# The low cost disruptive innovation by an Indian automobile maker

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## 1. Introduction

The post world war II era can be called as an era when East Asian NIEs emerged. There emerged first tier Asian tigers followed by the second tiers over the 1980s and the 1990s. China and India emerged as the fastest growing economy the 1990s. In the explanation on the first tier economies, the discussion on the role of the government policy in the East Asian NIEs has been prospering (Amsden, 1989; World Bank,1993; Chang, 1994). There has been discussion on the pattern of accumulation of technological capabilities by the firms in the catch-up countries: those developing countries with fast economic growth after the world war II (Lee, 1997; Porter, 1990; Dahlman et al.,1985; OECD, 1992; Hobday, 1995; L. Kim, 1997a) All of these views have attempted to explain how the successful catch-up countries have tried to catch up with advanced countries by assimilating and adapting foreign technology of the advanced countries (Bae,1997; kim,1980; Lee et al., 1988; Utterback and Abernathy, 1975; Vernon,1966). In this view, catching-up is considered as a question of relative speed in a race along a fixed track which advanced country firm has passed, and technology is understood as a cumulative unidirectional process

There are other stream of argument which emphasize that the catching up country firms can choose multi tracks. Because the technology has been constantly moving and so firms in the catching up can choose 'recently available better' technology. So the paths of the firms in the catching up countries are different from those of the advanced country firms in the past. Therefore the firms can skip a certain stage of accumulation of technological capabilities (Lee and Lim, 2001). Lee and Lim (2001) even argued that by choosing newly available technology, path creating catch up, creating 'new to the world product innovation', can be made possible (Lee and Lim, 2001). The best example could be the digital TV technology and the CDMA mobile communication technology where Korean firms could occupy the leading status in creating 'new to the world' innovation by early entry into the technology in the latter 1990s. As early as in the 1980s, Perez and Soete(1988) argued that firms in developing countries can emerge as leaders if their R&D activities in new emerging technology are initiated at an early stage of evolution of new technological paradigm. The path creating catch up cases revealed in Korea were the cases of early

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entry by Korean large firms such as Samsung and LG in the early 1990s which had the basis of accumulated technological capability in product and process development.

In the 2000s, could path creating catching up in China and India possible? Christensen's argument (1997) on disruptive innovation points out the possibility. Christensen, being interviewed in Vaitheeswaran (2008), argues that India and China are poised to trigger disruptive innovation. The disruptive innovation is the innovation made by innovator who make a challenge to "commercialize a simpler and more convenient product that sells for less money and appeals to a new or unattractive customer set" (Christensen and Raynor, 2003, 32). The innovator enter the market and offer inferior technologies and products at much cheaper prices and push incumbents into ever smaller niches and in the end out of the market. This argument is insightful. Considering that the Chinese and Indian market is expanding dramatically, the low income market can be attractive market for disruptive innovators. Considering that the Christensen's argument (Christensen 1997; Christensen and Raynor, 2003) was established on the basis of empirical evidence on those full fledged companies in terms of technological capabilities, one can conjecture that this kind of disruptive innovation could be made possible by Multinationals positioned in the low income countries. Can the disruptive innovation be possible by those local firms? Possibly in simple or not-sohpisticated product or technology. But not likely in the complex product or sophisticated technology. In the case of complex products or sophisticated technology, there are a lot of problems local firms have to overcome. Because the local firms are lack of technological capability enough to generate new technology, they are not likely to be the driver of disruptive innovation in the developing countries. If the disruptive innovation capability requires the capability to develop a product and manufacture the product, the capability requires accumulation process from their experience of product development and process improvement. The technological capability which is embodied in organizational processes and resources cannot be made or imitated in a short time (Teece et al., 1997). Those company without necessary capability shall be exposed to the risks in product or process innovation than other full fledged companies. They shall be exposed to risks in technology development processes and marketing process being lack of accumulated competences

So the research question is the following: Is disruptive innovation by the local firm without full fledged technological capability possible? If so, what are the processes to make the company be able to trigger the disruptive innovation in spite of not-having-full-fledged technological capability?

