons. First, EVs had limited driving ranges and would not have been suitable for the average American who travelled for long distances on a daily basis. Second, the price of petrol in the US was significantly lower than in most other countries, which made EVs less attractive for customers. However, Chetan Maini considered that a small EV would be better suited for the busy Indian urban roads. In addition, in India the price difference between electricity and petrol was significantly higher than in the US, thereby providing an important incentive for Indian drivers to switch to EVs. Under such circumstances, Chetan Maini proposed a long-term collaboration between Amerigon and the Maini Group. According to the Memorandum of Understanding, Amerigon agreed to provide critical and sophisticated proprietary components developed in the US, while the Maini Group (who held the majority stake in the venture) contributed with its expertise in low-volume manufacturing, the components which could be cost-effectively manufactured in India and the assembly line.

By 1996, the Maini-Amerigon Car Company, which had also benefited from some USAID (United States Agency for International Development) funding, had already produced three EV prototypes. However, as a result of the change of the majority shareholder at Amerigon, the US-based company left the joint venture with the Maini Group choosing to focus instead on heating and cooling technology.

In 1998, Dr. Lon Bell bought Amerigon’s EV division and decided to continue the collaboration with the Maini Group. In July 2000, Reva Electric Car Company (RECC) was created and all US-based operations were moved to India. The newly established company managed to secure debt financing worth Rs. 15 crore (approximately USD 3.4 million), while the Maini Group provided extensive operational support to RECC, including facilities and key staff.

3.4.2 The REVA cars

In 2001, the first Reva car (see figure 6) was launched on the New Technology Day (May 11th) in New Dehli. The Reva was a two-door hatchback which could seat two adults and two children. The car, which was equipped with a DC (direct current) motor powered by a 48V lead acid battery pack, had a driving range on a single charge of 80 km and a top-speed of 65 km/hr. The battery charging time was 2.5 hours for 80% of the capacity and 6 hours for 100%. The Reva was also equipped with a regenerative braking system which allowed the energy generated during the braking process to be used to recharge the batteries. It had high impact ABS vacuum formed plastic exterior body panels which were fitted on a welded tubular steel spaceframe (see Figure 7) which significantly reduced Reva's weight. The total weight of the car was 670 kg of which the battery pack represented 270 kg. The operating cost of the Reva was just Rs. 0.40 (approximately USD 1 cent) per km, while its maintenance consisted of a battery pack change once every three years. The selling price of the Reva was Rs. 2.5 lakh (approximately USD 5000).

The car was received with scepticism by customers. They criticized the Reva mainly for two reasons. First, in India, many people viewed cars as symbols of social status and the diminutive Reva did not do much to serve its owner's claim for social recognition. Second, the Reva cost the same as or even more than similar size IC cars available on the Indian market but its interior features were basic and austere. The reason for the no-frill interiors was that the lead-acid batteries (the only technology available at the time) were very heavy and impacted negatively on the car’s range and speed. Attempting to compensate for the weight of the batteries, the RECC engineers had pared down the interiors to minimum levels of comfort.

Figure 6. Reva car

Figure 7. Reva tubular spaceframe

Obviously, there was not much the company could do in the short-run to address the first criticism. However, RECC gradually improved the interiors and, six months later, they offered an option for an air conditioner with a pre-cooling feature which, at the time, was not available even on high-end models.

Another challenge that RECC faced was the lack of EV-specific infrastructure allowing users to charge their cars in public places. Consequently, the company had to create on its own the entire EV eco-system by installing charging stations in New Delhi, Bangalore, Mumbai, Pune and other Indian cities. As customers were complaining about car charger failures, RECC technicians found that the earthing of the electric connections in some customers’ homes was faulty. Therefore, the company made a point to check and adjust the customers’ domestic electricity connection. To make life even more complicated for RECC, between 2001 and 2004 the Indian government reduced taxation for IC cars in order to boost production and sales of indigenous models.

Under such circumstances, RECC top management believed that if the Reva were to prove itself in the global market, then domestic customers might become more receptive. The first markets targeted by RECC were countries where the Maini Group was already exporting its products such as the UK and Japan. In 2003, the Reva became the first EV to qualify for the EU roadworthiness standard. In January 2004, the Reva was launched in the UK under the brand name G-Wiz which stood for Green Wizard. The selling price was around £6000-7000. The car proved popular in London where EV drivers were offered numerous benefits such as congestion tax exemption, free charging (where the facility was available), and free parking.

In 2007, RECC launched a new version of the car, the Reva-i, with a more powerful AC (alternating current) motor and improved safety features such as front disk brakes and a collapsible steering column. Two years later, RECC launched the Reva L-ion, the world's first EV powered by lithium ion batteries.

Given the company's strategic choice to concentrate the bulk of its limited resources in technology development, RECC employed a rather unique marketing strategy to sell its Reva cars. RECC relied only on efficient PR, customer word-of-mouth and not a single cent was spent on advertising. In some countries such as the UK, the cars were sold exclusively online. This ensured that RECC's UK operations were 100% environmentally friendly as there was no printed paperwork. Overall, between 2001 and 2012 when the production of the Reva was ceased, RECC sold over 4600 cars, in more than 25 countries.

3.4.3 The partnership with Mahindra & Mahindra

Recognizing that RECC needed a capital infusion in order to fulfil its growth potential, the Maini family sold a controlling 55.2% stake in the company to the Indian multinational automaker, Mahindra & Mahindra Ltd. (M&M). According to an M&M press release (2010), the deal involved a combination of equity purchase and a fresh equity infusion of over Rs. 45 crore (approximately USD 10 million). Following the transaction, the Maini Group retained a

31% stake in the newly formed Mahindra Reva Electric Vehicle Company. Dr. Lon Bell, co-founder of RECC held 11%, while the remaining shares were spread among employees with stock options (Economic Times, 2010). Please see Appendix 1 for the organisational structures of Mahindra Reva's parent companies. Mahindra Reva was not incorporated under the M&M umbrella. Instead, it remained an independent company headed by the former RECC's founder and CEO, Chetan Maini, whose new job title became Chief of Technology and Strategy. In May 2015, Chetan Maini stepped down from his leadership role, remaining however and advisor for Mahindra Reva. He was replaced by Arvind Mathew, former President and Managing Director at Ford India and former CEO of Tata Advanced Materials Ltd.

In 2012, the Mumbai-headquartered M&M owned assets worth Rs. 712 billion (approximately USD 12 billion) and employed over 34000 people (Annual Report 2012-2013). M&M is part of the Mahindra Group, an Indian multinational conglomerate with operations in over 100 countries. The Mahindra Group was established in 1947 as a steel trading company and is currently involved in numerous sectors such as aerospace, agribusiness, automotive, components, construction equipment, defence, energy, farm equipment, finance and insurance, industrial equipment, information technology, leisure and hospitality, logistics, real estate, and retail.

M&M produces MUVs (multi-utility vehicles), SUVs, pick-up trucks, commercial vehicles, tractors, and two-wheelers. M&M produces over 20 models of cars such as Mahindra Scorpio, Mahindra Bolero, Mahindra XUV 500, Mahindra Quanto, or Mahindra Xylo. Following a partnership with French automaker Renault, M&M started producing in India Renault's passenger car Dacia Logan. The car was introduced in the Indian market under the M&M brand name as Mahindra Logan, and later as Mahindra Verito. In 2011, M&M acquired a 70% share of Korean automaker SsangYong Motor Company.

By becoming majority stakeholders in the Mahindra Reva venture, M&M acknowledged the future market of EV in the global context of depleting oil reserves, increasing pollution and climate change (Economic Times, 2010). In addition, M&M made a pre-empting strategic move as RECC was also targeted for acquisition by GM who planned to develop an electric version for its Chevrolet Spark. M&M also announced intentions to licence the electric technology (i.e. transfer EV technology to existent platforms) to power its Scorpio and Verito models, as well as the mini-truck Maxximo. However, M&M planned to have Mahindra Reva focusing on the development of new products (M&M Press Release, 2010).

In 2012, Mahindra Reva inaugurated a new manufacturing plant in Bangalore. The plant had an initial capacity of 6,000 cars per year which could be scaled up to 30,000 units per year or 100 units per day. The plant was designed to reflect the company's "green" philosophy and was awarded a Platinum rating from the Indian Green Building Council (IGBC). The new plant comprised a production facility where around 400 people could work, a test track, a technology demonstration area, office spaces and a conference area. However, the distinctive features were the building's design which allowed for natural ventilation and natural light, thereby reducing energy consumption, the use of solar power for industrial purposes and street lighting, and rainwater harvesting and treatment systems. According to a Mahindra Reva press release, the cars produced in this facility would be "born green" and they would be charged for the first time using solar energy.

3.4.4 Mahindra e2o

In March 2013, Mahindra Reva launched in New Delhi its new model the Mahindra e2o, which stood for 'energy-to-oxygen' (see figure 8 below). The e2o was a two-door hatchback which could comfortably seat four adults. The car's exterior design was based on sketches provided by DC Design, whose owner, Dilip Chhabria, had gained wordwide recognition after designing the first prototype for the Aston Martin Vanquish. Just like the Reva, the e2o had a welded tubular space frame. However, as an innovative touch, the impact-resistant ABS plastic body panels were colour impregnated which made them “scratch-proof” too. The e2o version to be sold on the Indian market had an automatic transmission and a 3-phase induction motor powered by 48V lithium-ion battery pack. The e2o’s driving range with a single charge was 100 km, while the top-speed was 81 km/hr. The export version of the e2o (which at the date of this study had not been launched) is expected to deliver higher performance as it will be powered by a 70V battery pack. The e2o also had an improved regenerative braking system. The total weight of the car was 830 kg, while a full charge of the batteries took 5 hours to complete.

Figure 8. Mahindra e2o

The e2o also provided a wide range of telematics-based features. The telematics allowed Mahindra Reva technicians to remotely monitor the performance of all e2os on the road and offer prognoses and diagnostics for the cars. In addition, the users could be permanently in contact with the car using a smartphone application which allowed them to monitor the charging status, pre-cool the car, lock or unlock doors, and receive alerts on various events related to the car such as a disruption in charging due to power cuts, safety related reminders such as a door being left unlocked or a parking brake not applied. The telematics also enabled the rather unique 'REVive' feature. This feature allowed users to get an emergency boost charge with a command on the smartphone to go an extra 8-10 km. The extra boost was possible by unlocking a reserve charge of the battery. There were two main reasons for developing this feature. First, Mahindra Reva engineers believed that it might alleviate the users range anxiety (i.e. the fear of running out of charge). Second, it ensured a more appropriate usage of the lithium-ion batteries which last longer and stay healthier if they aren't discharged completely.

Indicating that Mahindra Reva had learned from its past experience with the Reva, the top variant of the e2o was quite technology-laden too. The car had a 6.2" touchscreen audio and infotainment unit with inputs including DVD playback, USB (with iPod integration), Bluetooth (phone & audio streaming), and two Micro-SD slots (Media & GPS data). The GPS function of the infotainment unit was correlated with car's range indicator allowing the users to identify charging points on their route.

The operating cost of the e2o was Rs. 0.63 (approximately USD 0.01). The selling price of the top variant of the e2o in most Indian cities was around Rs. 7.5 lakh (approximately USD 12600), while in New Delhi it cost around Rs. 6.25 lakh (approximately USD 10600) as the local government offered some subsidies for EVs. This price made the e2o the most affordable EV in the world at the time of the launch and placed it in the same price range as IC cars of similar size available in India such as the Hyundai i10 or Chevrolet Beat. However, the e2o turned out to be three times more expensive the Tata Nano, India's most affordable IC car, which cost only around Rs. 2.3 lakh (approximately USD 3900).

3.4.5 Future Projects

At the time of our fieldwork, Mahindra Reva was working towards developing alternative charging techniques. First, they were working towards developing solar charging points which could be installed at the customers' residence. Second, they aimed to develop high-speed public charging stations which could be installed in Indian cities. The fast-chargers would be able to provide power for 25 km in just 15 minutes or a full charge in just 60-70 minutes.

In February 2014, Mahindra Reva launched the Halo, an electric sports car concept. The Halo (see figure 9) is a two-door, two-seat vehicle with a driving range of 200 km on a single charge, a top speed of 160 km/hr, and acceleration from 0 to 100 km/hr in just 8 seconds. Mahindra Reva plans to start selling the Halo in 2017, expecting a selling price of around Rs. 10-15 lakh (approximately USD 17,000-25,500).

Figure 9. Mahindra Halo

3.2 Data collection

As mentioned earlier, the case study approach involves a wide range of methods or procedures for data collection as the researcher attempts to develop an in-depth understanding of the subject of the inquiry (Creswell 2013). Accordingly, we have collected primary data through face-to-face interviews and non-participant observations. We have also collected extensive secondary archival data before, during, and after the fieldwork at Mahindra Reva.

Moreover, the use of multiple techniques for data collection allows the triangulation of the findings by corroborating the interpretations of various informants (insiders and outsiders to the 'case'), thereby enhancing the credibility of this doctoral study (Lincoln and Guba, 1985).

3.5.1 Interviews

The bulk of the data used for this case study resulted from interviews conducted during our fieldwork. The benefits of choosing interviews as the main data collection method for this research are straightforward: (i) the interviews allowed the reconstruction of past events, actions, and decisions, as well as the understanding of past and current organisational practices and strategies; (ii) the interviews provided a great diversity of information, thus allowing a good balance between breadth and depth (Marshall & Rossman, 2011); (iii) immediate follow-up questions and clarifications were possible; (iv) combined with direct observation, interviews allowed us to understand what meanings certain actions or decisions had for participants (Marshall & Rossman, 2011).

Following Pan and Tan's (2011) recommendations, we conducted the first interview with the lower-level manager who had provided the introductions during the access negotiation stage (i.e. the gatekeeper). This first informant helped us gain a better understanding of the phenomenon under scrutiny, provided an in-depth presentation of the organisation, explained the company's hierarchy and briefly described the activity of each department. The first informant also offered a list with 5 or 6 potential informants. For the rest of the interviews, we relied on 'snowball' or 'chain referral' sampling (Creswell, 2013; Pan and Tan, 2011) to identify informants. While most informants were Mahindra Reva staff, there were also a few exceptions. First, we interviewed the former and current CEOs of the Maini Group, who had played important parts in Mahindra Reva's history. They helped us gain a better understanding of strategies and dynamics within the Maini Group. In addition, these two informants also provided valuable contextual information which preceded and influenced the decision to set up an EV-producing company. Second, since Mahindra Reva had externalized the advertising for its products, we interviewed representatives of the two Mumbai–based advertising agencies contracted by Mahindra Reva. Strawberry Frog had been responsible for the 'Ask' campaign preceding the launch of the e2o, while Hungama was managing Mahindra Reva's social media presence. The representatives of the two advertising agencies provided important insights regarding the rationale behind Mahindra Reva's innovative marketing approach and described how the strategy was being implemented.

We conducted interviews with key organisational members at various hierarchical levels (please see Appendix 2 for Mahindra Reva's organisational structure) in order to obtain a variety of views allowing us to triangulate information across organisational strata. In this sense, top management and key decision makers were queried for a breadth of information, from company strategies and rationale of those strategies to personal opinions and experiences. Middle and lower-level managers were asked to discuss the implementation of company strategies, day-to-day activities, procedures, and challenges. All informants were asked to comment on the relationships with suppliers and partner organisations as well as on the socio-cultural context. The interviews were semi-structured and the questions were open-ended in order to allow participants to express and explain their ideas and opinions. Before each interview, we prepared a tailored interview guide which accounted for the respondent's position and exposure within the organisation, as well as area of expertise. With respect to interviewing style (see Walsham, 1995), we tried as much as possible to maintain a free-flowing conversation as we believed that there could be value in the respondents' digressions, especially when discussing the importance of the social context.

Table 2. Interviews

Informant category	***Number of interviews***
Top-level executives	12
Middle managers	13
Front-line employees	20

Overall, we conducted interviews with 45 informants. Please see Table 2 above for brief information regarding the informants' positions within the organisation and Appendix 3 for the full list of informants. The interviews lasted between 25 minutes and over 2 hours. In total, we have collected over 38 hours of data. With two exceptions, all the interviews were tape-recorded with the permission of the participants. Following Walsham's (1996) recommendation, the comfort of the participant was considered and, whenever necessary, we assured the informants that we were conducting an independent study and the findings would not be reported to the top management. In addition, the aim and nature of this study did not involve sensitive information which would require being anonymized.

3.5.2 Observations

In order to gain an in-depth understanding of the subject of the case study, we attempted to become part of the setting (Bailey, 1996) and to personally experience life within the organisation. During our four-month fieldwork, we were at the company's production facilities between 9 A.M. – 5 P.M. on all working days. We were offered a desk on the top management floor and free access to all areas of the organisation (with the exception of the design studio as the company was preparing the launch of the Mahindra Halo concept car and discretion regarding the car's exterior design was paramount). This allowed us to be present within the organisation for the entire duration of the fieldwork. Therefore, we had the opportunity to visit repeatedly both the company's old facilities as well as the new plant and to observe the staff in action. Visualizing everyday activities helped us better understand the interpretations shared by informants and the jargon they used during the interviews.

Since we were present within the organisation for the full working hours, we also had the opportunity to interact with and observe employees in a number of informal settings (e.g. the company cafeteria). We travelled every day in the company's shuttle bus to and from the company's production facilities on the city's outskirts. This gave us numerous opportunities to interact informally with a number of employees.

3.5.3 Archival data

In order to complement the primary data, we have also collected two categories of archival data. First, we collected a variety of documents and printed materials produced by Mahindra Reva such as organisation charts, internal publicity and newsletters, marketing hand-outs and company magazines. We used these materials to compare the interpretations we had constructed from primary data with the organisational image Mahindra Reva was trying to convey to internal and external stakeholders. Equally important, this type of materials allowed us to position in time the accounts shared by my informants.

Second, we collected vast amounts of articles and reviews published online by third parties and referring to Mahindra Reva and its products. This category of materials helped us gain a broad understanding about how customers perceived the company and the vehicles it produced. We have also discussed information derived from this kind of secondary data with the informants in order to grasp whether they viewed these third party generated materials as being accurate and fair.

3.6 Data analysis

Myers (1997) supported the view that data collection and data analysis are not easily separated in qualitative research, and, for this reason, they should be undertaken in parallel so that the two activities can inform each other. Accordingly, we regarded data collection and analysis as intertwined and simultaneous processes and allowed the analysis to influence the data collection and the elicited data to impact the analysis.

3.6.1 The role of theory

The theory used to inform the data collection and analysis plays a central part in qualitative studies (Walsham, 1995). According to Eisenhardt (1989), theory can be used in three ways in qualitative research: (i) as a guide for research design and data collection, (ii) as part of the iterative process of data collection and analysis, and (iii) as an outcome of the research. Each of these uses is reflected in the present study as shown next.

After access was cleared with Mahindra Reva top management, we started collecting secondary data from various online media. We then went back to the scholarly literature searching for an initial theoretical scaffolding which could inform our investigation and serve as a sensitising analytical device (see Blumer, 1954; Klein and Myers, 1999, Pan and Tan, 2011; Walsham, 1995). A sensitising concept "gives the user a general sense of reference and guidance in approaching empirical instances" (Blumer, 1954; p.7). We were aware the EVs had long been viewed as a disruptive technology (Christensen, 1997). In addition, on the Mahindra Reva website, there were several references regarding the frugality of the company's operations. Therefore, we started the fieldwork armed with a theoretical framework constructed around the concepts of 'disruptive innovation' and 'frugal engineering'.

Walsham (1995) cautions researchers about the danger of becoming trapped in the prescriptions of existent knowledge and missing "new issues and avenues of exploration" (p. 76). In order to avoid such dangers, researchers are advised to engage in an iterative process of data collection and analysis in which theoretical frameworks are expanded, revised or abandoned (Walsham, 1995). Similarly, Pan and Tan (2011) suggest that the theoretical lenses employed by researchers in their studies are dynamic and generative rather than static structures.

As we worked to "shape the different observations into an inter-connected, cohesive unit" (Kets de Vries and Miller, 1987; p. 245) in order to achieve thematic unity, we realised that our sensitising theoretical framework was too narrow to encompass the myriad of facts captured in our data. We, therefore, went back to the literature and continued to move back-and-forth between our data and the extant theory. Through numerous iterations of what Pan and Tan (2011) refer to as the "framing cycle" (i.e. the 'dialog' between the phenomenon, theory and data), we eventually came across Baker and Nelson's (2005) work on bricolage which provided a good characterization for the behaviours described by our informants. After adjusting the theoretical framework, we revised the scope and the focus of our next interviews as to incorporate concepts such as unconventional use of resources and knowledge sharing.

Regarding the use of theory as final outcome of the research process, Eisenhardt (1989) argues that the end-product of a case study could be concepts, a conceptual framework, propositions or a mid-range theory. In this respect, our study proposes a bricolage-based framework which explains the development of frugal and cost innovations in emerging markets. Moreover, the proposed framework suggests possible solutions for the challenges posed by disruptive (see Christensen, 1995) and discontinuous innovations (see Lynn et al., 1996).

3.6.2 "Text" analysis and theme development

For our analysis, we regarded all data from interviews, field observations, company documents, press releases, and media reports as 'text' or 'text-analogue' (see Heracleous, 2006; Kets de Vries and Miller, 1987). According to Myers (1997), an organisation could be regarded as a text-analogue. We relied on hermeneutics as the main mode of data analysis. Hermeneutics as analysis mode is rooted in philosophical hermeneutics which refers mainly to the theory of knowledge developed by Gadamer (1975) on foundations set by Heidegger. Gadamer (1975) argued that the correct way of interpreting a text does not necessarily imply understanding the meaning intended by the author of the text. The interpreters possess a 'historically affected consciousness' and, consequently, they should try to identify the ways in which the text makes sense against their individual backgrounds (Gadamer, 1975). These prescriptions are in line with the interpretivist epistemological assumptions which view the researcher (the interpreter) as an active participant in the knowledge creation process, thereby making hermeneutics very appropriate for the present study.

Hermeneutics, as data analysis mode, deals with understanding the meaning of a text or a text-analogue which is or seems unclear, incomplete, or contradictory (Taylor, 1976). In an organisation, different stakeholders could have confused, incomplete, and contradictory opinions on many issues and the role of the researcher is to make sense of the whole, represented by the organisation and the relationship between stakeholders (Myers, 1997).

In a hermeneutical analysis, "we come to understand a complex whole from preconceptions about the meanings of the parts and their interrelationships" (Klein and Myers, 1999; p. 71). However, as Gadamer (1975) pointed out, the relationship between parts and whole is circular in the sense that the anticipation of the meaning of the whole shapes the meaning of the parts which, in turn, influences the understanding of the whole. In the present study, the participants' interpretations are viewed as representing the parts of the text-analogue, while the shared meaning emerging from the interaction between the parts represents the whole (Klein and Myers, 1999).