| | Not-full fledged product and process innovation capability | Full fledged product and process innovation capability |
|---|---|---|
| Disruptive innovation in product and process | Innovation in the 2000s in China and India | US and advanced countries (Christensen and Raynor 2003; Christensen 1997 ) |

Table 1 disruptive innovation and innovation capability

If there exist a disruptive innovation by a local firm without full fledged innovation capability in India or China, one can offer three possible explanations. First, the company could succeed in the disruptive innovation by early entry strategy into new technical field. If a company enter into R&D activities in the field of emerging science or technology field and invest in developing commercialized product at an early stage by applying R&D results, the company can secure advantageous position (Lee and Lim, 2001; Lee, Lim and Song, 2004; Perez and Soete,1988). Even though the entry company does not have a full fledged capability, the company can compete with other firms from advanced countries who have not accumulated competences to carry out R&D and commercialize the R&D results in the new field. If the entry companies are successful, they can create leapfrogging or path creating catching up by producing new to the world products.

The second explanation is that disruptive innovation could be made through the local firms' collaboration with external organizations. Chinese academics argue that Chinese firms, lacking in R&D and even capacity of absorption, are adopting the open innovation model (Chen and Chen, 2005; Liu, 2005; Zhu and Chen, 2006). In order to secure both local and international markets, Chinese firms have been extensively researching and utilizing external (especially foreign) R&D capabilities in order to develop and produce products. Liu (2005) argues that Chinese firms differ from Korean and Japanese firms: Chinese firms do not have to rely mainly on internal capabilities of assimilation and absorption of foreign technology, as Korean and Japanese firms did, because they have now wider access to global sources of technology, including the latest technology Third, another possible explanation is the utilization of available process technology. If a catching up firm strategically utilizes emerging process technology, the company can secure competitive position by improved efficiency and effectiveness of the process. There has not been any empirical work available for supporting this explanation. But if one goes back to the Japanese firms' strategy of effective utilization of computer controlled automatic machine technology (NC machine) in building flexible manufacturing system of automobile industry in the 1970s, one can offer this kind of possible explanation. In the 1990s, there has been rapid growth of process technology which helps innovation process : digital innovation technology such as 3 D CAD, CAE and simulations supports innovation processes such as idea generation, designs and prototyping among others. With the diffusion of digital innovation technology, there have been discussions on emergence of new innovation processes through the digital innovation technology because the digital innovation technology changes the innovation processes (Thomke 2001, 2003; Dodgson et al. 2005; Baba and Nobeoka 1998) Among these, there has been an argument emphasizing that this digital innovation technology brings about radical paradigm shift in innovation process (Dodgson et al, 2003).

The disruptive innovation, developing country, technological capability are the key concepts of this paper. This study attempts to answer the research question by investigating a case of an industry where accumulated capability is important. The industry of the automobile which consists of more than 10,000 components and accumulated competence from experience of developing and producing a large volumes of cars. This study investigates the case of Indian 'people's car': Tata Motor Limited(TML)'s Nano.

## 2. Research Methodology

The research methodology is the case study approach. This study examined whether the Tata Nano can be regarded as disruptive innovation by comparing the expected pattern of the disruptive innovation and the observed pattern and reached a conclusion that it can be. This study investigated which of the three possible explanations mentioned above can be applied for the disruptive innovation, through comparison of the expected pattern and the observed pattern. It could be concluded clearly that the first explanation cannot be clearly applied. Therefore this study investigated whether the latter two explanations can be applied by incorporating the two explanations into a framework of explaining the case. It was examined whether the framework can be used successfully. The data which as been used are as the following table2.