For our analysis, all the interviews were transcribed verbatim. As we read the data repeatedly, we identified 'first order' themes which we labelled as constraints, frugality, challenging status quo, improvisation, partnership, collaboration, adaptability, resilience, frugal values, and customer engagement. It was at this stage that we realised the inadequacy of the frugal engineering lens to fully explain our data. Once we adopted bricolage as guiding framework, we were able to move the analysis to a higher level of abstraction. After revisiting the first order themes we had previously developed and the data extracts associated with each of them, we grouped our findings into three larger second-order themes related to various forms of bricolage: recombination of resources for new purposes, component bricolage, and collaborative bricolage. We found that these second-order themes comprehensively described and explained the accounts illustrated in our data, thereby providing thematic unity for our study (see Kets de Vries and Miller, 1987). Moreover, our bricolage-related second-order themes reflected recurrent actions and behaviours, as well as dominant events corresponding to the historical patterns observed in the dataset (see Kets de Vries and Miller, 1987).

We then verified if there were any significant data strands which did not fit into our initial second-order themes. We found clear indications regarding the techniques used to manage bricolage activities at organisational level. This became our fourth theme.

Further, although bricolage accurately reflected Mahindra Reva's strategy, the company relied on a mixture of bricolage activities and hard-core engineering practices to implement its strategy. Consequently, we developed a fifth theme reflecting the importance of engineering methods in implementing the company's bricolage-based strategy.

By applying similar data analysis principles to the remaining data, we identified two additional themes. The sixth theme tackles the influence of the Indian cultural context on Mahindra Reva's bricolage strategy, while the last theme refers to the company's efforts to communicate to customers an unusual, non-mainstream value proposition.

Chapter 4: Findings

In this chapter, we present and explain in detail the seven themes briefly introduced in the last part of our data analysis section. Please see Table 3 below for a better understanding of the chapter's structure.

The first three themes, labelled "Recombination of resources for new purposes," "Component bricolage," and "Collaborative bricolage," illustrate in detail different types of bricolage activities adopted by Mahindra Reva in its new product development efforts. These bricolage activities were performed at organisational (i.e. recombination of resources for new purposes and component bricolage) and inter-organisational (i.e. collaborative bricolage) levels. The interplay between the three types of bricolage will be further discussed in the next chapter.

The fourth theme explains how Mahindra Reva managed the bricolage activities covered by the first three themes. This fourth theme, entitled "Managing bricolage at Mahindra Reva", describes the managerial techniques and leadership styles adopted by the company's top-management.

The fifth theme, labelled "Engineering the bricolage", captures the engineering practices implemented by Mahindra Reva to support and complement its bricolage activities. As it can generate improvised and imperfect artefacts, bricolage is often regarded as an inappropriate approach to new product development. Therefore, Mahindra Reva adopted numerous well-established engineering practices to provide rigor and legitimacy to its activities.

The sixth theme, entitled "The cultural context", refers to the role played the local environment in Mahindra Reva's adoption of bricolage activities. The theme focuses on the value of frugality as an important antecedent of bricolage and discusses whether frugality is part of the Indian cultural heritage or a central dimension of Mahindra Reva's organisational culture.

The last theme, named "Frugal marketing", presents Mahindra Reva's marketing strategy. As the company had to 'make do' with free or low-cost communications channels such as social media networks due to its limited financial resources, it can be argued that Mahindra Reva's marketing campaigns represent another form of bricolage with resources at hand.

Table 3. Brief overview of the Findings Chapter

Main Themes	Sub-themes	Brief Highlights
Recombination of resources for new purposes	Challenging the status quo	As it was very small and resource-constrained, Mahindra Reva could not engage in the same design, development, and production practices as typical car makers. Thus, the company departed from established practices and developed its unique strategy involving creative recombinations of resources.
	Deploying extant knowledge in novel contexts	The company developed new knowledge (i.e. EV-specific knowledge) by applying extant knowledge (i.e. knowledge regarding electric forklifts) in the context of on-road vehicle.
	Developing battery packs through creative use of resources	Mahindra Reva developed EV battery packs by putting together (i) multiple lead-acid battery units used for conventional cars and (ii) Li-ion battery cells developed for small electronic devices.
	Using plastics instead of metal to reduce the weight and cost of the car	The company replaced the metal sheets typically used in the automotive industry for cars' exterior bodies with affordable plastics normally used to make canopies for military airplanes or water tanks.
	Frugal development of testing and design equipment	Mahindra Reva developed internally testing rigs by assigning new functions to typical EV components. Similarly, the company used unusual equipment for the exterior design of the e2o.
	Taking advantage of staff members' non-core skills	Mahindra Reva often relied on non-specialist skills of its employees to perform R&D tasks which would normally require formal training.

Main Themes	Sub-themes	Brief Highlights
Component bricolage	Determinants of component bricolage	The company engaged in component bricolage because (i) it could not afford major investments in tooling costs and (ii) any such investments would have increased the selling price of the car, thereby making it less appealing to price-sensitive Indian customers.
	Enablers of component bricolage	Mahindra Reva managed to engage successfully in component bricolage by relying on several key capabilities: (i) flexible designing, (ii) knowledge of extant components, (iii) component modification capabilities, (iv) modular designing of electric architectures, and (v) design alignment capabilities.
Collaborative bricolage	Collaborations involving multi-directional knowledge flows	Mahindra Reva developed its EV specific knowledge base through collaborations with both Indian and foreign partners.
	Collaborations involving one-way knowledge flows	When working with non-specialised Indian suppliers, the company had to educate these suppliers and transfer previously developed knowledge.
	The challenges of collaborative bricolage	Mahindra Reva struggled to maintain working relationships with foreign firms who usually required major volume commitments before engaging in collaborations. Moreover, the geographic distance impacted negatively the relationships. Consequently, Mahindra Reva had to collaborate mainly with Indian firms who had little EV-related expertise.
Managing bricolage at Mahindra Reva	Stretch goals	Mahindra Reva's top-management used the stretch goals technique to challenge employees to look beyond established practices and use resources creatively.
	Transformational leadership	In order to prevent employees from being overwhelmed by the highly challenging goals, Mahindra Reva's top-managers engaged in practices and behaviours congruent with a transformational leadership style.

Main Themes	Sub-themes	Brief Highlights
Engineering the bricolage	Adopting Japanese practices	As Mahindra Reva combined bricolage activities with engineering practices, the company implemented procedures of Japanese origin such as relying on suppliers located close by, involving the suppliers in the early stages of new product development, and transferring most of the design responsibility to them.
	Cost engineering	Mahindra Reva also implemented well-established cost engineering practices in order to ensure that its EVs would be the most affordable in the world.
	Mahindra Reva's original implementation of engineering methodologies	While implementing engineering practices, Mahindra Reva staff members performed a variety of activities which, according to the established norms, required high levels of specialisation. By ensuring that their employees had an overview of the company's entire repertoire of resources, Mahindra Reva protect the bricolage activities (i.e. creative use of resources) from being stifled by engineering practices.
	Formalising bricolage to ensure replicability	One of the central preoccupations at Mahindra Reva was integrating the flexible bricolage-based approach to product development into structured processes, practices, and routines which employees could replicate in new projects.
The cultural context	Frugality as part of the Indian heritage	Several Mahindra Reva employees suggested that the company's ability to overcome serious contextual constraints was rooted in the frugal values shared by many Indians.
	Frugality as organisational culture	Other employees argued that the frugal values supporting the bricolage activities undertaken by Mahindra Reva pertained to the organisational culture of the company and had been nurtured by the founders over the years.
Frugal marketing	The pre-launch phase	Due to its limited resources, Mahindra Reva had to 'make do' with free or low-cost communication channels such as social media networks for its marketing efforts. In

Main Themes	Sub-themes	Brief Highlights
		the phase preceding the launch of the e2o, Mahindra Reva tried to position its brand by creating a link between the technological change (i.e. from IC to EV) proposed by the company and the broader social and cultural changes taking place in India.
	The post-launch phase	In the post-launch phase, Mahindra Reva focused on effectively conveying its non-mainstream value proposition to potential customers using the same social media communication channels.

4.1 Recombination of resources for new purposes

This category of bricolage activities and processes refers to instances where available and easily accessible resources (e.g. knowledge, tools, or raw materials) are deployed in new contexts or applications departing from their conventional usage (Baker and Nelson, 2005). A summary of the creative use of resources at Mahindra Reva can be found in Appendix 4.

4.1.1 Challenging the status quo

According to the company's Chief of Technology and Strategy, two factors enabled the recombination of resources for new purposes at Mahindra Reva. On the one hand, being a new entrant in the automotive industry and having no prior involvement in the production of conventional IC cars allowed the company to challenge the industry's status quo. To some extent, it could be argued that being outsiders to the automobile industry shielded the founders from the industry's prevalent norms and practices. The informants suggested that they were aware of the norms in the automotive sector, but because they were not inveterate in such practices it was easier for them to depart from the well-travelled path and develop an original strategy. This argument bears a striking resemblance with Polanyi's reflections regarding one of his contributions to physics (Polanyi, 1963). He argued that, had he been more familiar with the developments in the field, he would have never developed his theory. He claimed that his ignorance had protected his ideas from being stymied by false, yet powerful and ubiquitous objections (Polanyi, 1963). Such "blissful ignorance" can take the form of a recognition heuristic which enables the pursuit of alternative solutions or otherwise unnoticed opportunities (Sarasvathy, 2001).

> *"I always say the fact that we were new in the industry and hadn't done these things before was a great advantage for us. When you are new in business you can ask why this has to be done this way, why can't it be done differently. You can question everything and this process enables you to think differently. Very often, when you do something for a long time, you don't question things anymore. […] Because EVs are different than what other carmakers were doing, we were able to think differently. We had the freedom and confidence to challenge conventional ways. If you do something that many others do, you tend to be more cautious about departing from the established line."* (Chief of Technology and Strategy)

On the other hand, the constraints and limitations faced by the small start-up company prevented the use of established practises and resources.

> *"It was a matter of reconceptualising the problem we had, in the context we had. You can't build a car the way we did unless you design it differently. All the constraints we were facing forced us to think differently. Our main constraints were that we were expecting low volume sales and we could only afford low capital investments. Therefore, we were looking for light-asset factory systems and low break-even points."* (Chief of Technology and Strategy)

A vivid illustration in this sense is represented by Mahindra Reva's reconceptualization of the typical automobile assembly line. According to our informants, who explained in detail the differences between typical assembly lines and Mahindra Reva's very own 'rolling chassis system', most automakers follow assembly practices which involve a more or less similar sequence of activities. The car chassis is usually fitted first with the engine, transmission, exterior metal body parts and other bulky components, with the wheels being mounted at the very end. These conventional assembly processes require huge conveyor systems which move the chassis from one workstation to the next. Such conveyor systems are very expensive and usually require specific investments for each car model to be put together on the assembly line. In addition, substantial investments in real-estate and machinery are required. Considering their limited resources and low expected volumes, Mahindra Reva's management departed from such conventional practices and envisioned a different and more frugal assembly line. The 'rolling chassis system' involves mounting the suspensions and wheels first and then rolling the wheeled chassis to every workstation to have all other components fitted. The 'rolling chassis system' is not only significantly less expensive than the conveyor system, but also more versatile as it can be used for the assembly of different models by simply rearranging the sequence of workstations with no additional investment.

These findings are in line with prior research arguing that entrepreneurial organisations that do not accept a priori limitations imposed by commonly adopted theories and practices manage to identify opportunities which are overlooked by other companies (Baker and Nelson 2005, see Weick 1979).

4.1.2 Deploying extant knowledge in novel contexts

The founders of the Maini Group felt that the company's experience with battery-operated handling equipment (e.g. forklifts) would provide a reasonable starting point for the EV venture. For over 10 years, Maini Materials Movement had developed useful knowledge regarding low-speed in-plant equipment which was tweaked and redeployed in the new context of on-road vehicles.

"The fact that we were doing electric forklifts gave us some confidence that we could do it. It gave us a preliminary understanding of the requirements of working with batteries, chargers, electric motors, controllers etc. By being in this kind of manufacturing, we understood fabrication, assembly lines, electronics, and most importantly we understood small batch production. In this kind of business, we deal with a number of different models in small batches, unlike a typical car or motorcycle company." (CEO Maini Group)

Another illustration of Mahindra Reva's capability to deploy extant knowledge in new contexts is provided by their idea to start producing telecommunication infrastructure components. In India, power outages are very frequent and can last between a few minutes and several hours. Since the towers and antennas of mobile telecommunication companies are connected to the main electric grid, the coverage of mobile telecommunication services is seriously impaired by the power outages. Mahindra Reva, who had developed unique capabilities in managing large packs of Li-ion batteries for EVs, believed that similar battery packs could be used to power telecom antennas for the duration of the power outage while automatically recharging once grid power returns.

4.1.3 Developing battery packs through creative use of resources

When Mahindra Reva did its initial designs, lead acid batteries were the only viable alternative for propulsion. However, lead acid batteries were designed for IC cars which require lower power discharge conditions. Having the experience of electric forklifts, Mahindra Reva engineers already had an idea about what adjustments would be required for the successful implementation of lead acid batteries in the new EV context:

"If you take a lead-acid battery off the shelf and try to drive a car on it, you will kill it in a matter of seconds. We 'worked' the chemistry and we managed to develop batteries packs on which cars could be driven for over three years. There was a lot of work fine-

tuning the battery composition but ultimately our innovation was based on existing knowledge which was subjected to a new context." (Head of Mobility Solutions)

Several years later, lithium ion (Li-ion) batteries were emerging as a superior technology. However, Li-ion batteries had been developed for small portable electronic devices. Mahindra Reva engineers had to develop big battery packs for the Reva-i cars weighing up to 250 kg by putting together individual Li-ion cells weighing about 50 grams each. The transfer of Li-Ion technology to EV context did not pose any chemistry problems. This time, the challenge was wiring together and monitoring thousands of battery cells. In order to address this problem, Mahindra Reva engineers placed micro-chips on each battery cell in order to transmit the information through radio frequency, thereby making the system wireless (Maini, 2013).

4.1.4 Using plastics instead of metal to reduce the weight and cost of the car

In terms of their cars' exterior body, Mahindra Reva management realized immediately that metal was not going to be a viable option as the company could not afford to invest in metal sheet stamping equipment. According to our informants, such an investment would have been impossible to amortise considering the low volumes the company was expecting to sell. In addition, the use of metal body parts would have required a painting shop, which was not only very expensive but also highly polluting, thereby conflicting with the company values. Thus, the company started exploring plastics as an alternative to metal sheets. In addition to requiring lower investments in manufacturing equipment, plastic body parts promised to be recyclable, significantly lighter, and dent-resistant.

"In India, there is a lot of traffic and lots of light accidents. If you bang your car it costs a lot of money to repair the sheet metal body. We needed something with high impact strength. […] Plastic made by vacuum forming was used to make canopies for military aircraft and 'bubbles' for helicopters. It seemed something we could use." (Head of Prototypes)

"For the plastic we used for the bumpers of our first cars, we used a process called rotation moulding. This process is generally used for water tanks. Nobody had used it for automobiles before, but we found that if you use the right equipment, processes, and materials, it can be used for cars quite successfully. In fact, it was cheaper, more resistant, recyclable, and it could be produced locally." (Chief of Technology and Strategy)

Although vacuum forming and rotation moulding processes were used in various industrial applications, they had not been used in the automobile industry before. Furthermore, the use of plastic panels for cars' exteriors was a quasi-novel approach. In 1998, about 30 months before the launch of the first Reva car, Micro Compact Car AG (MCC) - at the time a joint venture between SMH, maker of Swatch watches, and Daimler-Benz AG - had launched the first Smart car model with all exterior body parts made out of plastic. However, MCC was using a costlier process - injection moulding - to produce the plastic car body.

4.1.5 Frugal development of testing and design equipment

Our interviews also revealed that developing an innovative product using unconventional processes and materials involved significant efforts in experimenting and testing activities. As the costs of the typical testing equipment were exceeding the company's resources, Mahindra Reva engineers used basic physics knowledge to design alternative testing processes which could be carried out with the limited resources possessed by the company.

"To test the gradient that the car could climb, we had to find an innovative solution. For this kind of testing, other companies have facilities which allow them to test how the car is performing when going uphill at different gradients. If we wanted to do the same thing, we had to travel 2000 km or invest a lot of money in the facilities. Instead, we loaded the car with different weights to simulate the conditions of going uphill. Pulling a certain weight can be equivalent to climbing at a certain gradient." (Head of Testing)

and

"At some point, we had some axle shaft failures. Normally, axle shaft testing rigs cost about Rs. 1 crore [approximately USD 0.2 million]. To solve this problem, we used the natural frequency method. We locked the shaft on one side and on the other we had to create a natural frequency. We used one of our motors to twist the shaft and this way we found out the frequency which would cause the shaft failure. This cost us Rs. 15,000 [approximately USD 300], instead of 1 crore [approximately USD 0.2 million]. […] Big companies such as Tata Motors do not use this kind of methods. If you suggest something like this, they will laugh at you. They can't prove that these methods are wrong. In fact, the results are quite accurate, but they will still laugh at you and say that this is the 'jugaad' way of doing things. Our methods may be cruder but if you take the axle we have tested and put it on the Rs. 1 crore rig you will get the same results as we did. The only difference is that we have managed to save a lot of money in the process." (Head of Testing)

These quotes provide vivid illustrations for the company's tendency to consciously disregard prevailing practices and methodologies (Baker and Nelson 2005). In fact, the constraints and limitations acted as liberating forces providing greater latitude for Mahindra Reva engineers in the design of testing processes. The company's limited resources simply did not allow for established industrial practices to be realistically taken into consideration. Once Mahindra Reva engineers accepted this reality, they were able to find new uses for 'resources at hand' such as typical EV components (see Baker and Nelson 2005) and to creatively and effectively design original processes and equipment.

"We innovated the testing rigs not from intent but from compulsion – resources were sparse and as long as the contraption did what it was supposed to do, it didn't matter what it looked like. To test the battery as it would be used in the car, we used the motor controller and part of the motor and developed some software to control it and discharge

the battery in a similar way to how it would be done in the car. When we went to the battery testing facility in Kerala, they said that the standard we were looking for would cost us around Rs. 1.5 crore (USD 0.3 million approximately) – we developed our own battery testing facility for a mere Rs. 2 lakh (USD 4000 approximately).” (Maini, 2013)

Overall, Mahindra Reva’s in-house Testing Division went on to frugally design 12 testing rigs at around 1% of the cost of standard testing equipment, thereby saving some Rs. 100 crore (USD 20 million approximately) (Maini, 2013).

Our informants also reported instances when the process of using available resources or equipment for nonconventional purposes was less structured and the outcomes did not represent long term solutions but rather helped overcome one-time problems.

“When we first started working on the car which later would become the e2o, we had an initial exterior design from an American company. We even made a few prototypes using that design. Based on those initial prototypes, DC [Dilip Chhabria] Design provided some sketches which we liked very much. However, DC Design did not give us the CAD [data] of the design. For this reason, the first prototype we made using the DC Design aesthetics was completely hand-made, hand-tinkered. The left and right sides were not perfectly symmetrical. The people working on it did an unbelievable job considering it was all hand-made. It looked great until you started to examine all the minor details. In order to rework the surfacing, a typical car maker would have called somebody with a laser scanner and scanned the prototype. We could not afford to do that. Instead, we used a huge CMM [Coordinate Measuring Machine] we had. The CMM had the capability to digitize or pick-point coordinates on a surface. We made a special structure to mount the car [chassis, exterior body, and wheels] there. We lifted the whole thing and put it on the CMM. I still have the photos with the car on the CMM. I do not think there is any other car company in the world which has ever done something even remotely similar. […] We

took the point cloud data we got using the CMM and superimposed on the old CAD data that we had, checked the changes and then did the modified surfacing." (Manager Car Programme)

4.1.6 Taking advantage of staff members' non-core skills

Another example of how Mahindra Reva used resources in unusual ways involved the human resources. Aside from the engineering qualifications and skills required by the job description, some of Mahindra Reva's R&D engineers possessed extensive computer programming knowledge. This collateral knowledge proved to be a valuable 'resource at hand' which the company leveraged to make significant savings by replacing sophisticated software packages with common data analysis tools for internal, non-crucial simulations. The following illustrative quote is provided by a New Technologies and IP manager who held a Ph.D. in chemistry but no formal programming qualifications:

> *"At bigger companies, when you run simulations you use very expensive software. I use something as simple as Excel for some of our simulations to save costs and I managed to get quite good results. Ultimately, if you understand what you are doing you can use any tool. Of course, for activities where we need to get some certifications we use all the established tools. Also, some of these activities are outsourced to out parent company and they help us. [...] The codes for simulations are done and verified in-house. Fortunately, people here are quite good at that. The code verification can be quite expensive if outsourced and we manage to save a lot this way."* (Manager New Technologies and IP)

4.2 Component bricolage

We refer to the third theme emerging from our data analysis as component bricolage. Our definition of component bricolage is relatively straight-forward: the creation of original and innovative systems, relying mainly on off-the-shelf components, which were initially designed and developed for other vehicles. The concept is very eloquently captured by one of our respondents.

> *"Individual parts such as the batteries, motor, wheels or tyres do not make a car on their own. The integrated system is where the added value comes from. Our value proposition is not going to be affected by using individual components which are already available or less original. Some amount of standardized components, even available off-the-shelf, is going to give us a good cost-performance balance, while some amount of non-standardized original items is going to add some interlocking between us and the customers."* (Manager Sun2Car)

4.2.1 Determinants of component bricolage

The strategy to mix-and-match components already available on the market was rooted in Mahindra Reva's limited resources. The company was a pioneer in EV manufacturing and chose to focus on technology development which currently represents the company's core capability. The company holds over 40 patents for energy management systems, wireless battery management, efficient braking systems, remote diagnostics, and remote activation of energy (Maini, 2013). With a lion's share of company resources dedicated to R&D activities and another important chunk invested in the plant and assembly line, Mahindra Reva had little capital available for the development of components in non-critical areas such as mechanical parts, or interior and exterior design elements. Moreover, Mahindra Reva was anticipating low sales volumes which meant that related tooling costs could not be amortised by suppliers in a predictable time frame.

> *"When you make a new and innovative product, you are faced with inherent constraints. In the specific case of Reva, these constraints came from the fact that nobody believed in us or in EVs in general. Also, the volumes were likely to be low and the investment in*

tooling was very high. Unless the collaboration involved standard products or minor modifications of standard products, many suppliers or partners we wanted to work with were not willing to commit to this project without us paying for the development and tooling costs upfront and we simply did not have that kind resources." (CEO Maini Group)

The selling price of its vehicles was another major constraint Mahindra Reva was facing. With India in mind as the main market for its EVs, Mahindra Reva had to meet the requirements of a very price-sensitive customer base. Any development and tooling costs associated with non-critical components would transfer to the selling price of the EV and, thus, negatively influence the sales.

"We are trying to 'commonize' most of the parts to reduce the tooling investment and the time costs. The investment in tooling will get loaded on the manufacturing cost of the component and eventually on the selling price of the vehicle. We also try to use similar parts in two or more projects so that the development cost will get distributed and the cost burden on the consumer gets reduced. Consider the e2o dashboard. We are currently making a right-hand drive vehicle. For left-hand driving, we are not making a new dashboard. Our dashboard is modular and we can easily move from right-hand driving to left-hand driving." (New Product Development Manager)

When (Mahindra) Reva was controlled by the Maini Group, the component bricolage involved only high volume "insides" or parts which were not protected by intellectual property (IP) rights. Once Mahindra & Mahindra became a majority shareholder in the Mahindra Reva venture, the component bricolage process was significantly simplified. Because the new parent company was producing a wide range of automobiles, Mahindra Reva engineers and designers were given the opportunity to "bricolate" with an important number of previously IP restricted components originally used on Mahindra & Mahindra models. Moreover, Mahindra &

Mahindra was involved in joint-ventures with other global auto-makers which led to the introduction of international models in the Indian market under the Mahindra brand name. In one of the most successful such joint-ventures, Renault's Dacia Logan was presented to Indian customers as Mahindra Logan and, later, as Mahindra Verito. Such joint-ventures expanded even more Mahindra Reva's range of component available for bricolage, thus allowing the company to make significant savings.

"We try to use off-the-shelf components as much as possible to reduce tooling costs and development time. […] For example, the air-vents on the e2o are a carry-over from the Mahindra Logan/Verito. They had to take the permission from Renault. There was an agreement between the two companies. Some parts we can use, while others are black-boxes for Mahindra & Mahindra and can't be used for other models. Within a single air-vent, there are 26 small parts which require 26-27 tools which would make the total tooling cost exorbitant." (Head of R&D)

An illustrative example of how Mahindra Reva's engineers managed to develop an original system using commonly available components and minimal investments was provided by the very attractive instrument cluster (i.e. component located in most cars above the steering wheel and providing information such as speed, mileage or driving range, outside temperature etc.) of the Mahindra e2o.

"The supplier for the instrument cluster works with very high volumes. I showed him our design and I asked for a certain cost. He replied that it was impossible for our small volumes. Then I asked what if we could make our cluster on his existent [production] line. He then told me what I needed to do in order to make the cluster on his existent line. Finally, we managed to do a unique cluster from an aesthetic perspective but all the 'insides' were made from high volume components which were produced by the supplier at a very low cost. Only the exterior unit was custom-made but it wasn't very expensive.

Using this approach, the suppliers never gave us any problems because of our small volumes." (Chief of Technology and Strategy)

4.2.2 Enablers of component bricolage

Corroborating information from multiple respondents, we identified five main enablers of component bricolage (please see Appendix 5 for a summary of the evidence regarding the enablers of component bricolage): (i) flexible design; (ii) knowledge of existing components, which could serve envisioned purposes; (iii) component modification capabilities (i.e. the ability to adjust or "tweak" the identified components if they did not match the required performance specifications); (iv) the modularity of the electric architecture which allowed the use of EV-specific components in multiple projects; and (v) design alignment capabilities (i.e. the ability to integrate components and modules produced by various suppliers into a functional system with a consistent and attractive design).

The principles of *flexible design* are captured by the words of the lead designer. Referring to his work on future Mahindra Reva models, he explained that, since bricolage has become an approach embedded within the organisation, designs must be envisioned in such a way as to allow for future changes and alterations. Relying exclusively on ex-post design adjustments can seriously limit the number or extent of component bricolage opportunities.

"In order to really make a positive impact on the environment, our cars must be affordable. When I am working on my designs, I go and look at design elements such as air vents, buttons, controls which are available on our existing models or even on IC cars and try to use some of the existing or standard shapes and characteristics. Having in mind parts that can be carried forward from existing models can help us a lot in case we need to reduce costs later on. Of course, this can impact the uniqueness and originality of the interior, but I try to push the styling with the general volumes and to keep these elements quite simple. If you design something which looks extremely attractive and

surprising because it has never been done before, you run the risk of incurring really high costs. Therefore, I try to use in my designs elements which are at least inspired by existing ones to make sure that suppliers would be able to provide something without important tooling costs." (Lead Designer)

The second prerequisite of component bricolage (i.e. *knowledge of available components*) has been approached in prior studies. In order to achieve the envisioned goals, the bricoleur must develop a sense of familiarity or intimacy with the environment through extensive observation and systematic cataloguing of all elements of the setting (Duymedjian and Ruling 2010; Levi-Strauss, 1966). In our component bricolage context, this means that Mahindra Reva engineers and designers needed an exhaustive awareness of the parts and components used not only by Mahindra & Mahindra but also by other auto-makers as well as the IP regime of each component. This very idea was articulated by our next informant:

"I keep telling my guys when we start working on a part that we don't have to start from a clean slate. When we work on a new part or process, we have to look at the available benchmarks. The engineering, the headache is often done by others already. We don't have to reinvent the wheel for every single part. Let's see the benchmarks. Then we can map out what we already knew and what we have learned from the benchmarks and combine the two. I got this way of thinking from my experience at Chrysler. This helps us adjust our design to the existing constraints. On the one hand, we have the cost in mind and, on the other hand, the quality and the customers' expectations." (General Manager R&D Mechanical)

and

"Engineers and stylists love to work at something new. Sometimes we don't have that luxury here. We tend to use carry-over parts from other programs or off-the-shelf components and we try to integrate them into our design. At Chrysler or Tata, I could

get away with developing a new part although something similar was already available. Here, I have to be extra careful and make an effort to check if a certain part is available somewhere and try to use it in a smart way. If I absolutely must design a new part, I'm trying to design it in such a way so I can use it in multiple places, either on the same project or on a different one." (General Manager R&D Mechanical)

In relation to the third enabler of component bricolage (i.e. *component modification capabilities*), our informants underlined the importance of appealing, original interior and exterior designs, although they never shied away from admitting that they focused on practicality and affordability. To obtain such desirable designs, the off-the-shelf *components needed modifications* and adjustments to meet the desired aesthetics and to mask the original provenience.

"We always look to see whatever parts are available on the market. If we can find an off-the-shelf part, or tweak a little bit an existing part, or adjust our design accordingly we can save a lot of costs. We try not to be rigid in our designs. Developing a new part as per our designs can take months and cost lakhs of rupees. There is no point in doing that if we can make a slight modification to our design and use a part which is already available without any development and tooling costs. Of course, we cannot compromise on aesthetics because that would affect our brand image." (Head of R&D)

The *modular design* of the EV-specific parts was the fourth enabler of component bricolage. As hinted by previous quotations, Mahindra Reva tended to carry forward original design components wherever possible. This process implies using parts which involved important development costs (generally pertaining to the electric and electronic architecture) in multiple projects or models. For example, the company relied on the same electric architecture developed for the e2o to build electric prototypes of several Mahindra & Mahindra models such as the sedan Logan/Verito, the small-size goods carrier Gio, and the minivan Maxximo. The process is explained below:

"Our electric architecture is quite flexible and modular. The 40-volt e2o was designed specifically for India. The 72-volt variant is for export. The electric architectures are different but it is very easy for us to adapt the old one to meet the new requirements. Similarly, most parts we are using now will go into the electric Logan/Verito. Of course, the location of the parts will be different. In the e2o, the location is below the rear seat, while for the electric Logan/Verito the location will be below the bonnet. The layout is also different but most of the parts are similar and easily upgradable from one platform to another. This helps us to reduce costs and design time." (Head of R&D)

According to our informants, the ability to carry forward components in multiple projects was supported by the modularity of the electric architecture. A system is considered to be modular when it is built from independently designed sub-systems which yet function as a whole (Baldwin and Clark, 1997). The concept of modularity is rooted in the computer industry (Baldwin and Clark, 1997) which served as inspiration for Mahindra Reva too:

"I got the idea of modularity after examining the design of electronics. I remember changing the electronics so many times during our development process… Unless you use a modular design, you won't be able to keep the pace with the latest developments in electronics and you'll never be able to utilize the entire value that these developments can provide." (Chief of Technology and Strategy)

and

"[Our Chief of technology and strategy] views making cars the same way as making computers, picking the desired hard drive and matching it with the required software. Nobody had viewed the cars that way and the fact that we had actually never made cars before helped us in being more innovative and flexible." (Maini, 2013)

Broadly, the EV electric architecture includes two main categories: (i) the 'software' or the core of Mahindra Reva's patented Intelligent Energy Management System (IEMS), and (ii) the 'hardware' components such as the battery pack, the motor, the controller, or the charger. As our informants explained, the 'hardware' was produced exclusively by independent suppliers which could provide components suitable for various applications ranging from small four-sitter vehicles to trucks and vans. The 'software', however, represented one of Mahindra Reva's main competitive advantages and was designed to fit multiple 'hardware' combinations.

> *"The Intelligent Energy Management System works with different types of batteries [e.g. lead-acid or Li-ion]. It requires minor code changes, but it is structured to accommodate numerous variations. This is very important for us because our models use different batteries, different voltages, different numbers of cells. Plus, the chemistries are constantly changing. We need to be able to adapt to anything. This is the philosophy of our design."* (Head of New Technologies and IP)

and

> *"We developed our internal capability to adjust the software of the IEMS. This software does a lot of things within the vehicle. It interacts with the majority of the electronic parts such as the charger, motor controller or the instrument cluster. [...] The software is very flexible and can be easily upgraded. For example, if the marketing department wants to add some feature we can do it through the IEMS. Such additions or adjustments can be done almost without costs, no tooling costs, no hardware costs, no time to impact. We make the code changes, validate them properly and go for the implementation."* (Head of R&D)

For Mahindra Reva, modularity not only enabled opportunities for outsourcing (Baldwin and Clark, 1997, Ravishankar and Pan, 2013) but also supported experimentation allowing the company's engineers to try out a wide range of 'hardware' configurations (Baldwin and Clark, 1997), thereby facilitating component bricolage. Ultimately, the outsourcing of components and the bricolage represented important sources of cost savings. However, modularity also posed some challenges for Mahindra Reva. In order to ensure that the IEMS fits numerous ‘hardware’ configurations, it required continuous adjustment and an extensive knowledge of available ‘hardware’ components (i.e. the sense of familiarity with the external environment, we mentioned earlier). Mahindra Reva tackled this challenge by setting up a division in charge of monitoring relevant technological developments:

“Because EVs are not a mature technology like IC cars, there are a lot of developments still going on. One needs to keep an eye on these advancements in order to be able to feed the R&D in the technology pipeline. That’s why we have a separate division called ‘New Technologies’. This is not common to many other companies. Our division is supposed to build a technology roadmap, do preliminary work, exploratory work, get the project in some shape and pass it to R&D to incorporate it into new products. We do some sort of pre-R&D work.” (Head of New Technologies and IP)

From a technological perspective, Mahindra Reva’s *design alignment and integration capabilities* (i.e. the fifth enabler) were supported by the highly flexible IEMS which allowed the company to successfully integrate the EV-specific components. Design integration was equally important from an aesthetic perspective. This idea is underlined by a designer’s perspective on component bricolage and the challenges stylists face in their attempt to develop an original and pleasant car design while relying on a multitude of components borrowed from other designs:

“This handle is from Dacia Logan. This part is from a Chinese supplier. This is from Great Wall Motors. This is a Mahindra Scorpio handle. These buttons are adapted. The speakers and the sun visors too. This lamp is adapted. This handle grab here is a carry-over part. We take carry-over parts from everywhere in order to reduce costs. Obviously,

the challenge is to keep the design attractive after all this. We made the concept first and then started adapting it. This way we managed to retain the intended styling. For example, the control module is now a three-piece module. Initially, we wanted to use a backlit button panel which was glowing really nice. But it turned out that it would have been really expensive. Plus, there were no Indian suppliers that could support us. So we had to adapt the design to what was available on the market. This is why you see some empty space here. But overall I think it still looks pretty good." (Head of Styling)

4.3 Collaborative bricolage

Increasingly, scholars argue that technological innovation rarely involves the heroic efforts of solitary individuals or organisations. More often than not, innovation is a collective process which mobilizes the efforts and inputs of multiple actors pertaining to various domains (e.g. Chesbrough, 2006; Garud and Karnoe, 2003). Mahindra Reva developed a network of partner organisations which pooled in resources. The company's strong suit was its proprietary knowledge and R&D capability, but it lacked the resources to make significant investments in production equipment. Therefore, senior managers made the strategic decision to outsource the manufacturing of all car components to suppliers. Unlike typical outsourcing arrangements where only non-core activities are outsourced to specialized suppliers, this was an attempt to create core value in collaboration with non-specialized suppliers. In the late 1990s, only a few developed-country car-makers were experimenting with EV technology and suppliers had limited or no prior experience producing components for EVs. Mahindra Reva collaborated with suppliers of IC vehicle components as well as with companies in seemingly tangential industries such as electronics, aerospace and defence.

Our analysis revealed two types of collaborations. The first involved a process of joint design and development of EV-specific components whereby Mahindra Reva provided expertise and knowledge in EV technologies while the suppliers contributed with their industry-specific knowledge and production capabilities. For the second type of collaboration, Mahindra Reva had to educate its suppliers. The knowledge absorbed from Mahindra Reva allowed the suppliers to produce the components designed by Mahindra Reva. In this type of collaboration, the suppliers contributed only with their production capabilities. Please see Appendix 6 for a list containing the functionalities and suppliers of EV-specific components and Appendix 7 for a summary of the evidence related to collaborative bricolage.

Irrespective of the type of collaboration however, Mahindra Reva developed common or shared "repertoires" of resources with each of its partners (see Duymedjian and Ruling, 2010). Drawing on such shared repertoires, they carried out extensive collaborative experimentation to develop components for their EVs.

4.3.1 Collaborations involving multi-directional knowledge flows

According to the accounts shared by our respondents, Mahindra Reva's initial knowledge-base in EV technologies was developed through the collaboration between the Maini Group and Amerigon, a US-based vehicle design, system engineering and component supplier for the global automotive industry and a minority stakeholder in the initial Reva venture. The knowledge sharing was achieved by deputing key personnel with complementary skills and expertise from the Maini Group to Amerigon. Among the staff deputed to Amerigon were: one of the founders and former Chief of Technology and Strategy, who had built a solar car with his university colleagues and participated in the World Solar Championships held in Australia; Mahindra Reva's current head of prototypes, who was a passionate conventional car racer and had developed numerous race car prototypes; several engineers from Reva's sister company Maini Materials Movement (MMM), who had experience with electric forklifts and thus knowledge in battery management and production processes.

Another collaboration where the co-learning process and the development of the shared knowledge repertoire between Mahindra Reva and its suppliers was achieved by temporarily deputing Mahindra Reva engineers to work in the supplier's production lines involved the development of the tubular spaceframe structure (i.e. EV chassis).

"We are the one of the very few companies in the world using spaceframe structures for our cars. We needed to learn how to make space frames for the automotive industry. […] Our supplier knew steel and welding and had production capabilities. We understood the levels of stress and mechanical vibrations the spaceframe would be subjected to, the required reliability in case of crash, and the complexity of the vehicle context. We transferred all our knowledge by deputing our experts to their lines when we were building the first prototypes. There was an interaction and co-learning process in order to ensure the frames will have the required reliability in case of crash and last for 15-20 years." (VP for Business Excellence and Operations)

In domains which were completely novel to Mahindra Reva such as plastics manufacturing, knowledge was acquired through collaborations with third-party experts:

"It was a transfer of knowledge from experts to the company [Maini Group]. When we started nobody in India even made the tools required for the parts we needed. Even the development of tools took a lot of learning and experimentation in order to make them meet our needs with minimal investments. For example, in the case of the plastic body panels, the investments required were not very high. So, we found an American consultant who had previously set up thermoforming and rotation moulding plants. He spent four months here and helped with the machines and the personnel training." (Chief of Technology and Strategy)

Once sufficient EV-specific knowledge had been developed, the design of the first Reva car was completed and several prototypes were developed to prove the concept. Next, the company started looking for component suppliers in order to start the actual production of the car. The first suppliers Mahindra Reva established contact with were attracted by the novelty and the potential impact of the project:

"Sometimes suppliers do not do things only for money. When you do new projects they get excited by your passion, they empathize with you, they understand the struggles you go through and they like to support you. That's the nice thing about doing something different." (CEO Maini Group)

An example in this sense is represented by the chargers which were developed in collaboration with a US company. The supplier recognized the commercial and PR potential of the association with an EV-maker.

"In the case of the chargers we worked with a company in New Jersey – Transistor Devises Inc. – and created a joint technology tie-up which helped us reduce development costs by some 50%. This company was performing very well in the aerospace and defence industries. They were interested in entering the automotive industry but had no expertise in this sector. We had automotive expertise, while they were very experienced with electrics and electronics, so it was a mutually beneficial relationship. […] They believed this was a nice project to be involved in and wanted their name associated with it." (Chief of Technology and Strategy)

According to our informants, even ordinary and straightforward components such as the tyres had to be adapted to the particular requirements of EV. As the supplier had no knowledge in the context of EVs while Mahindra Reva was not knowledgeable in tyre rubber manufacturing, the solution emerged from a collaborative experimentation process. Eventually, the knowledge gained from the collaboration with Mahindra Reva was implemented in the supplier's core business.

"If you use normal tyres on EVs about 20% of the energy is lost. The tyre manufacturers said they do not have a solution for our problem. We believed that adding more silicon

in the tyre composition could help. So we started testing tyres with different compositions until we managed to reduce the energy loss to 2-3%. […] We were the first to introduce silica tyres on our cars in India. Today, our supplier provides silica tyres for IC cars too." (Head of Testing)

Our informants also reported instances when the collective bricolage involved more than two partners. One such instance took place more recently (i.e. after Mahindra & Mahindra took control of the company) and involved the development of a new technology for the moulding of the exterior body panels. In order to run experiments with a new moulding process, the resources (i.e. knowledge, tools, and machinery) of three co-bricoleurs were required. The multilateral collective bricolage was driven by the partners' mutual interest in developing the technology in question.

"We're looking to replace the thermoformed body panels with LFI [Long Fiber Injection] moulded parts and we conducted some experiments which involved two of our suppliers – MPC [Maini Plastics and Composits] and another company called Harita. We worked initially with our proto[type]-shop and we made a tool to produce an exterior ABS [Acrylonitrile Butadiene Styrene] skin. We took that tool to MPC and using their machinery and our tool they managed to make the part. Then we took the part from MPC to Harita which already has a mould for our existing parts. We put the part made at MPC in Harita's mould and added the LFI structure on the back of the ABS skin. Luckily for us, Harita is showing a lot of interest in pushing this technology so they were very happy to help us out. Aside from the equipment, Harita also provided some inputs about how to improve the process based on their experience with plastics. Their inputs helped us reduce the weight of our part." (General Manager R&D Mechanical)

4.3.2 Collaborations involving one-way knowledge flows

In the case of the car's gearbox, Mahindra Reva had the required knowledge but lacked the necessary tools and equipment. Maini Precision Products (MPP), also part of the Maini Group, had long been a supplier of high precision automotive components and assemblies and possessed the required equipment. However, because MPP had worked only with IC car-makers, the gearbox designed for the small electric Reva was completely new to them. Initially, Mahindra Reva technicians would come down to the sister and neighbour company (MPP) with their materials, use the MPP equipment and return to their Mahindra Reva workstations with the newly manufactured parts. As the volumes started to rise, the requirements and the production knowledge were passed on to the supplier.

> *"The gearbox is now made by the MPP. We designed it, built it and then transferred the know-how to them because they had the production capabilities. […] To put this in more detail, after we designed the gearbox, we had to buy aluminium castings and get them machined. Then we would put the gears in and assemble the whole thing. MPP has its own machining capability. Initially, we used to buy the castings, get them machined at MPP, get the castings back and do the assembling ourselves. The next step was to give them the gears and ask them to do the assembling too. Today they buy the materials, take care of everything, and supply the complete gearbox."* (Head of Prototypes)

Since the lead-acid battery supplier had been working exclusively with IC car-makers, it had no experience in testing large battery packs as those required by EVs. Our respondents felt that the prior experience with electric forklifts and more importantly the knowledge derived from the experimentation and the tinkering involved in the prototype development constituted the key elements Mahindra Reva was bringing into the collaboration with the battery supplier.

> *"The battery supplier for our first cars was a UK company. When we brought the batteries to India we found that the way they had tested the batteries wasn't right. We*

had to work with them to find the right structure and composition for the Indian conditions. We developed in India a lot of automated testing equipment. Once we found this equipment working so well, we actually sold it to our supplier. In a way, we actually managed the supplier's quality by providing testing equipment customized for EVs which we developed in-house." (Chief of Technology and Strategy)

Similarly, Mahindra Reva engineers developed motor testing equipment which was later transferred to the electric motor supplier in order to ensure the motors delivered by the supplier met the required standards.

"Although our supplier was very good at manufacturing standard motors, he didn't have the capability to deliver according to our requirements. We had to work together to develop all the components. We also did the testing together. Today, the supplier uses the dynamometer testing equipment developed in-house by us. In time, we transferred the responsibility for all components to them, and they deliver according to our standards. We held the supplier's hand in the areas where he didn't have the expertise and helped either with knowledge, design, or equipment. However, the suppliers did have the core production capability which we did not have. We actually had complementary strengths and the collaboration helped us both to do things much better and cheaper." (Chief of Technology and Strategy)

4.3.3 The challenges of collaborative bricolage

Senior managers envisioned the company as a technology and knowledge hub guiding the collaborative component development. The company retained only the assembly line and relied on external vendors for the production of all car components. Although this strategic choice helped Mahindra Reva reduce investment and development costs, implementation was challenging. Mahindra Reva was a small company with limited sales volumes and, thus, with limited bargaining power in relation to suppliers. Although the corporate parent - Mahindra &

Mahindra - allowed Mahindra Reva to tap into its extensive supplier base, the low volumes required by the company remained a constant problem in the relationship with suppliers. Moreover, senior managers explained that they chose Indian suppliers wherever possible as costs of established international suppliers could have significantly increased the overall cost of the car. Being dependent largely on the domestic supplier base, Mahindra Reva patiently nurtured their suppliers' knowledge base and capabilities.

> *"At Mahindra Reva, we generally do not drop suppliers, even if at some point they do not perform up to the standard. EVs are completely new to the Indian automotive industry and we are aware that suppliers are not always knowledgeable in EV technology. We go along with them and try to educate them. […] When we started testing the first parts delivered by our suppliers, they invariably failed within the first two days of testing. We had to have a hands-on approach and help our suppliers improve their products by transferring some of the knowledge we have accumulated in the last 15 years. […] Otherwise, we would not have our EV."* (Head of Testing)

The next quote provides an eloquent illustration of how Mahindra Reva managed suppliers' initial deficiencies in order to establish a mutually beneficial business partnership.