Table 2 Data Source for study

| Type of Data | Period for Collection | Where |
|---|---|---|
| Proceeding at conference | Nov. 2006 | JAPAN |
| Proceeding at conference | Oct. 2008 | USA |
| Proceeding at conference | Oct. 2008 | JAPAN |
| Interview by E-mail | Oct. 2008~ Jan. 2009 | n/a |
| Survey Interview by E-Mail | Jan. 3, 2009~ Jan. 29, 2009 | n/a |
| Document from Internet | Nov. 2008~ Jan. 2009 | n/a |

## 3. NANO from TATA : Disruptive innovation model?

For TML , the development project, which began back in 2003, was to develop the totally 'new' car project. That was the advanced engineering project of very low cost transportation system with four wheels. According to the interview of Wagh who led the project from 2005, what he heard from the CEO was "to develop a car within a target price of Rs.100,000 [3]which primarily brings the comfort and safety of a car within the reach of thousands of families, by meeting all the regulatory and key customer

3) pproximately 2,500

requirements."(Crazy Engineers, 2008) The goal was considered to be unachievable by many global manufacturing and industry commentators at that time (United States Securities and Exchange Commission,2008). This project was different from the previous project (developing a small truck, model name called Ace, with less than 1 ton weight) in that unlike the Ace, which had to be small and not necessarily inexpensive, Nano had to be both. This was regarded as a challenge to the company's own limitations by Wagh, who was the project leader (Singh, 2008) All of these clearly shows that the Nano development project was a serious challenge to the company.

Can we say that Nano is the disruptive innovation model? Let's see whether The TML meet the three litmus tests of the disruptive innovation model. First, let's see whether a condition for disruption market of new market is met. There should be "a large population of people who historically had not the money, equipment, or skill to do this thing for themselves, and as a result have gone without it altogether or have needed to pay someone with more expertise to do it for them" The TML Nano is targeted at Indian large population who could not afford to buy the car, in spite of their need of personal transportation . Because cars are too expensive for them, they give up or buy bicycle or motor cycle which they can afford to buy. Ratan Tata, the speech of the CEO of TML at the unveiling ceremony of the 'Nano' shows the target market in mind: "families riding on two wheelers, the father driving a scooter, his young kid standing in front of him, his wife sitting behind him holding a baby and I asked myself whether one could conceive of a safe, affordable, all weather form of transport for such a family."(Tata Motors,2008a) The target market was 'someone who aspires for a car which is beyond his reach.'(Indrajit Gupta&R Sriram,2008)

The second set of conditions for disruptive innovation for lower end market is (i) there are "customers at the low end of the market who would be happy to purchase a product with less performance if they could get it at lower price" (ii) there are a business model that enables a company to earn attractive profits at the discount prices required to win the business of over served customers at the low end. TML Nano is for providing a car at a price similar to the bicycle So TML Nano is targeted at the potential customer who would be satisfied with 'less performance' car with significantly low price.

In terms of business model, TML intends to initially produce 250,000 Nanos a year and expects demand to rise to 1 million annually (Automotive News Europe, 2008). The cost of developing the TML Nano for the production of 250,000 units production was Rs 1,700 crore which was equivalent to the cost of development of the first indigenous model project: Indica (The Times of India, 2008). Considering that the TML Nano is targeted at much larger market, including export market, than Indica focused on local market.

The third condition is that there should not be one or two companies who could sustain the competitive position with the disruptive innovation model. So far there is no company after the new car has been unveiled roughly a year ago. The conclusion is that the TML Nano has emerged as the disruptive innovation model, having finished development phase and initiated the production. Whether the disruptive innovation model shall end up with successful profit making and thereby succeed in undermining the source of competitiveness of other companies remain as a question.

## Low Riders

Tata Motors' plans would produce, in real terms, by far the cheapest car ever made.

| Car | Year introduced in U.S. | Horsepower | Price[1] |
| --- | --- | --- | --- |
| Model T | 1908 | 20 | $19,700 |
| Beetle | 1956 | 24 | 11,333 |
| Mini | 1961 | 34 | 11,777 |
| Tata Motors | 2008 | 33 | 2,500 |

[1] Adjusted to 2007 U.S. dollars.

*Sources: Tata Motors; Ward's Auto World; Edmunds.com.*

Source: As cited in Meredith (2008).