> *"After our UK lead-acid battery supplier went through a takeover, we started looking Indian supplier. […] The first battery packs our supplier delivered could be used to drive the EV for 1 km. They were not knowledgeable enough in chemistry. We had to work with them for about two years until they got the chemistry right and managed to fully develop the battery packs."* (Head of Testing)

Some suppliers derived significant benefits from the knowledge developed in collaboration with Mahindra Reva. Our informants observed that the manufacturer of plastic body panels grew at a faster rate than Mahindra Reva itself. Initially, Mahindra Reva had been the supplier's first and only client. Over time, however, the co-developed technology allowed the supplier to find other clients and significantly increase sales. At the time of the study, Mahindra Reva accounted for less than 30% of the production of this supplier. Generally, Mahindra Reva did not object to its suppliers exploiting the knowledge and technologies resulting from the client-supplier collaborations. Mahindra Reva believed that if suppliers expanded their client portfolios then they would achieve economies of scale which would then transfer to the company's EVs.

> *"We are happy when our suppliers expand their business due to the knowledge transferred by Mahindra Reva because we also get to benefit from their economies of scale by purchasing our parts at lower costs. The more knowledgeable and diversified [in terms of clientele] our suppliers become, the more cost and quality advantages we get."* (VP for Business Excellence and Operations)

As we previously discussed, because "collective bricolage is more than the ex-post connection of separately constructed arrangements" (Duymedjian and Ruling, 2010; p. 143), it requires each bricoleur firm to disclose and share resources with their partner(s) thereby contributing to the emergence of a shared resource pool or repertoire. Further, Duymedjian and Ruling (2010) argue "shared and close exposure" (p. 143) to the common repertoire is needed for the bricoleurs to become familiar with the inter-organisational resource pool. As we have shown above, the shared resource repertoire in the case of Mahindra Reva and its suppliers involved *bi- or multi-directional knowledge sharing processes* (e.g. Gupta and Govindarajan, 2000; Zimmermann and Ravishankar, 2014). Organisational knowledge management theorists (e.g. Nonaka, 1994) claimed that knowledge creation and sharing is achieved through social interactions often traversing organisational boundaries. This line of reasoning is confirmed by our informants who underlined the importance of extensive and continuous inter-organisational communication and interactions in the process of knowledge sharing involved in joint bricolage.

"In the design phase of the e2o there was a process of continuous improvement. Some of the improvements were dependent on the parts provided by our suppliers. This involved a co-learning process, correlating our knowledge base with that of the suppliers." (Head of Sourcing and Supply Chain)

and

"We tend to stick with the suppliers with which we had a good collaboration because we are very familiar with their capabilities and we understand where they could support us in the design or by sharing some of the initial investment." (New Product Development Manager)

Garud and Karnoe's (2003) argued that geographical proximity plays a critical role in collective bricolage ventures as actors with vested interests can contribute with inputs and share resources more easily in a closely-knit network. In a similar vein, our informants have described successful collaborations with Bangalore-located suppliers in which close interactions played a central role:

"For the windshield frame in the back, we had to choose between a supplier in Pune and one, here, in Bangalore. We went with the local supplier and this helped us a lot with some design changes we had to make after the supplier had started working. Because the supplier was nearby and we worked closely together, we managed to incorporate the changes reasonably fast and smoothly. The supplier also provided a lot of useful inputs. For example, we intended to bond [i.e. glue] the part to the space frame [i.e. chassis] but the supplier offered to provide a fastening system. Their suggestion eliminated the costs with the sealant and improved the assembly times because there was no drying time. [...] If the same thing had happened with the supplier in Pune, I think it would have been very difficult to manage the situation because of the distance..." (Head of Sourcing and Supply Chain)

and

"The charger is now supplied by the Maini Group. They make this charger only for us. Initially, we tried to work with foreign companies such as Emerson. The tooling costs were a lot higher and there were problems with the logistics, the time of delivery and the 10000-unit volume commitment they were asking for. The Maini Group is located nearby and we have had a long-term relationship with them, they sat down with us and adjusted their product [the charger they were using for their forklifts] according to our needs without incurring large tooling costs. Small or no tooling cost also implies less strict volume commitments." (Head of Sourcing and Supply Chain)

Moreover, our informants have confirmed that geographical criteria have been incorporated in Mahindra Reva's supplier selection strategy:

"We have a supplier strategy. We try to rely on Mahindra & Mahindra's supplier base or on suppliers with an earlier association with Mahindra Reva. But we also look at geographical proximity. We are located in Bangalore. Say there is a good Mahindra & Mahindra supplier in Mumbai and one in Bangalore near-by. Sometimes geographical proximity can trump the affiliation with Mahindra & Mahindra. We look for suppliers located in our proximity as much as possible. Geographical proximity is very important not only for reduced transportation and handling costs, but also for our interaction with the suppliers. If a problem arises we make a phone call and they can come down within an hour." (Head of Sourcing and Supply Chain)

Prior research (e.g. Audretsch and Feldman, 1996) argued that inter-organisational information exchange and knowledge sharing, especially tacit knowledge, are limited by geographical boundaries. Tacit knowledge or knowledge which cannot be verbally articulated (Polanyi, 1966) can be shared only by socialization processes such as observation, practice, interactions or other forms of shared experience (Nonaka, 1994). Despite recent IT progress which significantly reduces the cost information exchanges (Audretsch and Feldman, 1996) and even enables shared experiences such as video conferences, the extensive shared experiences required for tacit knowledge sharing such as the interactions between apprentices and their mentors (Nonaka, 1994) generally imply a shared physical presence. We believe that phrases such "we worked closely together" or "they sat down with us" used by our respondents capture precisely the sharing of tacit knowledge between Mahindra Reva and its suppliers. Therefore, we suggest that tacit knowledge is an important component of the shared repertoire of resources involved in collaborative bricolage. Although firms involved in collaborative bricolage can overcome geographical limitations in the process of tacit knowledge sharing by deputing experts to the lines of partner firms, spatial proximity supports socialization and, thus, tacit knowledge sharing.

Aside its importance in terms of tacit knowledge sharing, geographical proximity also spurs trust between co-bricoleurs. When partner firms share time, space and experiences they develop a sense of "closeness, resonance, and trust" (Duymedjian and Ruling, 2010; p. 144) which allows the bricoleurs to collaborate in the absence of conventions or based on rather informal conventions. Conversely, when interactions are limited due to distance and the resource repertoires remain separate, then more formal conventions are required to moderate collective bricolage (Duymedjian and Ruling, 2010). In this sense, our informants have explained the difficulties posed by collaborations with global suppliers as opposed to those with domestic suppliers:

> *"An important chunk of our bill of materials is imported. That means we are dependent to some extent on global suppliers. […] There is a big difference between interacting with a global supplier and working with a domestic one. On the one hand, our domestic suppliers either are affiliated to Mahindra & Mahindra or have had a long-time relationship with Mahindra Reva. These people know us and trust us. On the other, it is*

very difficult for us to retain global companies as Mahindra Reva suppliers because they ask about volumes and commitments. Sometimes, when they hear about our low volumes, we don't even get to discuss the actual component requirements." (Head of Sourcing and Supply Chain)

Our findings regarding the importance of geographical proximity in collaborative bricolage are also supported by the observation that some of (Mahindra) Reva's western partners were replaced in time by local companies. For example: Amerigon, Reva's initial partner shareholder, was replaced by India's Mahindra & Mahindra; Transistor Devices, the US-based charger supplier was replaced by Maini Material Movements; and the UK-based lead-acid battery supplier was substituted by the Indian battery producer Exide which currently intermediates the import of Li-ion batteries from a Chinese manufacturer (for more details please see Appendix 6).

4.4 Managing bricolage at Mahindra Reva

Bricolage was initially perceived as an individual activity where a solitary bricoleur develops a workable solution to a particular problem by engaging in a 'dialog' with his repertoire of resources (e.g. Levi Strauss, 1966; Weick, 1998). However, this doctoral study showed that bricolage can involve, in certain situations, organisational and/or inter-organisational processes. Despite other scholars taking similar vantage points (e.g. Ciborra, 2002; Garud and Karnoe, 2003), the underlying mechanisms employed by organisations in order to manage and institutionalise bricolage have remained underspecified. Hence, in this section we present Mahindra Reva's approach to managing bricolage.

4.4.1 Stretch goals

Often the starting point of bricolage activities is represented by the bricoleur's refusal to enact limitations (Baker and Nelson, 2005). Mahindra Reva was born from its founder's ambition who decided to ignore the advice of numerous naysayers and challenged cultural conventions and industrial norms (see Weick, 1979).

"Everybody told me I was a fool because I was already 65 and I was starting a technology company with no money. We were spending 1% of what GM was spending on similar projects, but I always kept a positive outlook on things and never doubted that this could be done." (Founder and former CEO of Reva and Maini Group)

In order to ensure that the employees shared a similar perspective and rejected a priori limitations, Mahindra Reva's top-management consistently set challenging goals for the company's staff. The goals were often highly improbable and extremely difficult to achieve given the organisation's current capabilities.

"As an organisation, questioning limitations and status quo made us different from other organisations. […] The goals I set for my staff are as such that if everything went perfectly, they would barely manage to accomplish them." (Chief of Technology and Strategy)

This managerial technique has been referred to in the academic literature as stretch goals (e.g. Locke and Latham, 1990; Rousseau, 1997; Sitkin et al., 2011). When organisations do not possess the knowledge or resources to achieve a stretch goal, they tend to search for novel ideas and solutions beyond established organisational knowledge and practices (Sitkin et al., 2011). According to Rousseau (1997), stretch goals spur "creativity and assumption-breaking thinking" (p. 528). We argue that stretch goals also encourage bricolage-based activities and solutions. First, since the attainment of stretch goals implies non-conventional approaches, organisations are likely to borrow knowledge from previously unrelated domains or recombine resources in unexpected ways in order to serve new purposes (as illustrated in a previous sub-section). Second, stretch goals support experimentation and trial-and-error learning (see Ingram and Baum, 1997) which we also indicated as an important component of bricolage activities.

Moreover, by driving the organisational search for solutions outside current practices and routines, stretch goals can help overcome organisational inertia and blindness, thereby inspiring disruptive innovations (see Raisch and Birkinshaw, 2008).

Despite important "facilitative" effects on organisational learning and performance, stretch goals can also have significant drawbacks (Sitkin et al., 2011). If employees perceived the stretch goal as unrealistic and not worth pursuing, their commitment to organisation's efforts could be seriously impaired (Sitkin et al., 2011). Similarly, if the problem at hand seems impossible and employees cannot identify any paths towards solving it, their responses might become impulsive, incoherent, and disorganized (Sitkin et al., 2011). Prior research (e.g. Bass and Riggio, 2005) indicated that transformational leadership can prevent such backfiring of stretch goal strategies by supporting organisational resilience and enthusiasm.

4.4.2 Transformational leadership

Our interviews revealed that Mahindra Reva and the Maini Group top managers consistently used practices and approaches associated with transformational leaders such as inspirational motivation, individualized consideration, intellectual stimulation, and idealised influence (see Bass and Riggio, 2005). For example, Mahindra Reva's Chief of Technology and Strategy recalled frequently challenging employees to step outside comfort zones and projecting optimism about the attainment of envisioned goals.

> *"I kept asking people in the organisation 'why can't you do it?' so many times until they understood that they actually could do it. […] I used to oversimplify things for my people, breaking problems into small steps which were easy to overcome. While we always kept the big picture in sight, it was important not to be overwhelmed by it."* (Chief of Technology and Strategy)

Such an approach is referred to by leadership scholars (e.g. Bass and Riggio, 2005) as *inspirational motivation* whereby managers not only communicate to their employees an exciting and appealing vision but also ensure that objectives are understandable and precise.

A respondent portrayed the Chief of Technology and Strategy as a leader showing high degrees of *individualized consideration* as he acted as mentor to many employees, attending to their needs and concerns, and providing empathy and support even on non-professional or personal matters.

> *"[Our Chief of Technology and Strategy] knows every single person within the organisation. He knows everybody's individual capabilities and how to get things done from them. […] He is interacting with us on different levels, giving us his ideas on how we could improve our daily work routines and our efficiency or how to reduce stress levels. […] He also tries to help everyone of us with our personal problems."* (New Product Development Manager)

After the Mahindra e2o was launched on the Indian market, the sales did not match the company's expectations. Our informants agreed that the main cause of the low sales volumes was the price of the vehicle. Although the price of the e2o was around 40% of the market value of the next most affordable EV alternative, it remained significantly higher than the price of the average IC car sold on the Indian market. In order to identify solutions to further reduce the cost of the vehicle, Mahindra Reva top-management organized an organisation-wide brainstorming session. For the event, all employees were invited to the plant and were presented with a number of India's most popular IC cars as well the company's own e2o. Furthermore, the major components of each model were presented separately and production processes were explained in detail. After closely examining the vehicles, components, and processes, the employees were asked to anonymously make suggestions on how the cost of the e2o could be reduced. By the end of the event, Mahindra Reva's circa 360 employees had produced over 2000 suggestions. Although at the time of our data collection, the company's staff was still processing the suggestions and we cannot tell whether any of the resulting solutions were actually implemented, the exercise is a vivid illustration for top management's attempts to *intellectually stimulate* the employees by challenging them to be creative and innovative. The employees felt their voice and input could actually contribute to the company's fortune and, since the suggestions were anonymous, there was no risk of embarrassment and criticism if their suggestions would be considered trivial or useless. In a similar vein, our respondents mentioned that the company regularly organized informal "open house sessions" where employees would "float ideas" regarding the issues and challenges faced by the organisation.

The Maini Group CEO mentioned that he tried to provide a good personal example in order to promote desirable behaviours, give a sense of direction within the organisation, and challenge the employees to adhere to his values.

> *"There are some things you cannot do in terms of training. But you can create a certain atmosphere by doing things in a certain manner, giving personal example and people start understanding that this is the way to work. We didn't have any formal programs in frugal engineering but, if somebody in this organisation wants to buy a machine or a piece of equipment, I probably ask about 100 questions. In some companies, managers may ask 15 questions, and in others, they would just sign the order form. The 100 questions are a way of checking if we don't have other solutions already available, if the machine is right for us, if it has the right capacity and cost. When people know that every conversation in the company follows this pattern and that you don't make a decision on something which costs money just like that, they start asking the same 100 questions internally. […] I think that being a small company has helped Mahindra Reva establish*

this frugal mind-set. I guess using this kind of hands-on approach would be more difficult in a larger organisation." (CEO Maini Group)

This approach is consistent with the *idealised influence* component of transformational leadership (see Bass and Riggio, 2005) where managers act as role models, guiding employees through every interaction.

4.5 Engineering the bricolage

Levi Strauss (1966) contrasted the bricoleur with the 'ingenieur', a concept drawing on the French engineering tradition (see Duymedjian and Ruling, 2010). Unlike the bricoleur who relies on assigning new and non-conventional applications to existing resources, the 'ingenieur' has a more structured approach to problem-solving based on established rules and predetermined ways of using resources (Duymedjian and Ruling, 2010). Departing from this perspective, our findings indicate that the bricolage and engineering approaches to technology development are more complementary than they are divergent. This idea was eloquently articulated by an informant:

> *"What we do today is a mix of the two approaches. When we do a prototype, we quickly produce a solution to prove that the concept works. This approach is all about having a practical orientation rather than a very structured, process-oriented approach to problem-solving. But later, our R&D department takes the knowledge about how the concept works provided by the prototypical illustration and creates a very structured process to create a mass-manufacturable product. That requires all the engineering capabilities that we can muster."* (Head of Mobility Solutions)

As our informant suggested, the solutions developed through bricolage-based processes required formalisation and institutionalisation in order to ensure the replicability of the results irrespective of context and the personnel involved (see Duymedjian and Ruling, 2010). Moreover, bricolage artefacts are often imperfect, strange-looking but workable solutions

(Lanzara, 1999). For such artefacts to become products which would successfully address the needs of a multitude of users/consumers, they must be adapted, improved, and tested. According to our informant, such task requires the rigour of established engineering methodologies.

In a similar vein, the following quotation explains the risks of relying excessively on bricolage approaches:

> *"There are areas where very ingenious solutions were found within the frugal means of this company without sacrificing quality, but there are sometimes dangers of experimenting too much and trying to find alternatives to the right path and that results in not doing things completely in their rights. There has to be a very fine balance."* (VP for Business Excellence and Operations)

4.5.1 Adopting Japanese practices

Thus, in order legitimize bricolage approaches to new product development in the eyes of customers, competitors, and even its own employees, Mahindra Reva adopted a range of engineering methodologies well-established in the automotive industry. For instance, in order to ensure consistency and to formalise the collaborative bricolage activities with their suppliers, the company adopted conventional practices popularized by Japanese automakers in the 1980s. These included the reliance on suppliers located in their vicinity in order to encourage communication, knowledge sharing, and collaborative problem solving (as shown in a previous sub-section) and the involvement suppliers in the early stages of designing new products (see Clark and Fujimoto, 1991; Ray and Ray, 2011) to reduce costs and design times:

> *"We refer to the involvement of suppliers in the new product development as 'vendor on board'. The earlier we take the vendor on board, the better it is for the project. Ideally, we should get the vendor on board at the time of concept designing. We shortlist a few suppliers with whom we are currently working or have collaborated in past and we invite*

them over. We tell them what we need and how we intend to go about doing. Then they provide input based on their experience and production capabilities. Because we usually already have a working relationship with these suppliers for other projects or parts, they are happy to contribute with their input although at this point there is no written agreement between them and us." (Head of R&D)

Another practice of Japanese origin was to provide suppliers only with the envisioned functionality of the components rather than to specify their design and, thus, to transfer (at least in part) the responsibility of the design to suppliers (Clark and Fujimoto, 1991; Ray and Ray, 2011).

"The wheel-well [which is a protective part fitted above the tyre, under the exterior body] is usually an injection moulded or vacuum formed plastic part. Since the profile of the part is semi-circular, the material should be very flexible and not too thick so that it can bend easily. One of our suppliers suggested that they could produce a part with these characteristics using rotation moulding [a process normally used for water tanks] instead of injection moulding or vacuum forming. You see, rotation moulding requires significantly lower investments compared to the other processes. However, the downside is that the cost of each part produced through rotation moulding is higher than the cost of parts product using injection moulding or vacuum forming. But considering that we required small volumes of the part it made a lot of sense to use rotation moulding at least for the time being." (Manager New Product Development)

Another informant explained that the involvement of suppliers in the design stage played an important role in the 'make-buy' decision at Mahindra Reva as the interaction enabled the company to assess the opportunity of transferring the responsibility of component design to suppliers.

"We share the concept with the suppliers and decide whether to buy an off-the-shelf part or to design and develop a new part ourselves. In this process, the supplier provides input based on their experience on how to reduce defects and get the parts 'first time right' and also on how to reduce costs. In the make-or-buy decision the first priority is to harness the supplier's capabilities in order not to invest [e.g. in tooling]. However, there are EV-specific components which suppliers are not familiar with and we have to develop them ourselves. The same goes for components of IP nature." (VP for Business Excellence and Operations)

4.5.2 Cost engineering

Cost engineering is another example of established practice implemented by Mahindra Reva. Cost engineering refers to a systematic approach aiming to efficiently balance costs, quality and time requirements (Amos 2004). According to our informants, cost engineering was a practice religiously followed at Mahindra Reva as the company's goal was to provide EVs which could compete in terms of price with conventional cars sold in India.

"We need to design-to-cost. The cost is driving our designs. We cannot design a part and only later on worry about the costs. We would end up nowhere. We would have to invest lots of money and the car would end up costing as much as the EVs our competitors are offering. Our EV has to be the most affordable in the world. We think of the cost implications of every line we draw in the design of a component. […] We always think of ways and means to develop a product with minimum investment, time and part costs. This is the basis of design at Mahindra Reva. We start with the end-user price and work in a reverse direction. We subtract dealers' margins, our margins, taxes, and arrive at the envisioned BoM [bill of materials] cost. Then we allocate an amount for each component. We give this target to the design team and they select the materials and processes accordingly. […] However, design-to-cost involves a team effort. It is not just about the

designers. At the concept stage, we have a brainstorming session with different departments like Proto[type]-shop, Assembly Line, or New Product Development. The idea generation is very important. Cross-functional input can really help the design. Then we get inputs from process engineering, from vendors etc. A lot of resources are available within the eco-system. It is a matter of identifying them. For example, at Mahindra & Mahindra there are lots of related departments such as plastic technologies, rubber technologies, which can provide really useful inputs. Finally, the outcome of the design process will be a good product, with a good design, with the lowest investment and part cost and with very good quality. This process takes some time but it gives very good results." (Head of R&D)

4.5.3 Mahindra Reva's original implementation of engineering methodologies

Although cost engineering is currently adopted by most automakers, Mahindra Reva's implementation of the process was different than that of local competitors. Mahindra Reva relied on extensive and continuous interdepartmental interactions. According to respondents with extensive work experience at much larger companies, Mahindra Reva's relatively small size allowed and encouraged organisational dialog and collaboration. In contrast, the process structure in bigger and more bureaucratic companies actually inhibited interaction, thereby reducing the number of sources of valuable input.

"At Mahindra Reva, engineers like me have a lot of exposure to understand the vehicle and the parts from scratch. We get involved in the concept drawing and we know the history of the changes in the product design. We also work closely and directly with suppliers. Tata Motors is a lot more bureaucratic. They have one cell which takes care of the initial prototype development. For vehicle building, they have separate engineering, purchasing and development teams. These teams also have their own budget. Then, there is a separate costing cell which has the responsibility to negotiate with

suppliers. Very few people know the full picture from concept design to production." (Manager New Product Development)

Our interviews also revealed that responsibilities at Mahindra Reva required a higher degree of versatility compared to the requirements of more established organisations characterized by high levels of division of labour.

"At Tata one is confined within the boundaries of the job description. For example, the guy working on the shock absorbers has been doing just that for his entire career. Here [at Mahindra Reva] there is some job rotation and we constantly interact with all other departments. Everybody knows what is happening in all areas of the company. I, for one, know most of the details of the car. This would be impossible in bigger companies. I would never get sufficient exposure." (Manager New Product Development)

and

"An average engineer at Mahindra Reva does many more things than an engineer working for Tata or Chrysler. For example, at Chrysler, I had 8 engineers working only on the design of the underbody. Here, I have 8 engineers for the whole programme. This is an advantage because our engineers have more exposure and become capable to do, for example, not only a door, but also a hatch and a body. The disadvantage is that people have a lot more work to do, and they can make mistakes." (General Manager R&D Mechanical)

In a similar vein, Duymedjian and Ruling (2010) argued that bricolage activities do not support specialization and bricoleurs require knowledge and expertise spanning multiple disciplines and practices which are traditionally separated by organisational and professional boundaries. Although the relative lack of specialization may impugn the legitimacy of bricolage as organisational process and conflict with the individual professional identities of engineers (Duymedjian and Ruling 2010), our informants exhibited a keen sense of satisfaction with the opportunity to expand their knowledge and expertise. Although on a superficial level this versatility may appear as a consequence of the company's limited resources, we suggest that Mahindra Reva's original implementation of engineering practices was related to the company's ultimate goal of supporting, complementing, and legitimizing bricolage. If Mahindra Reva had adhered to a classical implementation of engineering practices, then specialization and division of labour would have stifled organisational interaction and communication, thereby preventing the emergence of a coherent knowledge repertoire.

4.5.4 Formalising bricolage to ensure replicability

One of the major challenges faced by organisations relying on bricolage is posed by the transferability of repertoires and the replication of the procedure (Duymedjian and Ruling 2010). Prior research has suggested that such challenges could be overcome by ensuring that the capabilities of individual bricoleurs are incorporated and diffused across the organisation (Duymedjian and Ruling 2010). According to our respondents, after Mahindra & Mahindra partnered with the Maini Group in the EV venture in 2010, one of the central preoccupations at Mahindra Reva was integrating the flexible bricolage-based approach to product development into structured processes, practices and routines which employees could replicate in new projects. For this purpose, experts in process development and implementation were transferred from Mahindra & Mahindra to Mahindra Reva or recruited from other big established companies. One such expert explained the struggles the company was facing:

> *"In a family business you have enthusiasm and commitment. When the group is small, people go the extra mile to make things happen. This is why Mahindra Reva was not merged with the automotive division of Mahindra & Mahindra and it was kept as a separate entity. […] The strength of a 'professional company' such as Mahindra & Mahindra lies with the internal systems and processes. The company is not relying on key individuals but on these processes. At Mahindra Reva there are people who have*

become indispensable. For example, people got used to running at our Chief of Technology and Strategy for every small problem they were facing. He is a technocrat and knows the technology like the back of his hand and he can guide people. But while Reva used to be a one-product and one-programme company, Mahindra Reva is now a multiple-programme company delivering many products and our Chief of Technology and Strategy can't hold everyone's hand anymore. Therefore, his knowledge must be embedded in processes. We are now trying to build a process-driven organisational culture." (Head of Car Programme)

Mahindra Reva's quest to formalise and institutionalise bricolage involved not only the implementation of processes and routines but also the creation of new organisational structures. A division was set up with the exclusive purpose of identifying new opportunities for the company to deploy its battery management capabilities such as the telecommunication application discussed earlier in the chapter.

"Our department is looking at new business development. Mahindra Reva has existent knowledge and IP in certain areas which are rather unique in the country today. In this sense, we are very uniquely positioned. We try to capitalize on that and look at other areas where our knowledge may be applied and what markets we could get into. The core technology is there, we just need some incremental effort to make modifications and apply it in a new context. This effort required is obviously lower than the effort required to enter in that new space with zero knowledge. I analyse this incremental effort, the time cost, and see if the effort can be justified with respect to emerging opportunities. Our incremental effort may be small but the returns could be huge. […] The core knowledge we are trying to reapply is our experience and knowledge with large capacity Li-ion batteries. Understanding how very large Li-ion battery packs behave and our expertise in managing them safely (with 0 risks) in applications which involve people is not easy

to come by in this country. […] The fact that we have a modular and scalable system can give us an advantage in moving away from our initial technical application and reapplying that knowledge." (Head of Mobility Solutions)

4.6 The cultural context

During our data collection, we came across accounts of how Mahindra Reva repeatedly managed to beat the odds and overcome troubles despite important resource constraints. This posed the question whether the environment or context in which the company operated had any influence on Mahindra Reva's achievements. We initially broached the subject by referring to the concept of 'jugaad'. As mentioned earlier, jugaad is a Hindi and Punjabi slang word which referred initially to improvised, self-repaired vehicles, 2, 3, or 4-wheelers which could transport more passengers than traditional vehicles and were prone to all sorts of mishap (Birtchnell, 2011). The meaning of the word then gained amplitude and implied "making do" and quick-fix innovations with limited, available resources. Eventually, in business and management contexts, jugaad has come to denote an improvisational style of innovation (Jana, 2009), resource-constrained product development approaches (Sharma and Iyer, 2012) or "an acceptable form of frugal engineering, […] a tribute to Indian genius" (Maini, 2013). Despite these positive recent connotations, it became apparent that the informants were disenchanted by the word's original meaning and some viewed jugaad as a source of systemic risk on Indian roads (see Birtchnell, 2011). Therefore, they rejected the notion of jugaad in relation to their work at Mahindra Reva. However, our informants appeared happy to adopt the concept of frugality when discussing their activity.

Two sub-themes regarding the value of frugality emerged from our data analysis. The dominant sub-theme viewed frugality as a value shared by many Indians, while the other sub-theme illustrated frugality as an integral characteristic of Mahindra Reva's organisational culture.

4.6.1 Frugality as part of the Indian heritage

Some of our respondents have discussed frugality as a cultural characteristic specific to Indians in general:

> *"We, Indians, are taught cost reduction by our parents since we are born because we have to save everything. It is part of our bloodstream."* (Founder and former CEO of Reva and Maini Group)

and

> *"Although we don't really talk about frugality in the company, it is in our genes. It is embedded in the way we think and work."* (Head of New Technologies and IP)

The respondents felt that such cultural heritage played an important role in the new product design and development processes as managers and engineers always strive to provide higher value for less cost. Moreover, the cultural value of frugality allowed the company staff to design and develop products which focused more on customers' immediate needs rather than lifestyle wants (see Jana, 2009):

> *"If you have this [frugal] culture, when you are designing you'll think 'oh, that's not good value, we must do something better because I wouldn't buy it'."* (Chief of Technology and Strategy)

Recently, both jugaad and frugal product development have received increasing attention in the academic and business literature due to the economic downturn in developed countries. In the face of decreasing consumer spending, western companies are trying to 'import the Indian mind-set' (Jana, 2009) in an attempt to develop products which are more economical both for companies and consumers. For this purpose, Harman, an American producer of audio and infotainment systems, based a product development unit in India (Govindarajan, 2012). Similarly, Cisco, another American technology company, not only established a second global headquarters in Bangalore, but also ensured that their US-based software development teams included Indian engineers (Jana, 2009).

Several informants claimed that Mahindra Reva benefited a lot from its employees' ability to adapt and achieve envisioned goals despite their limited resources rather than using constraints as justification for failure.

> *"Indian families often have many children but only limited resources. So, the parents teach their children not to look at wealthier families and ask for more, but to adjust to their circumstances. […] In their lives, Indians have to adjust on so many different levels… For example, when [arranged] marriages happen, people are told to adjust. This is why the marriages last longer. Because people adjust to the circumstances, they are ready to make a compromise for the mutual benefit. This cultural aspect is also present in our organisation. When people join this company and see that it has limited resources they strive to achieve the goals without demanding too much from the management. […] When I joined this organisation, I was coming from a big company but the first thing I told myself was that I would adjust to this new place and I would not start making demands. I did not ask for 20 people working under me. I sat down and did the work myself."* (VP for Business Excellence and Operations)

The previous quotation hints to the bricoleur's refusal to enact limitations (Baker and Nelson, 2005). Bricolage as organisational process implies that company employees share an attitude of 'making things happen' despite adverse conditions. While stretch goals and transformational leadership can help inspire employees, some of our informants also suggested that the Indian cultural context may have favoured organisational bricolage.

> *"The culture of adaptability specific to Indians helps us deal with the constraints. If you can nurture this adaptability you can be very successful."* (Chief of Technology and Strategy)

4.6.2 Frugality as organisational culture

One informant perceived frugality as a component of organisational culture rather than something associated with 'being Indian'. He also pointed out that there were many Indian companies that behaved in a non-frugal manner and that the frugal mind-set gave Mahindra Reva its edge against Indian and international competitors.

> *"Frugality is a culture. Some companies have a quality culture, others don't. Some are very good at marketing, some are not. Some have a frugality culture, others don't. Companies succeed on various parameters and this frugality culture is part of our competitive advantage."* (CEO Maini Group)

The same informant also explained that challenging conditions and resource constraints helped individuals and companies in India become more efficient and resilient. Therefore, our data suggests that western companies would benefit from 'importing' the bricoleurs' refusal to enact limitations as they are increasingly facing constraints and limitations posed by the economic recession.

> *"While it is a part of the Indian culture to adapt to circumstances and make things happen despite scarce resources, this is because we were faced with certain circumstances. If Westerners do not seem to behave similarly, it is probably because they weren't confronted with our circumstances. Had they faced the same problems they would probably learn to adapt as well. [...] In this sense, the frugal mind-set is not specific to India. It is just a consequence of the adaptability we developed through our experiences. However, if Indians work in a company driven by frugality, they are able to understand it far better."* (CEO Maini Group)

4.7 Frugal marketing

All activities carried on at Mahindra Reva were impacted by the company's limited resources. Product advertising and promotion activities were no exceptions. In addition, the budgets allocated for such activities would have impacted the EV's price, thus conflicting with the company's goal of delivering the most affordable EV in the world. Therefore, the company had to 'make do' with free or low-cost communication channels such as social media networks.

According to our informants, Mahindra Reva chose to engage potential customers through social media for several additional reasons. Firstly, the company expected the initial adopters of the Mahindra e2o to be well-educated Indians with above average incomes[6]. The company's marketers envisioned such individuals as very selective about how they spent their free time. Therefore, costly mass-media channels could prove inefficient in reaching such discerning audiences. However, virtual social networks seemed to be a constant presence in the daily routines of targeted customers and could have provided an effective, yet affordable meeting place with the envisioned audiences. Secondly, the company also believed that their innovative product would appeal to technology-savvy individuals. Our informants argued that due to their technological prowess these individuals had a predisposition for adopting emerging technologies. Thus, the use of ICT innovations such as virtual social networks was considered an indication of such predisposition.

> *"Mahindra & Mahindra as a group relies a lot on digital [channels] because that's where they think their audience is. A lot of young Indians who are educated, have above average incomes and can afford to buy a car are generally present on social media and it is easier to reach them at this level. Even the older group, people who have savings which would enable them to buy a new car are also on social media to a large extent.*

[6] It should be noted that most Indian customers with above average incomes can be included in the middle-of-the-pyramid customer segment which we have consistently discussed throughout this thesis.

[…] We also target early adopters of technology and we feel that the digital space and media are a good way to engage with them. Plus, it is very cost-effective.” (Account Manager Advertisement Agency)

Thirdly, our respondents claimed that conveying the non-mainstream functional attributes of EVs to potential customers required extensive, continuous dialog and interactions rather than the monotonous, unidirectional iterations of conventional mass-media advertisements.

“In mass-media channels, we can only get limited time to ‘speak’ to people. This car has so many features which are unfamiliar to customers and need to be explained. For example, an important selling point of this car is the ‘return on investment’ that buyers get in the next 3-5 years. It is very difficult to explain to customers the whole process through which they can save money in a 30-second TV ad or a half-a-page print ad. This kind of ideas can be easily and effectively communicated through social media. Here we can put up a longer post or a series of posts explaining to customers everything there is to know about the car. Also, the engagement through this medium is far higher than through most regular media vehicles.” (Account Manager Advertisement Agency)

4.7.1 The pre-launch phase

Our data revealed that in weeks preceding the launch of the new EV (i.e. the e2o), Mahindra Reva attempted to position itself as a company because the lack of brand recognition was perceived as an important disadvantage.

“Many people like a company or brand before liking a particular product. Mahindra Reva was a completely unknown brand, so just going and selling an innovative product without establishing what they stand for, who they are, does not really work.” (Account Manager Advertisement Agency)

In addition, EVs were offering performance along attributes such as zero CO_2 emissions, and immunity to conventional fuel price fluctuations, which were either less important to or not valued at all by mainstream automobile users who focused on top-speeds and mileage on a single fuelling (see Christensen 1997). Thus, the company had to position its brand in relation to other interest points of potential customers. According to our respondents, the marketing strategy aimed to incorporate themes and issues which were salient to customers:

> *"A lot of traditional advertising starts with the brand or product and tries to convince customers that the advertised product would address their needs or desires. Instead, we identified trends, movements, issues that are going on in society, tapped into that and tied it to the brand and the product."* (Account Manager Advertisement Agency)

Our interviews showed that Mahindra Reva's pre-launch campaign attempted to expand the brand boundaries in order to encompass major social trends emerging in India, instead of exclusively advocating the company's core values of technological excellence and environmental responsibility. Our informants felt that there were two important social trends in India the company could relate to. First, according to one informant, social activism and civic engagement had gained momentum in India in recent years. This tendency was exemplified by the 2011 large-scale anti-corruption movement emerging in India (Joseph, 2011). It lasted over one year and concluded with the adoption of an anti-corruption bill (Joseph, 2011). Although the bill reflected only partially the demands of the protestors, the movement proved the citizens' ability to bring about change through civic action (Economic Times, 2013).

> *"People in India are increasingly preoccupied with social issues such as women's rights or corruption. India is waking up and asking questions. We thought it is very relevant that people are asking questions because this is the only way that change can come about."* (Chief of Technology and Strategy)

Secondly, our informants suggested that Indian youth were increasingly challenging religious and social orthodoxies and adopting more liberal values due to processes of westernisation and acculturation supported by the proliferation of information and communication technologies. Consequently, Mahindra Reva chose to build their campaign around these emerging trends advocating for individual empowerment and challenging inherited beliefs and circumstances.

> *"The youth of today are questioning everything. They no longer want to do things the way their parents and grandparents did in the past. India used to have a very faith-oriented culture, so people always thought that there was something they were meant to be doing. If their parents were doing something, then they were supposed to do the same thing. That was something they were born into. Now things are changing and we wanted to tap into this cultural shift that is challenging conventions."* (Account Manager Advertisement Agency)

and

> *"The campaign will tap into the hunger for change in an increasingly confident India."* (Mahindra Reva press release)

Obviously, Mahindra Reva was a profit-driven, commercial organisation, and thus social change was not one of its primary objectives. However, our interviews revealed that the company always strived to deliver reliable products, be highly innovative and drive technological progress in India, thereby reflecting the founders' sense of national pride. The mission of the Maini Group, (Mahindra) Reva's initial parent company, is summarized below:

> *"In 1973, when I started the company [the Maini Group] the reputation of Indian companies was lousy. We never supplied quality products, we didn't meet deadlines and we got very bad write-ups in Western media for it. I wanted to show everyone in the world that we could make here, in India, products at quality standards comparable to those*

delivered by industry leaders. We always considered us to be competing with the best in the world, not just with our next-door Indian neighbour. [...] As a company, we picked up products which were ahead of their time in our Indian context, which nobody wanted to touch because the technology was very advanced, the market was very small and the profitability was not there." (Founder and former CEO of Maini Group)

In a similar vein, Mahindra Reva's Chief of Technology and Strategy explained that the pre-launch campaign was inspired by the company's goal to drive change in the automotive industry.

"The campaign was also rooted in our DNA as a company. The fact that we always questioned status quo and the way things were done in the auto industry has helped us to be very innovative and has brought us this far." (Chief of Technology and Strategy)

The same informant continued by pointing out that, at least in his case, the initial ambition for technological pioneering and leadership eventually evolved into bigger and more important concerns:

"Initially, I was more excited about the technology itself and what it could represent for the Indian industry. But, over time, the ideas of energy security and environmental responsibility became more important for me." (Chief of Technology and Strategy)

As a consequence, we suggest that Mahindra Reva's pre-launch campaign was not just a marketing stunt void of content but rather the meaningful association of the ideas of technological progress and positive social change. The relationship between technology and society has been long debated in the academic literature. On the one hand, adepts of technological determinism argued that technological progress has profound influences on social developments and cultural values as described by the "[...] three-word logical proposition: 'technology determines history'" (Williams 1994, p. 218). On the other hand, scholars advocating the "social shaping of technology" claimed that technology is moulded by society through culture, economics, and politics (e.g. Mackenzie and Wajcman, 1985).

Moreover, the relation between technological and social change is of particular relevance for the adoption of non-mainstream value propositions of disruptive innovations. Christensen (1997) argued that customers turn their attention towards non-mainstream attributes when their requirements for attributes they consider most important are satisfied. The "social shaping of technology" perspective could suggest another scenario conducive to the adoption of disruptive innovations. Remarkable social developments may determine cognitive reorientations of customers towards new values and ideals gaining salience. Following these cognitive reorientations and owing to newly embraced values, customers may begin to place greater weight on functional attributes which were initially considered of secondary importance or non-mainstream, thereby adopting disruptive technologies. This idea is supported by our respondents who felt that a change in customers' perceptions and attitudes would be necessary for EVs to gain traction on a wider scale.

> *"The company believed that for EVs to be successful, a change in customers' perception about cars is required: what are the expectations about cars, what is it that a car should do and what is it that it shouldn't do..."* (Account Manager Advertisement Agency)

Irrespective of cause-and-effect disputes, the inextricable connection between technology and society (Murphie and Potts, 2003) has been widely accepted in the academic literature. Emerging from the reasoning illustrated above, Mahindra Reva's "Ask" campaign encouraged people to ask questions about issues important to them. The central idea of the campaign was that progress and positive change are possible only if the right questions are asked, thereby galvanizing the search for appropriate answers. In the weeks preceding the launch of the Mahindra e2o, a 90-second video was circulated exclusively on social media (e.g. Facebook, Twitter, Youtube, blogs). Throughout the video, people raised their hands to ask various questions for which currently there are no answers. In the final seconds of the video, viewers were invited to post their own questions on the company's website. In order to increase engagement and participation, social media users were offered the possibility to create and share their own version of the Ask video starring themselves and their friends. The success of the campaign was quite impressive. Within the two weeks of the campaign, the video was watched by more than 400,000 unique users, a quarter of which in the first two days of the campaign. Moreover, over 12,000 unique users went on Mahindra Reva's website to post their questions. One informant summarized the outcome of the pre-launch social media campaign:

> *"During the weeks of the campaign we got a very positive response. Everything was completely organic. There was no paid advertisement for the video, no sponsorship, nothing at all. […] There was this big on-going conversation with people asking questions, others suggesting answers and raising new questions…"* (Account Manager Advertisement Agency)

4.7.2 The post-launch phase

After the launch of the e2o, Mahindra Reva had to focus on conveying its non-mainstream value proposition to potential customers. According to our respondents, the Mahindra e2o represented a cost-effective (about 5% of the running costs of conventional cars), environmentally friendly (zero CO_2 emissions), easy to service (remotely) mobility solution. However, although attractive, these features were only of secondary importance for many automobile users. Mahindra Reva found that the functional attributes most valued by mainstream automobile buyers remained driving range with a single fuelling, top-speed and engine power (see Christensen 1997). The purely electric Mahindra e2o with its maximum driving range of 100 km and top-speed of 80 km/h was perceived to be inferior to internal combustion cars on mainstream attributes and thus difficult to sell.

Under such circumstances, Mahindra Reva faced the challenge that is seen as typical for disruptive technologies: it had to find an initial niche of adopters for its product (see Christensen 1997). Thus, the company's social media marketing campaign aimed to underscore the relevance of the functional attributes offered by the e2o in the mind-set of potential customers. Therefore, Mahindra Reva's marketers identified *cost-effectiveness* and *eco-friendliness* as the central attributes of the company's value proposition and tried to frame them in order to resonate with customers' individual interests, priorities, values, and beliefs.

Despite consistent economic growth over the last years, India is still among the lower-middle-income countries according to the World Bank 2014 classification. Therefore, Mahindra Reva's marketing strategy relied on the assumption that *cost-effectiveness* is a value situated at the forefront of the typical Indian cognitive framework. Our informants claimed that even individuals with incomes exceeding the local average shared similar values:

> *"In India value for money is very high at every level. If you introduce a space shuttle in India, the first question you're going to get is 'What's mileage for this thing?' That's the Indian DNA."* (Chief of Technology and Strategy)

Our informants further explained that the main priority of Mahindra Reva's corporate social media presence was to address the customers' price-sensitive nature by building awareness about the cost savings customers could get in the long run. The company took two main routes to communicate its value proposition. First, the marketers at Mahindra Reva tried to "mobilize" potential customers by addressing their grievances and frustrations. Similar ideas can be found in the literature on social movement literature (e.g. Snow et al., 1986) which documented an important connection between "intensely felt grievances and susceptibility to movement participation" (Snow et al. 1986, p. 465). In this sense, Mahindra Reva has identified escalating fuel prices as an important cause for grievance, an injustice for which governments and big oil companies were jointly responsible. Moreover, social movement participants are likely to act upon their grievances, only if they believe that their actions have a reasonable chance of success (Piven and Cloward, 1977). Since reducing or controlling fossil fuel costs may not be possible in a market economy, Mahindra Reva's marketers tried to deal with the customers' grievance by underscoring the idea that EVs provided immunity to fuel prices.

> *"We use frequently the price of petrol in our social media campaigns. Ever since petrol prices have been deregulated in India, they have increased almost every month. So every time petrol prices go up we put up some posts about how it makes a lot of sense to own an e2o."* (Online Marketing Assistant Manager)

A significant number of posts on Mahindra Reva's social media profiles illustrated the company's attempt to position their value proposition as a reasonable and effective solution to the customers' anxiety caused by constantly increasing fuel prices:

- *"77 and counting… It won't be much longer until petrol touches Rs. 100! What's your take on this?"* (posted on 17.07.2013)
- *"Petrol price hiked again? No problem if you have an e2o."* (posted on 15.07.2013)
- *"Counting the days to the next petrol hike? Or will you be counting savings with the e2o?"* (posted on 05.06.2013)
- *"Leave the petrol behind, not all of your money."* (posted on 28.05.2013)

Another clever post (from 28.10.2012) building on the same idea included a photo of a billboard which was advertising the latest offer from a major Indian bank: petrol loans.

Our interviews also revealed a second strategy employed by the company to connect with the customers' preoccupation for cost-effectiveness. This approach involved illustrating all the long-term benefits that EV users could accrue, such as significantly lower running and maintenance costs. Similar strategies were documented by social movement scholars (e.g. Granovetter, 1978, Klandermans, 1984) who have argued that potential social movement adherents usually assess the positive and negative consequences of action or inaction when deciding whether or not to join a particular movement. In our case, Mahindra Reva focused on financial or material consequences because cost-effectiveness was perceived as being highly salient in the Indian collective mind-set. Therefore, in order to convince customers to turn away from conventional cars and adopt its non-mainstream value proposition, Mahindra Reva's marketers emphasized the savings customers could expect in return for compromising on mainstream functional attributes such as driving range or top-speed.