Figure 1 Low Riders

Christensen and Maynor (2003, p.49) regard Ford created the first wave of disruptive growth with T model and Toyota and Nissan created the second and the Koean Hyundai and Kia third. Then the TML could be the fourth wave. Due to the TML Nano, Tata Group ranked the $6^{th}$ in the Business Week-B&G 2008 listing of the world's 25 most innovative Companies (United States Securities and Exchange Commission (2008, p.16) TML Nano has set up a disruptive innovation model in that it provided the cheapest car model in the world as an historical event targeting at the market which has not been traditionally regarded as "the market" .

## 4. The process of low cost disruptive innovation: the framework

The disruptive innovation process is initiated form the company's understanding of market opportunity and technological opportunity. From the opportunity, the company comes up with disruptive innovation model. Being a risky project, the disruptive innovation project needs strategic decision making. The disruptive innovation project initiated from its strategy of low cost innovation which targets at the customer with low income. This strategy of low cost disruptive innovation should be implemented with the processes for cost reduction. The first is application of lean design principle. This process could be made possible by removing unnecessary functions and components or substituting the materials. Initially, the existing product has expected value(Ve ) at expected cost (Ce) in existing car 'to be in competition'. The target in developing the product is to reduce cost per value by creating acceptable value (Va ) at acceptable cost (Ca) for the targeted customers. Although customers might react to the price, instead of cost, let's assume that customers react to cost of the car, presuming that the price of a car is most influenced by cost. The second is exploring best design solutions utilizing digital innovation technology. In reducing cost, the company could strategically utilize available best process technology which is useful for recuing cost. In the automobile industry where digital media based designing and digital simulation and digital mock up is prevalently used. The digital innovation technology is presumed to be most influential process technology. The process using the digital innovation technology is a process using digital data. The digital process saves time and cost by providing opportunities to see the result of digital design process through provision of visual 3 D designs and simulated results. In this sense, the digital process includes play process. The play process means the process of checking the results or impacts of the design into the completed product and manufacturing processes. This play process goes beyond individual engineers level because the marketing people and engineers and production engineers can see the results of the play result 3 D mock ups, simulation results) and interacts.) Also the other stake holders can provide information and feedback.

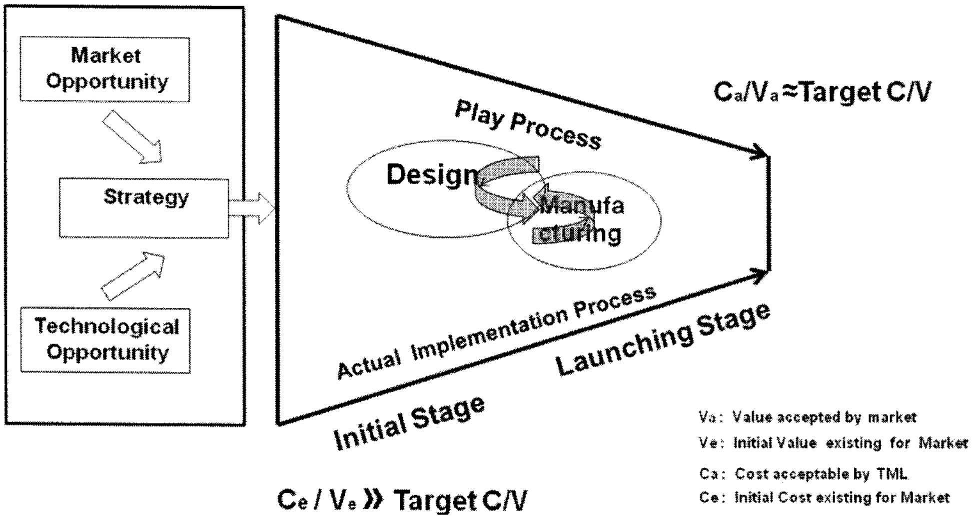

Figure 2 Framework of Research

4.1 Market opportunity

There has been increased market opportunities for automobiles in India. With its huge population and growing middle class with fast economic growth, there is a view that India is just now entering the consumer market phase of its economic evolution (Bukoveczky, 2008). Meredith (2007) reports that annual passenger vehicle sales in India shall be doubled to two million units year. India's auto industry has grown at an average of 12% for the past decade. This means that there has been expansion of market demand for personal transportation system.