> *"We want to compare EVs with conventional cars in terms of driving costs, maintenance etc. These kinds of posts work really well. They have the highest number of interactions and attract the highest number of unique users."* (Account Manager Advertisement Agency)

and

> *"Now we have come up with a calculator showing customers how much they could save every day on fuel costs and then we hint at what they could do with that money, for example going to the cinema or have dinner out."* (Account Manager Advertisement Agency)

Aside from precisely indicating the savings on fuel costs provided by EVs, posts on the company's Facebook page hinted at how EVs are more practical than other popular transportation alternatives and illustrated other sources of savings such as lower maintenance costs compared to conventional cars:

- *"Did you know you spend more per kilometre in an auto[rickshaw] than you do by flight over the same distance?"* (posted on 24.07.2013)
- *"Maintaining your tyres and brakes can be a pain. But you can change that with the e2o [as the regenerative braking reduces the need to apply mechanical brakes thus resulting in the longer life of brakes and tyres]."* (posted on 09.05.2013)

Environmental friendliness was the second important ingredient in Mahindra Reva's non-mainstream value proposition. However, unlike cost-effectiveness or value for money, eco-friendliness and environmental responsibility were not very salient values in the Indian context, according to the informants. As they explained, while financial constraints are a persistent and ubiquitous problem in India, pollution and other environmental concerns are perceived as less pressing matters.

> *"It is easy for people to relate to cost savings or new and exciting technologies because these are palpable, familiar issues for them. On the other hand, there is no environmental conscience in India right now. Eco-friendliness is more in the background, an intangible concept with limited immediate implications for them."* (Account Manager Advertisement Agency)

Moreover, Mahindra Reva's marketers explained that customers' values are classified in a hierarchy reflecting their prominence in the individual or collective mind-set.

> *"India has a huge 'bank' of issues: corruption and poverty would be up here, while pollution and other such issues would be down there. Environmentalism is not the most critical issue that people are concerned about today."* (Account Manager Advertisement Agency)

Similarly, sociological research argued that the salience of values depends not only on the extent to which they are attainable and compatible to individual/collective convictions, but also on the perceived seriousness of a related problem or grievance (Snow et al., 1986).

Under such circumstances, Mahindra Reva's marketers used the company's social media presence to point out the harmful effects of the pollution caused by IC cars, thereby promoting and nurturing environmentalist values. Our respondents felt that in the long run, increased environmental consciousness would contribute to a shift in automobile users' preferences towards the currently non-mainstream attributes of EVs.

"It is a process of changing the customers' mind-sets. This is a difficult thing and it is a long-term objective. Eco-friendliness may not be a major selling point now, but it is one of the core values of the company and it has to be reflected in the posts we are putting up on social media." (Account Manager Advertisement Agency)

On the one hand, the company suggested through Facebook posts that customers could take effective action in the fight against pollution and climate change by purchasing an EV, thereby reducing their CO_2 footprint:

- *"Burning petrol doesn't just choke you, it also melts the Arctic cap."* (posted on 13.09.2013)
- *"Estimates say that the Arctic will be ice-free by 2030 due to global warming."* (posted on 19.08.2013)
- *"Crawling traffic contributes eight times as much air pollution as traffic moving at regular highway speed. It's time to go electric"* (posted on 06.06.2013)
- *"Taking the cycle to work is great. The next best thing is driving the e2o to work."* (posted on 18.05.2013)
- *"Climate change has many faces, like the blistering heat you face while in traffic. How do you think the e2o can help?"* (posted on 20.04.2013)

On the other hand, Mahindra Reva posted on its Facebook page environmentally conscious tips and advice on how to reduce pollution or conserve limited resources such as:

- *"Making a rainwater barrel is a great way to harvest rainwater if you're in a city"*. (posted on 01.07.2013)
- *"Candle holders, newspaper stands, vases and more – instead of chucking those PET bottles, put them to good use. Follow the link to see how you can reduce waste, recycle… and grab eyeballs."* (posted on 22.11.2012)

Although lacking any commercial message, these kinds of posts were clearly meant to develop environmentalist values in the conscience of potential customers, which in turn would increase the appeal of Mahindra Reva's non-mainstream value proposition.

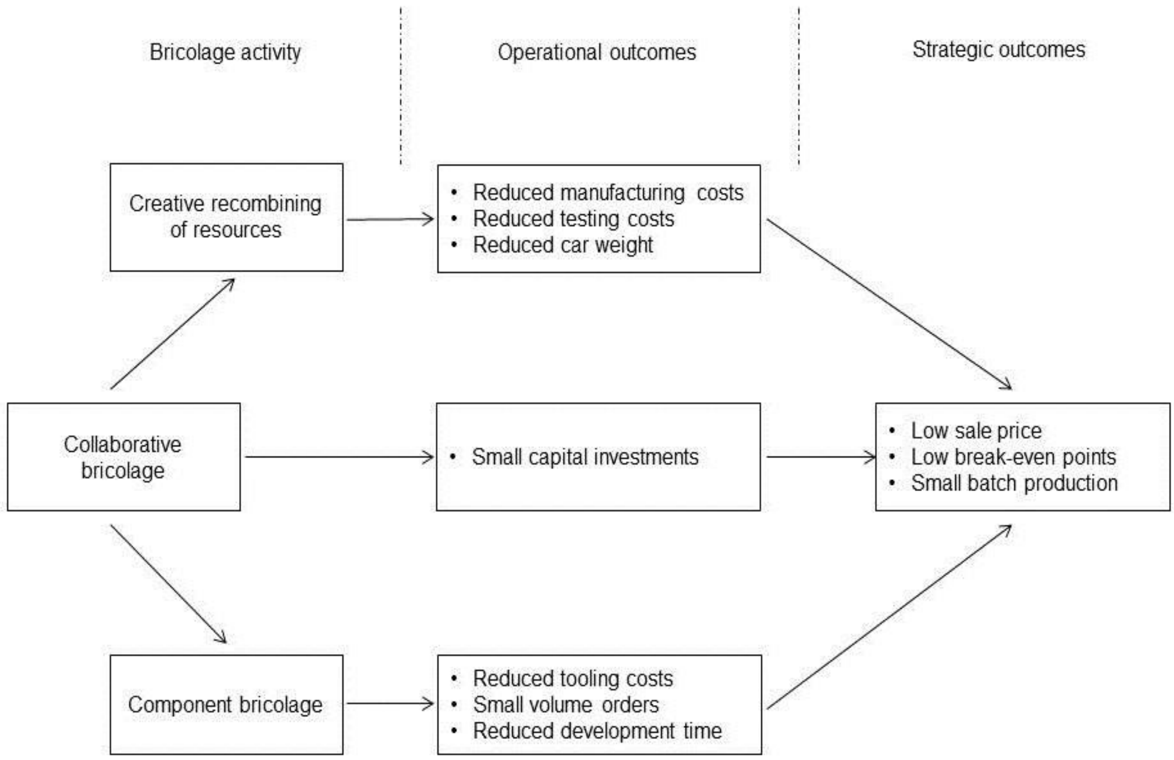
> *"[The rainwater barrel post] is part of the bigger picture. We are an environmentally conscious company and we care not just about the car we are trying to sell but also about other pressing concerns. People can make a big difference in protecting the environment on many other levels not just by buying an EV."* (Online Marketing Assistant Manager)

Chapter 5: Discussion

5.1 Outcomes of bricolage

According to our informants' estimates, Mahindra Reva spent only about 1% of the amount invested by competing carmakers such as GM or BMW in the development of their EV models. In order to compensate for the limited resources, Mahindra Reva pursued a bricolage-based strategy. We identified three types of bricolage activities (i.e. the recombination of resources for new purposes, component bricolage, and collaborative bricolage) as representing the core of the company's strategy. Of these, the first two typologies refer to activities undertaken on an organisational level, while the third involves an inter-organisational effort. The company's bricolage-based strategy delivered outcomes on two distinct levels, which we labelled as operational and strategic (see figure 10 below).

Figure 10. Operational and strategic outcomes of bricolage



5.1.1 Operational outcomes of bricolage

The operational outcomes are those which allowed the relatively small and resource-constrained Mahindra Reva to carry out an otherwise very costly technology development process. The *creative recombination of resources* allowed the company to significantly reduce production and testing costs. For example, using plastic produced through cost-effective processes such as vacuum forming and rotation moulding instead of metal sheets for the exterior body parts of the car had a major impact on the company's cost structure. Although most carmakers outsource variable percentages of the car components, they almost always do the metal-stamping and painting of the exterior car body in-house. This involves acquiring and maintaining very expensive production equipment and painting shops. By using colour-impregnated plastic instead of metal, Mahindra Reva managed to outsource the production of the exterior body parts as well. This allowed the company to make savings both on equipment and on the construction of required facilities. Similarly, by developing testing equipment in-house from basic EV components such as motor, controller, and charger, the fixed costs of standard testing rigs incurred by most other companies in the automotive sector were avoided.

Through c*omponent bricolage* (i.e., by using off-the-shelf components and parts) Mahindra Reva aimed to take advantage of the extant production capabilities of suppliers. The development of original parts usually implies investments in tools and equipment which are termed in industry jargon as tooling costs. In principle, suppliers are happy to cover tooling costs as long as the buyer places orders big enough to cover the initial tooling investment made by the supplier. Otherwise, suppliers would normally ask for upfront payments towards the tooling investment. However, Mahindra Reva could not afford to make upfront payments nor firm commitments to purchase parts in big volumes because EVs are still regarded as niche products and the company expected low sales numbers. Thus, by using wherever possible off-the-shelf components and parts which suppliers could produce using equipment and tools already in place, Mahindra Reva managed to avoid both initial tooling costs and the suppliers' demands for big volume commitments.

The partnership-led *collaborative bricolage* was the consequence of the company's strategic decision to outsource all the car's components with the exception of the IEMS and helped the company to conduct its product development without any capital investments in production equipment. The only fixed costs incurred were related to the in-house R&D facilities, the assembly plant, and the line equipment. Overall, the minimal initial investments required by the three types of bricolage allowed Mahindra Reva to engage in EV technology development and production despite the company's limited resources.

5.1.2 Strategic outcomes of bricolage

The bricolage approach also helped the company achieve what could be termed as important strategic outcomes (see Figure 1 above) which allowed Mahindra Reva to (i) offer customers the most affordable EVs in the world, (ii) have low break-even points, and (iii) have flexible production volumes, easily scalable according to the customers' demands. As shown above, the company incurred low manufacturing and testing costs thanks to its bricolage-based strategy. In addition, the choice of plastics for the car's exterior body significantly reduced the total weight of the car, leading to the use of smaller and less expensive battery packs and, thus, reducing further the selling price.

Moreover, due to collaborative bricolage arrangements, the company's fixed costs not only became very small relative to industry standards but were also amenable to amortization over multiple projects since their nature (i.e. R&D facilities and assembly plant) was not related to a specific EV model. With fewer and smaller capital investments the company was also able to achieve low break-even points. From this perspective, bricolage can be viewed as a strategy to mitigate the risks and uncertainties posed by the development of new technologies in a turbulent emerging market context. Lastly, the use of outsourced components produced with minimal tooling costs helped the company to maintain flexible relationships with the suppliers. Put differently, Mahindra Reva was able to buy components in small volumes and produce its EVs according to customers' demands, thus ensuring that resources did not get stuck in excessive inventories.

5.2 Contributions to the bricolage literature

5.2.1 Bricolage as strategy

While prior research has described bricolage as an antecedent or skill (e.g. Ernst et al., 2015; Cunha et al., 2014) or entrepreneurial behaviour (e.g. Baker and Nelson, 2005), this study demonstrates how bricolage can also be a carefully planned and executed strategy, especially in contexts that require companies to experiment heavily. Through its business model, Mahindra Reva carefully planned and executed its technological innovation. Thus, while bricolage implies a preference and inclination for active problem-solving, it can also incorporate very extensive planning and strategizing.

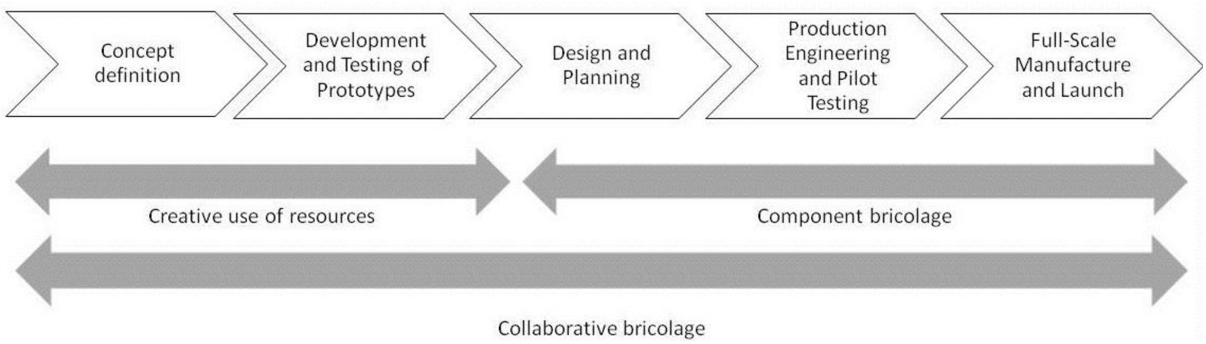
Scholarly literature suggests that multiple organisations involved in collaborative bricolage build shared repertoires and that tacit knowledge is an important component for such communal repertoires of resources (Duymedjian and Ruling, 2010). However, as far as we can tell, this body of research has illustrated collaborative bricolage mostly using secondary data (Garud and Karnoe, 2003) and discussions around the development of shared repertoires have been largely theoretical (e.g. Duymedjian and Ruling, 2010). Our empirical material corroborates Duymedjian and Ruling's (2010) suppositions by underlining the importance of developing shared repertoires for the success of collaborative bricolage. We would argue that Mahindra Reva strategized the development of shared repertoires quite differently from the typical collaborative strategies of larger companies. While such companies encourage technology sharing in their outsourcing agreements, they tend to be very restrictive about their suppliers' engagement with other customers (see Alcacer and Oxley, 2014). By contrast, our informants reported that they did not mind suppliers servicing other companies using knowledge and components co-developed with Mahindra Reva. This approach helped suppliers to expand their client portfolios and to achieve economies of scale. With this success, the prices of components decreased. Further, suppliers became less rigid in their demands for big volume commitments from Mahindra Reva.

Our analysis also highlights how the geographical distance between bricolage partners has a significant bearing on the deployment of a collaborative bricolage strategy. Development of shared repertoires calls for extensive social interaction and transfer of tacit knowledge. Despite recent progress in information and communications technologies (ICT) which has significantly reduced the cost information exchanges and enabled virtual meetings, video conferences etc., tacit knowledge sharing generally requires a shared physical presence. The Mahindra Reva case empirically demonstrates how the development of shared repertoires happens best in a closely-knit and co-located network of bricoleurs.

5.2.2 Bricolage activities and the stages of new product development

This study shows how multiple types of bricolage activities could relate to different stages of the new product development process in emerging markets (see figure 11 below). Our findings indicate that the creative use of resources was predominant in the concept development, prototype building, and testing stages, while component bricolage was prevalent in later stages such as design, production engineering, and full-scale manufacture. This strategy is probably explained by the fact that EV technology is still in its infancy. In the mid-1990's, at the time Mahindra Reva started its work on EVs, there were very few suppliers of EV-specific components in the world. In India, no company had any experience with EV technology development. Thus, the concept definition and prototype development at Mahindra Reva involved a wide-ranging search for resources and extensive experimentation. On the other hand, design, production engineering, and full-scale manufacturing involved working mainly with common mechanical parts and design components. For these later stages, numerous automotive suppliers were locally available and, thus, the company relied on off-the-shelf components developed originally for other vehicles. Collaborative bricolage played a significant role throughout the entire product development process in that strong relationships and collaborations with suppliers underpinned the other two types of bricolage. For example, using lead-acid batteries developed originally for IC cars (i.e. creative use of resources) involved an extensive collaboration with the battery supplier in order to develop an appropriate chemical composition for EVs. Similarly, the adjustment and tweaking of off-the-shelf parts (i.e. component bricolage activities) required the support and production capabilities of suppliers.

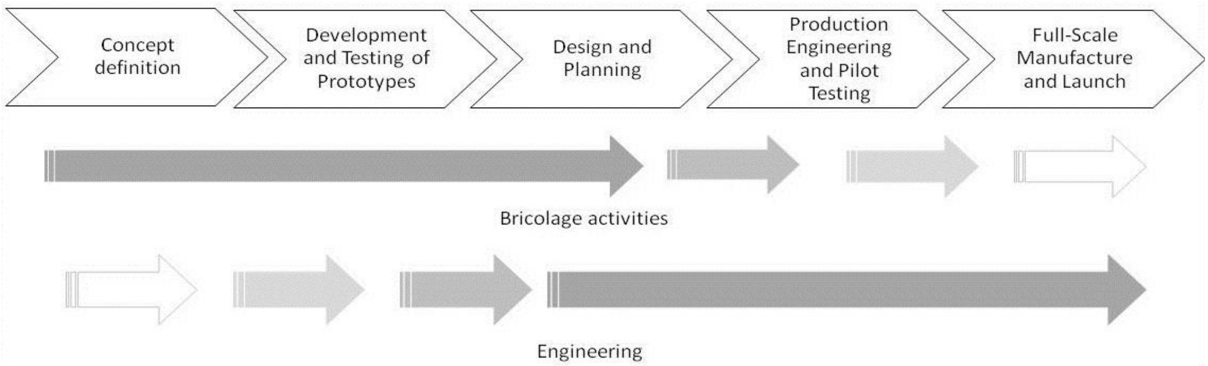
Figure 11. EV development process and interplay of bricolage activities



5.2.3 Bricolage and engineering

Contrary to prior research which described the bricoleur and the engineer as opposing figures (Duymedjian and Ruling, 2010; Levi-Strauss, 1966), Mahindra Reva's experience indicates that bricolage and engineering can be complementary, rather than mutually exclusive activities (see Figure 12). On the one hand, bricolage allows the creative use of resources, thereby enabling resource-constrained innovation. On the other hand, engineering processes consolidate the legitimacy of the innovator (see Duymedjian and Ruling, 2010) by preventing and correcting the imperfections of bricolage outcomes. At Mahindra Reva, bricolage was predominant in the concept definition, prototype development, and (in part) design stages. In these stages, the company sought workable alternatives and experimented extensively by mixing-and-matching components. However, during production engineering and full-scale manufacture, there was little room for imperfections. Thus, in these stages engineering methodologies were predominant. The Mahindra Reva case study also shows that, in some respects, bricolage and engineering complemented each other throughout the technology development process. For example, while the development of battery packs for EVs could be an instance of bricolage, it also involves extensive chemical engineering and simulation efforts. Similarly, production engineering could rigorously follow well-established engineering practices while relying on off-the-shelf components and extensive collaborative bricolage.

Figure 12. EV development process and interplay of bricolage and engineering



5.3 Contributions to innovation research

5.3.1 Frugal innovations as outcomes of bricolage strategies

This study suggests that the notion of bricolage offers a structured and deeper explanation of how frugal and cost innovations from emerging market come about. Cunha et al. (2014) recently put forward a systematic analysis of the scholarly literature on product innovation in resource-poor environments. Their analysis focused on three forms of scarcity - lack of time, lack of material resources, and lack of affluent customers - and identified improvisation, bricolage, and frugal innovation as three streams of literature, which respectively correspond to each form of scarcity. The analysis of the Mahindra Reva case suggests that many emerging-market firms face simultaneously at least the last two forms of scarcity identified by Cunha et al. (2014). Unlike big DMNEs which may possess slack resources, emerging market firms tend to have limited material resources[7] and target low-income customers. The complex contexts within which technological innovations in emerging markets take place demand nuanced theorizing, which can account for both endogenous and exogenous categories of challenges. The multi-layer bricolage framework presented here is one such a theorizing attempt. On the one hand, the bricolage-based strategy employed by innovators at Mahindra Reva allowed them to overcome endogenous constraints (i.e. lack of resources) by generating what we labelled as operational outcomes. On the other hand, the bricolage helped Mahindra Reva address the exogenous challenges (i.e. customers' price expectations and technology adoption patterns) by delivering strategic outcomes.

As Cunha et al. (2014) note, research on frugal innovation is generally based on empirical evidence from emerging markets and is still mostly atheoretical. This doctoral thesis as well as some evidence from prior empirical work (see Eyring et al., 2011; Ray and Ray, 2011) suggests that bricolage can be regarded as a comprehensive theoretical framework informing studies on innovations targeting BOP and, sometimes, MOP consumers. While Cunha et al. (2014) have positioned bricolage and frugal innovation as two separate, fully-fledged strands in the product innovation literature, we argue that the theoretical scopes of the two notions are quite different. On the one hand, bricolage is a mature, well-rounded theory used as an analogy to illuminate numerous phenomena from various disciplines. On the other hand, frugal innovation refers mostly to outcomes (i.e. technological artefacts or products) achieved by resource-constrained emerging-market innovators. Therefore, we suggest that bricolage can be a very useful guiding theory when opening the black-box of emerging-market

[7] Mahindra Reva has been a small and resource-constrained technology company for most of its history. Even after it was acquired in 2010 by the Mahindra Group, the company was not absorbed into the new parent company. Mahindra Group chose to keep Mahindra Reva as an independent entity under the leadership of its founder in order to preserve Mahindra Reva's unique identity as an innovative company.

innovations. In other words, we argue that resource constrained and frugal innovations can be viewed as an outcome of carefully designed and orchestrated bricolage strategies.

5.3.2 Bricolage strategies and discontinuous innovations

This study also illustrates how a bricolage strategy can be central to the development of a discontinuous innovation. EVs are currently causing technological discontinuities as the technology is relatively new for customers, firms, and indeed for the entire automobile industry (see Garcia and Calantone, 2002; Veryzer, 1998). The extant capabilities of established automotive companies may not be enough to develop EVs. New knowledge bases need to be developed, numerous technical solutions need to be scoured, tested and improved, new production lines and infrastructures (e.g. charging facilities) must be set in place for EVs to become commercially viable products. Many EV makers have difficulties identifying appropriate market segments for their products. IC vehicles are an ubiquitously accepted technology and it is very difficult for EV producers to identify significant non-user market segments. At the same time, in order to take full advantage of the benefits offered by the EV technology, users of conventional automobiles will have to change their behaviours and commuting habits.

Bringing to market discontinuous innovations such as EVs could take a long time and can be a highly expensive and risky process (Birkinshaw et al., 2007; Lynn et al., 1996; Veryzer, 1998). As Lynn et al. (1996) explained it, "the technology is evolving, the market is ill-defined, and the infrastructure for delivering the still-developing technology to the as-yet-undefined market is non-existent" (p. 10). This thesis shows how in such scenarios, a bricolage strategy featuring practices significantly different from those used for continuous or incremental innovations (see Lynn et al., 1996; Veryzer, 1998; 2005) can underpin the development of products which have the potential to generate technological discontinuities and market disruptions.