TML Nono's target price is 100,000 rupees one lakh, in Indian terms of measurement or about $2,500 at current exchange rates. One of the major strategic market is the market for scooters and motors. Roughly 7 million scooters and motorcycles were sold in India 2006, typically for prices between 30,000 rupees and 70,000 rupees, about $675 to $1,600 (Meredith, 2007). TML Nano's target market is lower end automobile market and two wheelers such as motor cycles (Gupta& Sriram,2008) Given the expanded market opportunities of lower end automobile market and two wheeler market, the company could see the market opportunities for 'the cheapest car in the world.'

### 4.2 New technological opportunities

In the 1990s, there emerged the process technology, the digital innovation technology which shapes changes in the innovation process with Computer Aided Design(CAD). The emergence of 3 D CAD, CAE (Computer Aided Engineering), simulation and digital manufacturing made possible the visualization of process and checking the engineering problems at the earlier stages than before. Over the 1990s, 3D CAD technology, which used to be a drafting tool, became system technology which expanded the function of some of simulations and expanded to include the interact with product data base, CAE and other simulation tools. Even these technology could be connected to Computer Aided Manufacturing (CAM) system or digital manufacturing.

With the diffusion of these digital innovation technology, new processes have been formed and have been spread to various organizations. One of the new processes are play process, as have been mentioned. The other process is front loaded process. Front Loaded process is the process in which problems at the later stage is 'loaded' at the earlier stage and solved in earlier phases of a product development process (Thomke & Fujimoto, 2000). Front loaded product development which was originally modeled after Toyota Automobile's product development process (Fujimoto 1989; Clark and Fujimoto 1991) has evolved to include digital process of front loaded problem solving (Fujimoto and Thomke, 2000).[4] Front Loaded processes, which originally formed without digital technology, used to be the challenging processes which could be implemented by the most advanced in managing product development process. The digital innovation technology help the company to find the future problems in manufacturing. This front loaded development process could shorten time to market and cost in development. In the case of Toyota and Nissan automobile, the time between the design freeze to production was reduced from 24 monts to 10-13months (Negishi, 2002). Nissan reported the great improvement in Ramp Up Time and Ramp Up Quality through Front Loading process (Nakagima, 2005). With the diffusion of digital innovation technology which enable the front loaded process, the front loaded process could be diffused to other firms. The digital innovation technology saves time of product development by helping the company to see the future problem in assembly by identifying the results of designs with 3 D shape and the future problems in the performance of the design-completed-product through simulation and other computer aided engineering. By sharing the digital data, the collaboration of relevant staffs in different division even over the digital space is made possible. For example the design

4) To take an example project of front loaded product development in Toyota in the 1990s, one can talk of Toyota Automobile's V-COMM project which was implemented between the mid 1990s and 1998. This project was for reducing design changes drastically (Negish, 2000).

team can get feedback from the marketing people and manufacturing people by showing the product design information including 3 D CAD visual design over digital space and they can solve problems in earlier stage.

With the advancement of Product Data Management in the latter 1990s and the advancement of design rule, the additional new processes could be formed. The design analysis tradition of value analysis value engineering(removing costly designs or low value added design) could be connected with digital technology. The result is the emergence of lean designs. The philosophy of lean design inherits the tradition of 'lean production'. The lean design became more popular in the 2000s(Anderson,2006). This lean design process is different from front loaded process in that the lean design focuses on reducing designs with waste (e.g. the unnecessary design or excessively expensive design considering cost), while the front loading process focuses on reducing designs with possible problems at the later stage of product development. In the 2000s due to the diffusion of IT technology such as PLM and digital engineering system, the advanced approach to lean design has emerged. This 'lean design' is not only related to product design itself but also the manufacturing process design.

The lean design process and front loaded processes are commonality in that both processs can be made with digital technology or without digital technology. But recently with the advancement of digital innovation technology, the lean design processes and front loaded processes are incorporated into the functionality of digital innovation technology. With play process, one can not only reduce costs and problems by identifying problems but also explore results various designs with less burden of costs. The industries which have been greatly influenced by the diffusion of digital innovation technology are aerospace industry and automobile industry. The automakers design and develop a substantial part and structure of new vehicles digitally and test the strength of its parts and evaluate its performance and implement crash tests, and try several combinations of the design—all digitally—even before they build the first prototype (Talgeri, 2008).

If the designer can see the result of one's own design with play process, this can complement the weakness of novice designer or who are lack of experience of designing a product. Similarly the relatively inexperienced company can avoid the problems or costly designs through play process. When a new product is developed by an inexperienced company, previously the company had to face the design error and had to correct designs at the stage of manufacturing. But if they invest in creating product development process utilizing the digital innovation technology, then they can validate the design in spite of the lack of the experience by using simulations, CAEs and digital assembly process (visualized manufacturing process designs) using 3 D CADs. Major and Gibbels (2006) shows an example of new entrant offshore design company who could be able to see the problems and solve problems in manufacturing process through simulation and other digital process even though the company did not have manufacturing experience. This implies that the entrant to the new product design can solve problems in spite of the lack of experience of integrating design and manufacturing, they can solve problems in the design stage through utilizing the PLM technology.

4.3 Strategy

The TML has a strategy of developing the cheapest car in the world while keeping the minimum requirements. The strategy had a clarity in terms of cost and the quality of the product. "What was defined was the cost: Rs1 lakh, about $2500 (at the time the smallest car cost around Rs2.5 lakh), without compromising on aesthetics, value to the customer, or safety and environment requirements, says Jai Bolar, senior manager (development), ERC(engineering research center), and a member of the initial team. (Tata Motors 2008)

In order to develop the cheapest car, the major priority strategy was to reduce the cost of the car by adopting lean design strategy(Financial Express,2008). The strategy relevant processes includes extensive search for the ways to reduce cost while the minimum requirements for the comfort and safety and environment regulations[5]. To steer the cost minimizing process, the parameter was set up. Through creating a statistical tolerance sheet for critical failures in product design, the team could control critical parameters in order to maintain balance between cost and performance balance.(Financial Express,2008)

Second strategy to support the first strategy is investing in the digital process technology. According to United States Securities and Exchange Commission (2008 , p. 20), TML has emphasized utilization of digital innovation technology "to enhance the digital development capabilities." United States Securities and Exchange Commission (2008 , p. 20) reports that 'We have aligned our end-to-end digital product development objectives and infrastructure with our business goals and have made significant investments to enhance the digital product development capabilities especially in the areas of product development through Computer Aided Design/Computer Aided Manufacturing/Computer Aided Engineering/Knowledge Based Engineering/Product Data Management." The product design and development center (ERC) is "equipped with computer-aided design, manufacture and engineering tools,...., designed to create a digital product development environment and virtual testing and validation, resulting in faster product development cycle-time and data management."[6]

The TML regarded the opportunities of utilizing digital innovation technology seriously and has close ties with Dassault Systemes. It has a close cooperative relationship with Dassault systemes who is the leading provider of PLM.[7]

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5) "....As a result, the team has taken the benefit of best practices from other industries such as cycle manufacturing or PC manufacturing that involve mass manufacture and assembly," says Santosh Bannur, senior manager, planning, Passenger Car Business Unit (PCBU). "... We also took internal benchmarking inputs from our teams in Jamshedpur and Lucknow," adds Atul Vaidya, assistant general manager , planning, PCBU. from Tata Motors (2008)

6)Other facility includes "apid prototype development systems, testing cycle simulators, advanced emission test laboratories and styling studios are also a part of our product development infrastructure and are regularly used in product development." United States Securities and Exchange Commission 2008 , p. 20)

7) That's something he also tells Ratan Tata each time they meet. "For the first 15 minutes, Ratan tells me about his new projects knowing fully well that I will reveal some new secrets. ···.". ···.The

This strategy of utilization of digital technology is the strategy to utilize best available process technology.