The Mahindra Reva case shows how a bricolage strategy deliberately incorporates a 'probing and learning' process of innovation. Based on multiple case studies, Lynn et al. (1996) documented an investment-intensive, iterative 'probing and learning process' as a strategy conducive to the successful commercialization of discontinuous innovations. Their study showed that innovating firms develop their discontinuous products by probing candidate markets with early versions of the product, learning from the outcomes, improving the product, and then probing the market(s) again. In all the cases explored by Lynn et al. (1996), the probing and learning process took decades and cost several hundreds of millions of dollars. In Mahindra Reva's case, probing and learning helped the company transition from the first Reva EVs which were very small (the rear sits allowed sufficient space only for one or two small children) to the recent e2o model which is significantly more spacious and powerful than the Reva. The company learnt from selling the earlier Reva model that many potential Indian customers regarded cars as symbols of social status and, therefore, considered diminutive and underpowered models such as Reva to be unappealing. This knowledge helped the company develop the e20 model. Interestingly, our informants observed that they conducted their probing and learning using only a very small fraction of the resources invested in similar projects by competitors such as GM, Tesla or BMW. This would suggest that a bricolage strategy can make the process of developing discontinuous innovations significantly less costly, thus reducing the risks associated with developing products for which a clear market has not been identified yet as well as allowing for an increased number of probing-and-learning iterations. Such iterations can turn out to be crucial for the successful commercialization of discontinuous innovations not only because they help companies improve their product, but also because each step helps potential customers become familiar with technologies, which they might otherwise greet with scepticism.

5.3.3 Bricolage strategies and disruptive innovations

Further, this study shows how bricolage strategies may address (at least to some extent) the "sales" challenge posed by disruptive technologies (Christensen, 1997). "EVs have the smell of a disruptive technology" (Christensen, 1997; p. 189) in addition to being a discontinuous innovation. While IC cars are far superior to EVs in terms of performance along mainstream attributes such as top-speed and driving range with one charge, it is becoming increasingly evident that current performance levels of IC cars far exceed their practical applicability (see ETI, 2011; Klenner et al., 2013). Their advertised top-speeds far exceed the permissible legal speed limits in most countries (Klenner et al., 2013). Moreover, studies have also shown that, on average, two-leg car journeys taken for many private or business activities do not exceed 50 miles (ETI, 2011), thereby making 300-mile driving ranges on a single fuelling irrelevant for a significant number of practical commuting patterns. Such performance "overshooting" or "oversupply" (Bowen and Christensen, 1995; Christensen, 1997) suggests that the global automobile market may be ripe for disruption by innovative technologies (Christensen, 1997; Klenner et al., 2013). Yet, the adoption rate of EV technology is still not very high (ETI, 2011). The reticence of mainstream users regarding EVs is most likely caused by the price of EVs which significantly exceeds that of similarly sized IC cars. EV-related market research indicated that less than 5% of customers are willing to pay the price premium currently demanded by EVs relative to conventional cars (ETI, 2011). As Adner (2002) suggests, "while disruption is enabled by sufficient performance, it is enacted by price" (p. 686). This thesis shows that, by keeping product development costs low, bricolage strategies can help companies significantly reduce selling prices and improve sales of potentially disruptive products.

Moreover, Christensen (1997) argued that a company's first EVs should be done "fast and on a shoestring" (p. 165) to account for the possibility that this first offering may not fully address the requirements of targeted customers and allow the company to learn what those requirements are. Christensen's (1997) suggestions proved valuable and showed extraordinary insight, especially considering that they were made at a time when only one or two EV models were commercially available. However, he has not offered any suggestions on how managers could go about to produce automobiles "on a shoestring". This doctoral thesis addressed this gap by showing that bricolage strategies with their operational benefits could be appropriate when pursuing such challenging goals. As we showed earlier with the examples of Mahindra Reva's highly flexible IEMS and electric architecture which can be easily transferred from one platform to another, bricolage strategies are particularly useful when dealing with disruptive products because they allow "feature, function, and styling changes [to] be made quickly and at low costs" (Christensen, 1997; p. 165).

5.3.4 Frame alignment as a marketing strategy for disruptive innovations

In a related vein, Christensen (1997) argued that it would be a mistake for EVs makers to target the general market, thereby placing EVs in direct competition with IC vehicles. Instead, he argued, they should try to identify an appropriate niche of customers which would value the non-mainstream attributes of the EVs such as low operating costs and low impact on the environment. Christensen (1997) goes as far as arguing that, if pitched to the right target audience, even the low speed and short driving range of EVs could be perceived as benefits rather than disadvantages. For example, the parents of US teenagers may value the low top speed and limited driving range of EVs. As teenagers may sometimes be reckless drivers, their parents may see the low performance of EVs as a way of minimizing the possibility of an accident (Christensen, 1997). Although no EVs maker has targeted yet the niche identified by Christensen (1997), BYD, which is partly owned by Warren Buffet's Berkshire Hathaway, and Nissan are currently focusing on the London taxi market (Foy, 2014). BYD and Nissan's strategic move into the London taxi market is supported Mayor Johnson's initiative to have only zero-emission taxis in London by 2018 (Foy, 2014). Moreover, BYD has also entered the Hong Kong taxi market, albeit with limited success (Huifeng, 2015).

It is, thus, apparent that a niche marketing strategy is most appropriate for disruptive innovations. However, it remains unclear how innovating firms can communicate their non-mainstream value propositions to the targeted niches of customers, especially if these are geographically dispersed and cannot be approached directly like the taxi service providers. This can be a critical aspect in the adoption of innovative products because, although two groups (e.g. innovating firms and their targeted customers) may have related interests and share similar values, they may be unaware of each other's existence and intentions (see Sandeep and Ravishankar, 2016). In the findings chapter, we showed how the company communicated its value proposition to a niche consisting of well-educated, technology-savvy Indian customers. The choice of the communication medium (i.e. social media), which allowed the company's marketers to deliver targeted messages to geographically dispersed potential customers at relatively low costs, was consistent with the company's strategy to "make do" with the limited resources available.

Further, we draw on the on the literature on frame alignment and social movement participation (e.g. Benford and Snow, 2000; Snow et al., 1986) to analyse Mahindra Reva's effort to communicate its non-mainstream value proposition. The concept of interpretive frames developed by Goffman (1974) refers to cognitive schemata which facilitate individual sense-making and categorisation of events and experiences. By assigning meaning to occurrences, interpretive frames also guide individual attitudes and behaviours (Goffman 1974, Snow et al. 1986). Snow et al. (1986) found that social movement support and participation is dependent on four frame alignment processes (i.e. bridging, amplification, extension, and transformation) which ensure the similarity or congruence between individuals' interpretive frames and the values, ideologies and actions promoted by social movement organisations

(Snow et al. 1986). Frame alignment is achieved through “various interactive and communicative processes” referred to as micromobilisation (Snow et al. 1986). In Mahindra Reva’s case, the company tried to align the interpretive frames of Indian customers with the non-mainstream value proposition of EVs and the process of micromobilisation was achieved through extensive interaction and dialogue supported by virtual social networks such as Facebook, YouTube, and Twitter.

The data presented in the findings chapter showed that, in the pre-launch phase, Mahindra Reva relied on frame extension to gain brand recognition and customer support. Frame extension is a process through which an organisation espouses values and beliefs held in high regard by their target audience (Benford and Snow, 2000; Sandeep and Ravishankar, 2016; Snow et al., 1986). In other words, through frame extension, organisations such as Mahindra Reva adopt themes and issues which are salient for customers, although incidental or less central for the company (see Benford and Snow, 2000; Snow et al., 1986). Mahindra Reva was technology company advocating a shift of technological paradigms from IC vehicles to fully electric ones. Although this technology shift can be an important message in itself, the company’s marketers believed its target audience was more concerned and adamant about the social changes taking place in India. Consequently, through the Ask campaign, Mahindra Reva expanded its original frame advocating the change of technological paradigms and adopted a more generic frame of change which included themes of socio-cultural and political change.

In the post-launch phase, Mahindra Reva employed frame alignment mechanisms to communicate efficiently its value proposition. The company relied on frame bridging to deliver a message of cost-effectiveness to potential customers. Frame bridging refers to “the linkage of two or more ideologically congruent but structurally unconnected frames regarding a particular issue or problem” (Snow et al., 1986; p. 467). The frame bridging process attempts to mobilize latent, “untapped, and unorganised sentiment pools” (Snow et al., 1986; p. 468).

As explained earlier, Indian customers tend to share a frame of frugality and demand very high value for money. While this frame was central when they assessed the selling price and performance of an IC car, Indian customers seemed to be unaware of long-term cost savings offered by an electric vehicle. Thus, a central theme of Mahindra Reva's social media campaigning was to provide clear evidence showing that Indian drivers would achieve important long-term savings from low operating and maintenance costs, which would more than offset the slightly higher purchasing price. To make this point, the company's marketers often discussed on the Mahindra Reva corporate social media pages the hikes in petrol prices and provided an original calculator which allowed social media users to compute how soon the savings on fuel would amortise the total cost of an EV based on their commuting patterns.

Similarly, Mahindra Reva employed frame amplification to enhance the salience of the eco-friendliness attribute of its EVs in the mind of the targeted customers (see Benford and Snow, 2000; Sandeep and Ravishankar, 2016; Snow et al., 1986). Frame amplification is usually required when an organisation's central frames are met with indifference by the target audience (Sandeep and Ravishankar, 2016; Snow et al., 1986). In such a situation, the organisation must clarify and invigorate that particular interpretive frame in the mind of the audience (Snow et al., 1986). In India, environmental issues do not come to the forefront of the collective mind as is the case in more developed countries because there are other problems which are perceived as more stringent and in need of solving such as endemic poverty, poor healthcare, and corruption. To address the lack of salience of environmental issues and to underline the value of their non-mainstream offering, Mahindra Reva's marketers engaged in extensive conversations on the company social media pages regarding the direct negative impact of pollution and global warming on the quality of life in India. In addition, Mahindra Reva attempted to educate their targeted audience on how to reduce their carbon footprint and how to conserve water.

Thus, the evidence from the Mahindra Reva case study indicates that frame alignment processes could be used to sell the non-mainstream value propositions of disruptive innovations in general and of EVs in particular.

5.3.5 Emerging markets as settings for the development of disruptive innovations

The findings from the Mahindra Reva case reinforce and add to prior research (e.g. Hart and Christensen, 2002; Markides, 2012), which has suggested that emerging markets are an apt setting for the introduction and development of disruptive innovations. BOP-MOP consumers from emerging markets may have lower performance requirements than developed-country consumers. Thus, they are more likely to adopt early versions of potentially disruptive technologies, which may be inferior to mainstream technologies in terms of performance (Hart and Christensen, 2002). Second, the low(er) incomes of targeted emerging market customers provide a strong incentive for the innovating companies to focus on lowering the price of their disruptive products.

However, prior studies (Hart and Christensen, 2002; Markides, 2012) have mainly discussed disruptive innovations developed in emerging markets through the paring down of mature technologies such IC cars, microwave ovens, refrigerators, and mobile telecommunication services. Examples of companies introducing radical or "really new" innovations (see Garcia and Calantone, 2002) to emerging markets are, however, sparse. While DMNEs often find emerging-market customers unattractive due to their low incomes, emerging-market innovators do not always possess resources that will enable them to innovate at the "technological frontier". This case study shows how a small, resource-constrained emerging market company can develop and offer to its customers a nascent and potentially disruptive technology product.

5.3.6 Bricolage, open innovation, and open-integrated architectures

It is a fairly obvious observation pointing out that the development of Mahindra Reva's EVs was an open innovation effort. The EV development was clearly distributed among a wide network of partners who contributed with their resources and design capabilities to the innovation process. The Mahindra Reva case is very similar to the advances in the regenerative medicine achieved by a network of innovators in Brazil (see McMahon and Thorsteinsdottir, 2013). Both cases involve the development of radical technologies and the open innovation approach was the only viable solution as none of the individual actors was capable of developing the technology on their own due to their limited knowledge and material resources.

The relationship and the extent of overlap between collaborative bricolage, as defined in the present study, and open innovation are less obvious and, thus, worthy of consideration. Both concepts refer to distributed innovation processes involving multiple participants. However, there are some noteworthy differences between collaborative bricolage and open innovation. While open innovation implies that participants contribute with originally designed and manufactured components, they rarely share their resources in the process or engage in joint design activities. On the other hand, collaborative bricolage often requires the partner organisations to pool-in their resources to the point where common or shared repertoires (see Duymedjian and Ruling, 2010) are created. The partners build on these shared repertoires and jointly design and develop original components. In the Mahindra Reva case, the sharing of resources specific to collaborative bricolage was achieved by deputing key employee and physical resources to the partners' facilities. The development of the EV charger and the tubular space frame (both described earlier) provide eloquent illustrations of how collaborative bricoleurs jointly design and develop components.

This study makes another important contribution to the innovation literature by providing another rare yet valuable example of a product with an open-integrated architecture.

Together with Boeing's 787 Dreamliner and Apple's iPod, Mahindra Reva's EVs emphasize the limitations of Fujimoto's (2007) conceptual framework which held that an open-integrated product architecture cannot exist. The fact that the architecture of Mahindra Reva's EVs has an open nature is unquestionable as the individual components are designed (sometimes jointly designed as we showed above) and produced by separate, independent firms. The integrated architecture of the EVs becomes apparent when examining the mapping between functions and physical components (see Ulrich, 1995). For example, the regenerative brakes serve a dual function: (i) they reduce speed and stop the moving vehicle and (ii) when the brake is applied the system produces kinetic (mechanic) energy which is transferred to the motor. Consequently, the EV motor serves multiple functions as well. In its normal function, the motor is a consumer of electric energy which it turns into kinetic energy to put the vehicle in motion. However, in the reverse function, the motor is a generator of electric energy as it turns the kinetic energy coming from the brakes into electricity which is then stored in the battery. Similarly, the IEMS has numerous functions: (i) it continuously monitors the battery cells and the power consumption, (ii) it equalises the use of individual battery cells using algorithms that improve the driving range and extend the battery life, (iii) it controls the charger and the EV motor, (iv) it controls the instrument cluster, and (v) it sends data back to the company and allows the remote servicing of the car through a telematics system. This evidence clearly illustrates a many-to-many mapping between functions and physical components, thus supporting our claim that Mahindra Reva's EVs have an open-integrated architecture. It should be noted that, while we argue that Mahindra Reva's EVs have an integrated architecture, we do not dispute our informants' arguments that the same EVs have a modular design. Indeed, the car design was broken down into major subsystems and modules which were developed (and co-developed with Mahindra Reva) by third-party suppliers. However, these discrete subsystems and modules were carefully integrated into a coherent system design by the flagship company (i.e. Mahindra Reva). It should be further noted that the component/module interfaces for Mahindra Reva's EVs (as well as for the 787 Dreamliner and the iPod) were not standardised. Such standardisation would have been impossible given the highly innovative nature of these products. The component interfaces were either co-developed or negotiated by the flagship company and its partners.

As mentioned in the literature review chapter, the system and design integration can be a strenuous, time-consuming, and risky exercise which requires the flagship company to possess extraordinary design capabilities. However, if the subsystems, modules, and components are jointly designed and developed by the flagship company and its suppliers as it happens in the case of collaborative bricolage, the system and design integration can become a less demanding task. Moreover, the evidence provided in this case study shows that design activities are critical for the success of collaborative bricolage ventures and, thus, excludes the idea of the experiential and improvised "design in action" documented by Lanzara (1999) in the case of information systems developed through bricolage. This adds to the amounting evidence showing that bricolage can produce optimal solutions and not just improvised, transient artefacts (see Lanzara, 1999).

Therefore, this doctoral thesis makes an additional contribution to the innovation literature by showing that modularity and integration are not mutually exclusive in product architecture and that open-integrated product architectures do exist in reality.

5.4 Managerial implications

This study illustrates a strategy allowing organisations to (i) engage in discontinuous technology development efforts with limited resources and (ii) provide customers with high-tech, innovative products at affordable prices. These findings should present interest for managers from both emerging and developed countries.

5.4.1 Implications for emerging-market managers

From the perspective of emerging-market managers, this study complements prior research which suggested that a good way for emerging market firms to catch up with their Western competitors in terms of technological capabilities is to enter early into new technological systems instead of importing mature technologies and, thus, remaining laggards behind companies from rich nations (e.g. McMahon and Thorsteinsdottir, 2013). The experience of Mahindra Reva shows that such ambitions are not outside the reach of emerging-market firms despite the resource constraints and institutional voids they face. With creative resource recombinations and innovative collaborations, emerging-market managers can turn their firms' resource limitations into significant cost advantages at a global level. Strategies and business models "that are forged in low-income markets travel well" (Hart and Christensen, 2002; p. 52); that is, they can be successfully redeployed in high(er)-income markets. Managers in emerging-market companies may find some of the practices discussed in the study useful and relevant to their plans of disrupting the global market with high-tech discontinuous innovations. The findings further suggest that nurturing a pragmatic mind-set amongst the workforce, embracing flexibility in organisational design and dismantling rigid organisational structures will increase enactments of competitive bricolage-led strategies.

5.4.2 Implications for managers of developed-country multinational enterprises

Managers of DMNEs which consider entering emerging markets can greatly benefit from exploring and understanding the strategies of local competitors. Strategies and business models from the western world may not always find success in emerging markets. The arguments presented in this study can help DMNE managers derive "contextual intelligence" (see Khanna, 2014) which is often crucial for the development and deployment of successful business models in emerging markets. Given the global economic downturn, companies all over the world are experiencing, in one form or another, some of the challenges faced by companies in emerging markets. In this sense, only a few DMNEs may be able to afford very expensive R&D endeavours or find it is reasonable to do so. Breakthrough-seeking innovation strategies usually imply high prices for the resulting products, while many customers are cutting back on their expenditures and favouring low-priced items (e.g. Ernst et al., 2015; Markides, 2012). The Mahindra Reva case study provides some insights into how managers might employ bricolage as a cost and risk reducing strategy for innovation and new product development, particularly when working with discontinuous and disruptive technologies. Many DMNEs may be reluctant to accept bricolage as a legitimate innovation strategy in its own right, especially if they have been successful innovators in the past. However, we would argue that unless they adjust and adapt their mental models to new contexts, they may find themselves facing stern competition from emerging-market challengers, who are poised to offer high-tech, but affordable innovations for BOP-MOP consumers.

5.5 Limitations and future research

Our findings are based on a single case study. Obviously, there will be variations in the extent to which our findings are transferable to other contexts or industries, be it in emerging markets or developed countries. Some caution must be exercised in generalising these findings, although we would suggest that bricolage strategies like the one presented here may work well for new, small companies in a range of nascent industries.

Glorifying bricolage was not the aim of this thesis. It is worth noting that bricolage is not a bullet-proof strategy for sustainable competitive advantage. Rather it should only be viewed as a cost-effective approach to developing discontinuous and disruptive technologies. It may not necessarily guarantee better sales and profits. In fact, despite developing perhaps the most affordable EVs in the world, it is worth noting that Mahindra Reva has not yet been very successful in penetrating the Indian automobile market. Competition from manufacturers of low-cost conventional cars in the Indian market (e.g., Tata, Maruti Suzuki, Hyundai etc.), the absence of governmental subsidies for EVs[8] and the underdeveloped EV-specific infrastructure have meant that the achievements of the company's bricolage strategy in pure financial terms have been rather modest. We are, therefore, not in a position to claim that these EVs have received a rousing reception in the market. However, this does not take away from the main argument of this study: a carefully planned and implemented bricolage strategy helped the company produce a technologically sophisticated and innovative product. Recent reports in the business press suggest that the company is considering an elaborate internationalisation strategy. It remains to be seen how well Mahindra Reva's EVs will perform in developed markets which arguably have more favourable conditions (for instance, availability of state subsidies for EVs).

Our data regarding the importance of the Indian context in the adoption and deployment of bricolage strategies is inconclusive. Bricolage seems related to resource-constrained environments with cultures where frugality plays an important role. This view was supported by several informants across many organisational levels. These informants claimed that frugal attitudes and behaviours instilled by their families matched Mahindra Reva's values and contributed to the employee acclimatisation within the organisation. However, other informants argued that organisational culture was more important than national culture for the successful implementation of bricolage strategies. Their main argument was that many Indian firms had not adopted frugal values. In fact, they recalled that, when the Mahindra Group acquired the controlling stake in Reva, the chairman of the Mahindra Group stated that he hoped Reva's frugal values would be diffused throughout the entire Group. Moreover, these informants claimed that they tried to disseminate frugality through personal example and by setting stretch goals (see Locke and Latham 1990, Rousseau 1997, Sitkin et al. 2011) to

[8] It appears that the Indian government is all set to offer financial incentives to EV producers in the near future. (http://indianexpress.com/article/business/business-others/with-budget-boost-electric-cars-may-become-cheaper/)

challenge their employees. This seemed to be a successful management technique at Mahindra Reva. Given this ambivalence of our data set, a fruitful direction that future research may take is exploring the impact of organisational and national cultures on a company's propensity to engage in bricolage.

It would also be interesting to explore using larger data sets the contextual elements which support and hinder bricolage-led strategies for technology innovation. More empirical work is needed to examine how factors such as the characteristics of the innovating company (e.g. size, age, origin, etc.) and targeted market (e.g. low-income vs. high-income), the nature of the innovation (e.g. discontinuous and disruptive vs. sustaining and incremental) and the stage in the technology life-cycle will impact a company's bricolage strategies.

Chapter 6: Conclusions

In this doctoral thesis, we set out to explore how resource-constrained firms from emerging markets manage the process of technological innovation and, in doing so, to address the limitations of extant literature which had not provided sufficient insight regarding the replicable organisational and inter-organisational processes underpinning the development of frugal and cost innovations. To open the "black box" of emerging market innovation, we employed an in-depth qualitative case study of Mahindra Reva, the only EV producer in India. Given the exploratory nature of our study, the qualitative methodology allowed us to analyse and understand what actually happens within the innovator organisation, specifically what are the behaviours, attitudes, and processes which support the development of high-tech, yet affordable products. The Mahindra Reva case was highly relevant for our research objectives as it is a small company (less than 400 employees) which successfully developed potentially disruptive products with very limited resources. According to our informants, the development of their latest model, the Mahindra e2o, was achieved with about 1% of the budget allocated by BMW for the i3 model. Moreover, Mahindra Reva targets mainly emerging market customers which are significantly less affluent than customers from developed countries. The BOP-MOP customer segments in countries like India and China are becoming increasingly attractive to numerous firms as studies suggested that sustaining future growth requires unlocking these customer segments (see Atsmon et al., 2012). Thus, the Mahindra Reva case provided a unique opportunity to explore how emerging market firms develop new radical products while overcoming their resource limitations and addressing the cost requirements of their customers.

We drew on the notion of bricolage, rooted in anthropology and used extensively in entrepreneurship studies, to capture and explain the technology and new product development approach at Mahindra Reva. In this thesis, we employed a broader perspective on bricolage (see Baker and Nelson, 2005) and defined the concept as the creative use of generic, nonspecialised resources in novel contexts. This study demonstrated how a multi-dimensional bricolage strategy (i.e. creative use of resources, component bricolage, and collaborative bricolage) helped the company overcome resource-constraints and develop affordable EVs using minimal investments compared to developed-country competitors. The thesis also showed how the company implemented and managed the bricolage processes and strategy through complementary engineering processes, stretch goals, and transformational leadership.

This doctoral thesis made several important contributions to the bricolage and innovation literature bodies. First, it showed how in addition to being a skill and an antecedent of innovation and entrepreneurship (see Baker and Nelson, 2005; Ernst et al., 2015), bricolage, under certain conditions, can also be a deliberately orchestrated strategy. In Mahindra Reva's case, the bricolage approach to new product development generated both operational and strategic outcomes. The former allowed the company to overcome endogenous constraints (i.e. limited resources) and develop a radical technology "on a shoestring", with minimal capital investments, while the latter helped Mahindra Reva to address exogenous constraints (i.e. the cost requirements of customers) by offering the most affordable EVs currently available. Second, this thesis illustrated how various types of bricolage activities relate to different stages of the new product development process in emerging markets. Mahindra Reva creatively recombined resources in the early stages of the new product development and relied heavily on component bricolage in the later stages. Moreover, these two types of bricolage activities were enabled by extensive collaborations with suppliers (i.e. collaborative bricolage). Third, the thesis provided insights into the complementarities between bricolage and engineering activities. While bricolage enabled resource recombinations and cost reductions, engineering activities eliminated imperfections and provided legitimacy to the innovator. Fourth, this doctoral thesis opened the black-box of emerging market innovation and identified the bricolage processes and strategies that are often underpinning the development of frugal and cost innovations. Fifth, it showed that cost-effective bricolage processes can be central to the development of potentially technological discontinuity-creating and market-disrupting products. Such products pose two important challenges. They are usually very costly to develop, while their wide-scale adoption is difficult and slow because customers are rarely willing to pay the price premium demanded by innovators in order to amortise their R&D expenses. The cost reductions enabled by bricolage-based strategies could help innovators address both these challenges. Sixth, the thesis argued the collaborative bricolage strategies can lead to the development of products with open-integrated architectures. Moreover, it showed that modularity does not exclude integration in product architecture. In the case of many highly innovative products (e.g. Boeing's 787 Dreamliner, Apple's iPod, Mahindra Reva's EVs), different firms designed and developed separate modules which were then integrated into a coherent, functional system by the flagship company. These findings addressed the limitations of prior innovation literature which held that modularity and integration are conceptual opposites and, implicitly, suggested that open-integrated product architectures could not exist (see Fujimoto, 2007). Finally, this thesis provided some brief insights regarding the marketing strategies that could be employed by companies offering disruptive technologies to communicate more effectively the benefits of their non-mainstream value proposition.

Defined by the Research Councils UK as the "the demonstrable contribution that excellent research makes to society and the economy", the impact of this doctoral thesis is threefold. First, the findings and contributions of this study should be of interest for managers from both emerging markets and developed countries. On the one hand, emerging-market managers may find in this thesis useful insights on how they could use bricolage strategies to turn their resource constraints into important cost advantages and attempt to disrupt global markets with highly innovative yet affordable products. On the other hand, the managers of

DMNEs may find valuable information regarding the strategies of their emerging-market competitors who are currently successfully serving the majority of local BOP-MOP customers. Such "contextual intelligence" (Khanna, 2014) may help DMNEs adjust their own strategies and address the particularities of fast-growing emerging markets. Second, the ultimate beneficiaries of bricolage strategies employed by both indigenous companies and DMNEs are the BOP-MOP customers in emerging markets. Frugal and cost innovations developed through bricolage processes and strategies stand to improve significantly the life quality of these previously marginalised BOP-MOP customers. Moreover, if companies would engage more in bricolage activities to develop low-cost products and turn BOP-MOP non-consumers into consumers then these companies could significantly improve their growth rates. Third, if the cost reductions associated with bricolage strategies can contribute to a faster adoption and diffusion of discontinuous and disruptive technologies that are sustainable and eco-friendly (e.g. electric vehicles) then producers, consumers, and non-consumers alike will benefit from a less polluted, cleaner environment.

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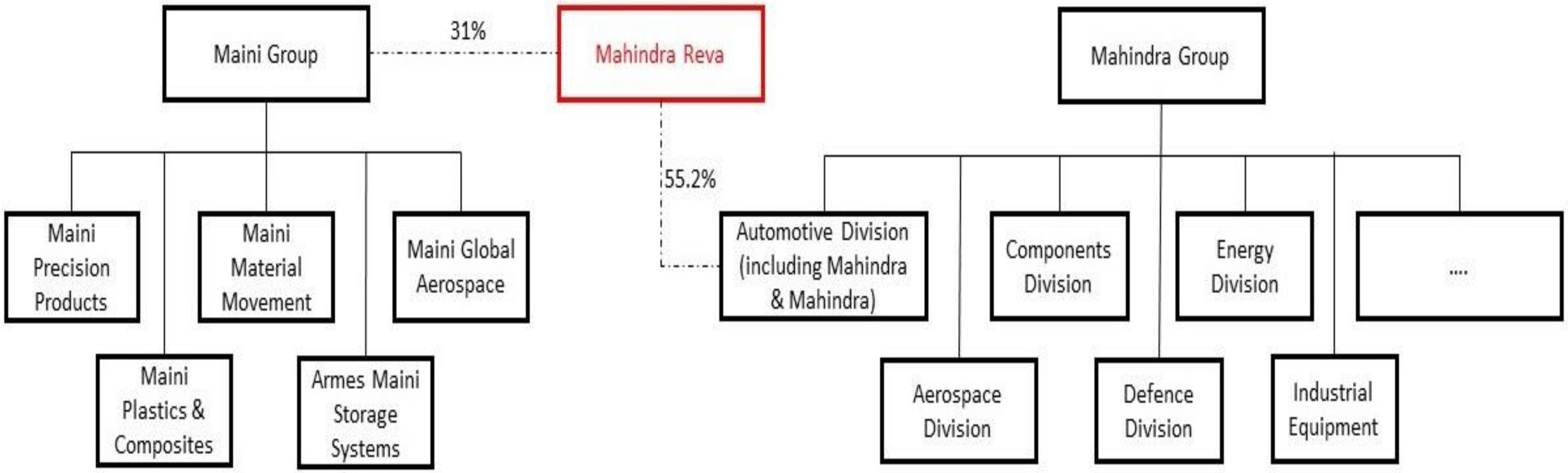
Appendices

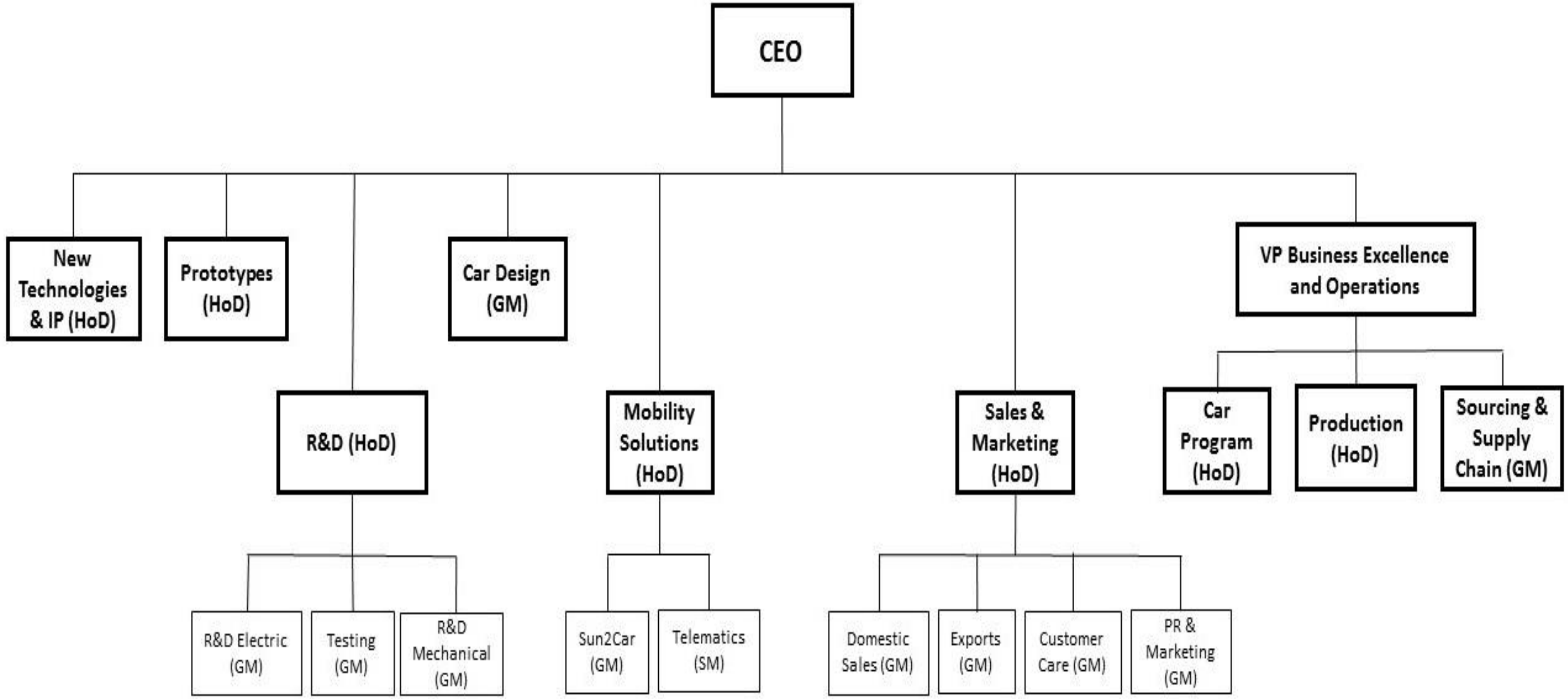
Appendix 1. Organisational structure of Mahindra Reva's parent companies



Legend: Dotted lined denote that Mahindra Reva was not absorbed by neither conglomerate and remains an independent company.

Note: The Mahindra Group includes numerous other divisions such as Aftermarket, Agribusiness, Consulting, Education, Farm Equipment, Financial Services, Hospitality, Information Technology, Logistics, Luxury Boats, Real Estate, Retail, and Sports.

Appendix 2. Mahidra Reva's organisational structure



Legend: HoD – Head of departments; GM – General manager; SM - Senior Manager

Appendix 3. List of informants

Informant's name	Department	Position
Neha Nagaraj	Mobility Solutions (Strategy)	Deputy manager
Hrishikesh Neve	Car Design	Senior manager
Yashpal Singh	Mobility Solutions (Telematics)	Deputy manager
Neel Mathews	Sun2Car	General manager
Pratap Jayaram	Prototypes	Head of department
Giridhar Katta	Car Design	General manager
Shanmuga Kirchenaraj	Sourcing and Supply Chain	Senior manager
V. Rajagopalan	Customer Care (Helpdesk)	Manager
Mohammed Iqbal	Customer Care (Complaints)	Manager
Pooja Thawrani	Online Marketing	Assistant manager
R. Prakash	New Technologies & IP	Head of department
Vinten Diwakar	New Technologies & IP	Manager
Shashank Varma	Production	Head of department
Brajendra Kumar	Car Program	Deputy general manager
Rituraj	Sales and Marketing	Manager
Syrus Nedumthaly	New Technologies & IP	Manager
Amit Nema	Car Program	Deputy general manager
Amitabh Vaidya	Car Program	Head of department
Hubert Tassin	Car Design	Lead Design
Sameer Kulkarni	New product development	Deputy general manager
B.J. Ujwal	New product development	Manager
Mahakrishnan	New product development	Manager
Durgashankar Das	New product development	Manager
Kartik Gopal	Mobility Solutions	Head of department
Yuvraj Sarda	Mobility Solutions	Assistant manager
Ashish Tarte	R&D	Head of department
Srihari Kurnool	R&D (Mechanical)	General manager
Siddhanth Rath	Mobility Solutions (Telematics)	Engineer
Amit Nema	Car Program	Deputy general manager
Baneswar Banerjee	Sales	Deputy general manager
Balaprasad Shukla	Customer Care	Manager
V. Prabhakar	Sourcing and Supply Chain	General manager
Abhay Patwardhan	R&D (Electrical)	General manager
Keshav	R&D	Consultant (Retired)
V.M. Suresh	R&D (Testing)	General manager
Ponni Rai Selvan	Sourcing and Supply Chain	Manager
Umesh Krishnappa	Car Program & Operations	VP Operations
Mithila Saraf	Strawberry Frog - Project Manager	
Shobha Popat + team	Hungama - Project Manager	
Pavan Sachdeva	PR & Marketing	General manager

Informant's name	Department	Position
P. Deep	Exports	General manager
Albert Francis	Sales	Sales Consultant
Sudarshan Maini	Maini Group - Founder and former CEO	
Sandeep Maini	Maini Group - CEO/Chairman	
Chetan Maini	CEO/Chief of technology and strategy	

Appendix 4. Creative use of resources (Summary)

Resources	Conventional application	Innovative application	Illustrative quotes
Knowledge and expertise with low-speed, indoor, electric equipment	Electric forklifts and golf buggies	On-road electric vehicles	*"Electric forklifts gave us a preliminary understanding of the requirements of working with batteries, chargers, electric motors, controllers etc. We understood fabrication, assembly lines, electronics, and most importantly we understood small batch production. In this EV business we deal with a number of different models in small batches, unlike a typical car or motorcycle company."* (CEO - Maini Group)
Lead-acid batteries	Ignition for IC vehicles	Power for EVs	*"If you take a lead-acid battery off the shelf and try to drive a car on it you will kill it in a matter of seconds. We 'worked' the chemistry and developed battery packs on which cars could be driven for over three years."* (Senior Manager - Mobility Solutions)
Lithium-Ion batteries	Portable electronic devices	Power for EVs	*"We had to develop big battery packs for the Reva L-ion cars weighing up to 250 kg by putting together individual Li-ion cells weighing about 50 grams each. Since each battery cell needed monitoring, hundreds of wires would come out of each one of them, checking the power and the voltage. [...] We placed a microchip in each battery cell to absorb all this information and transmit it to the Intelligent Energy Management System."* (Founder and former CEO)
Plastics produced through vacuum forming and rotation moulding	a) Aeronautics; b) Liquid storage facilities	Exterior body parts for EVs	*"In India, there is a lot of traffic and lots of light accidents. We needed something with high impact strength. [...] We went for plastic made by vacuum forming, which is used to make canopies for military aircrafts and 'bubbles' for helicopters."* (Senior Manager - Prototypes) *"For the plastic in the bumpers of our first cars, we used the 'rotation moulding' process, which is generally used for water tanks. Nobody had used it for automobiles before, but we found that if you use the right equipment, processes and materials, it can be used for cars quite successfully."* (CEO)
Basic EV components	Typical EV functions	Testing equipment	*"To test the battery, we used the motor controller and developed a software to discharge the battery just as it would be done in the car. When we went to the battery testing facility in Kerala, they said that the standard we were looking for would cost us around Rs. 1.5 crore (US$ 0.3 million approximately) – we developed our own battery testing facility for Rs. 2 lakh (US$ 4,000 approximately)."* (Founder and former CEO)

Appendix 5. Enablers of component bricolage (Summary)

Enabler of component bricolage	Illustrative quotes
Flexible design	*"I go and look at design elements such as air vents, buttons and controls which are available on our existing models cars or even on IC cars and try to use some of the existing shapes and characteristics. Having in mind parts that can be carried forward from existing models can help us a lot in reducing costs later on. Of course this can impact the uniqueness and originality of the interior, but I try to push the styling with the general volumes and to keep these elements quite simple. I use elements which are at least inspired from existing ones to make sure that suppliers would be able to provide something without increasing tooling costs."* (Front-line employee - Styling)
Knowledge of existing components which could serve the envisioned purpose	*"At a bigger company, I could probably get away with developing a new part although something similar was already available. Here, I have to be extra careful and make an effort to check if a certain part is available somewhere and try to use it in a smart way."* (Middle Manager - R&D Mechanical)
Component modification capabilities	*"We always try to find an off-the-shelf part which can be tweaked as per our requirements. Developing original parts can take months and cost lakhs of rupees. There is no point in doing that if we can make a slight modification to a part which is already available and can be used without incurring any development and tooling costs. However, we cannot compromise on aesthetics because that might affect our brand image."* (Senior Manager - R&D)
Modular design	*"Our electric architecture is quite flexible and modular. The 40-volt e2o was designed specifically for India. The 72-volt variant is for export. The electric architectures are different but it is very easy for us to adapt the old one to meet the new requirements. Similarly, most parts we are using now will go into the electric Logan/Verito. Of course, the location and layouts will be different but most of the parts are similar and easily upgradable from one platform to another. This helps us to reduce costs and design time."* (Middle Manager - R&D Electrical)
Design alignment capabilities	*"The challenge is to keep the design attractive after all this mix-and match. We made the concept first and then started adapting it. This way we managed to retain the intended styling. For example, the control module is now a three-piece module. Initially, we wanted to use a backlit button panel which was glowing really nice. But that would have been really expensive. So we had to adapt the design to what was available on the market."* (Senior Manager - Styling)

Appendix 6. EV components: Functionality and suppliers

Component/ Module	Functionality	Supplier
Charger	The charger allows the battery pack to be recharged by plugging-in the vehicle to the electricity grid. More recent chargers allow for the possibility to 'fast charge' (i.e. recharge 80% of the batteries in 15-30 minutes).	The EV chargers were developed through a collaboration involving Mahindra Reva and Transistor Devices Inc. (USA). Currently, the chargers for Mahindra Reva's EV are produced by MMM.
Lead-acid battery packs	The battery pack provide the electric energy that powers the EVs. The first battery packs were developed by putting together around 20 customised lead-acid batteries.	The original UK-based supplier was replaced by Tudor India, which used customised Prestolite batteries.
Li-ion battery packs	The Li-ion battery packs consisted of approximately 5,000 individual Li-ion battery cells.	The Li-ion battery cells were produced by a Chinese company and imported to India through Exide Industries Ltd.
Motor controller	The motor controller takes power from the batteries and delivers it to the motor. The acceleration pedal sends signals through a pair of potentiometers which 'tell' the controller how much power it is supposed to deliver.	The first controllers were developed by Mahindra Reva in collaboration with Curtis Instruments Inc. (USA). To date, Curtis Instruments is still supplying the controllers for Mahindra Reva's EVs.
Motor	An EV motor performs a dual function. On the one hand, it converts electrical energy from the batteries to mechanical energy which sets the vehicle in motion. On the other hand, the motor converts mechanical energy from the regenerative braking system into electrical energy, which is then stored in the batteries.	The EV motors were developed by Mahindra Reva in collaboration with Kirloskar Electric Company (KEC) which was part of the Kirloskar Group (India). It is unclear whether KEC still provides the motors for Mahindra Reva.
Plastic body panels	Mahindra Reva used plastic body panels to reduce production costs and the total weight of the car. The ABS (Acrylonitrile Butadiene Styrene) panels were initially produced through processes of vacuum forming, thermo-forming, and rotation moulding. Currently Mahindra Reva is experimenting with Long Fibre Injection (LFI) thermoformed body panels.	The ABS panels were developed by Mahindra Reva in collaboration with MPC. The LFI panels involves the tripartite efforts of Mahindra Reva, MPC, and Harita Plastics (India).
Tubular spaceframe chassis	With a spaceframe chassis the suspensions, motor, other EV-specific components, and body panels are attached to a skeletal frame of tubes. The body panels have little or no structural function. Examples of cars that use this type of chassis include Audi R8 and Lamborghini Gallardo.	The spaceframe chassis were developed by Mahindra Reva in collaboration with MMM, which has remained the chassis supplier.

Appendix 7. Collaborative bricolage (Summary)

Collaborations related to	Partner's contribution	Mahindra Reva's contribution	Illustrative quotes
EV charger	Knowledge and expertise with electrics and electronics for aerospace and defence industries	Automotive and EV expertise	*"We worked with a US-based aerospace company and created a technology tie-up which helped us reduce development costs of the charger by 50%. They were interested in entering the automotive industry but had no expertise in this sector. We had automotive expertise, while they were very experienced with electrics and electronics, so it was a mutually beneficial relationship."* (CEO)
Tubular space frames	Knowledge of steel welding and production capabilities	EV requirements (stress levels, vibrations, crash resistance)	*"We are the only company in the world using space frame structure for our cars. […] Our supplier knew steel and welding and had production capabilities. We understood the levels of stress and mechanical vibrations the space frame will be subjected to, the required reliability in case of crash, and the complexity of the vehicle context. We transferred all our knowledge by deputing our experts to their lines when we were building the first prototypes. There was an interaction and co-learning process in order to ensure the frames have the required reliability in case of crash and last for 15-20 years."* (Senior Manager - Production)
Motor	Production capabilities	EV-specific knowledge and testing equipment	*"Although our supplier was very good at manufacturing standard motors, they did not have the capability to deliver according to our requirements. We had to work together to develop all the components. Today, the supplier uses the dynamometer testing equipment developed by us. In time we transferred the responsibility for all components to them, and they now deliver according to our standards. We held the supplier's hand and helped with knowledge, design and equipment. However, the suppliers did have the core production capability which we did not have."* (CEO)
Lead-acid batteries	Production capabilities	EV-specific knowledge and testing equipment	*"The battery supplier for our first cars was a UK company. When we brought the batteries to India we found that their testing procedures were not adequate. We had to work with them to find the right structure and composition for the Indian conditions. We developed a lot of automated testing equipment in India. Once we found this equipment working so well, we actually sold it to our supplier. In a way we actually managed the supplier's quality by providing them testing equipment customized for EVs."* (CEO)

Collaborations related to	Partner's contribution	Mahindra Reva's contribution	Illustrative quotes
EV gearbox	Production capabilities	Knowledge on how to design and build EV gearboxes	*"Our supplier had their own aluminium processing capabilities. Initially, we used to buy the castings, get our staff with the casting to the supplier's plant, and get the castings processed using their equipment. Then we would get the castings back and do the assembling ourselves. In time, we transferred the know-how to the supplier and now they take care of everything and supply the complete gearbox."* (Senior Manager - Prototypes)