### 4.4 The process of product development

Let's define the product development process in the following way in TML. The Tata Motor's product development process undergoes research and development, manufacturing and marketing activities for prospects who are potential customers. The product development process was the organizational process enabled by the digital innovation technology.

If a company uses the PLM technology in product development process, the company can examine the results of one's own design through play process, as seen in Fig. 3, this play process is the process enabled by the technological platform: PLM

This product development process is implemented in combination of play process (e.g. making digital mock ups) and actual implementation process(e.g. building prototypes). It includes actual implementation process and play process. The play process is used to examine whether the design shall have problem in actual implementation process and validate the design. The product development process is also made in cooperation with external suppliers or consulting companies.

The play process is based on the platform called PLM infrastructure as shown in Fig. 3. These are provided by PLM Vendors. As a platform, TML is known to have PLM system and digital enterprise system as shown in Fig. 3, which is not an unique condition. These companies provide software and the installation and consulting service for helping firms to establish digital processes.

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Tata-Dassault equation doesn't just pop up in isolation. Tata Motors is a major client and work on the 'Nano' has gathered steam. "The whole plant has been designed and simulated in advance so that there's no wastage. Also, with franchisees, they can replicate the same plant across the country," says Charles. (" " is an Interview with CEO Bernard Charles of Dassault Systemes by The Economic Times as cited in Mitra [2008]). The articles show that there has been a meeting between the CEO of Tata and Dassault Systemes. This implies that both the CEOs regards PLM project in Tata is strategically important to both companies.

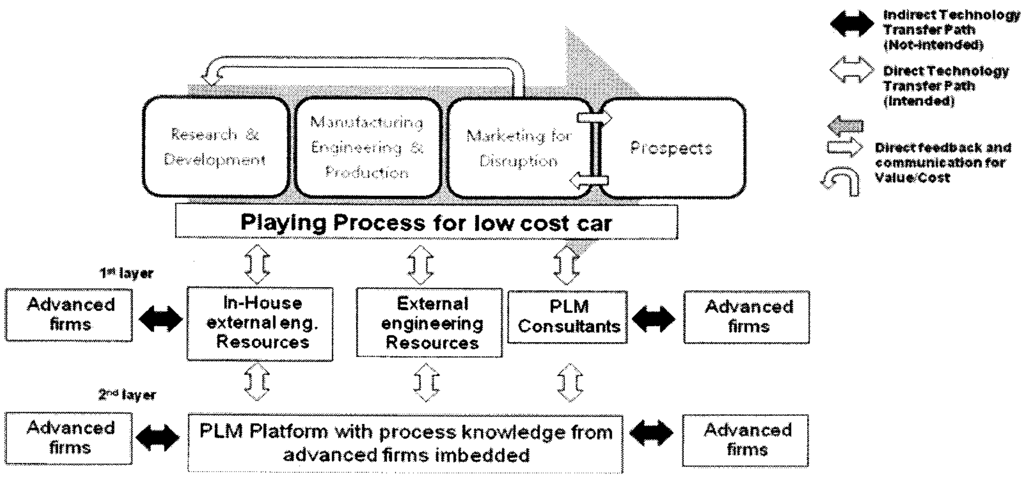



Figure 3 Playing Process with PLM and interaction with external companies

**The digital innovation technology including PLM is the tools, which is capital goods, used like a machine for improving product development process. Rosenberg (1977) discussed technological convergence of the machine tool of which design embodies the knowledge for improving production process. Likewise, the digital innovation technology incorporate the know-how for improving product development process. As shown in Fig. 3, the software maker develop the software by interacting with users, the maker develops the customized options or designs for the software. Software Vendor can acquire industrial knowledge when they are often requested to improve functions or develop customized functions by their clients. The developed customized options are used to enhance the functionality of the design of the software for further advancement. This means that the company who adopt the most advanced digital innovation technology adopts the most advanced processes and software which embody processes and know how at other advanced firms.**

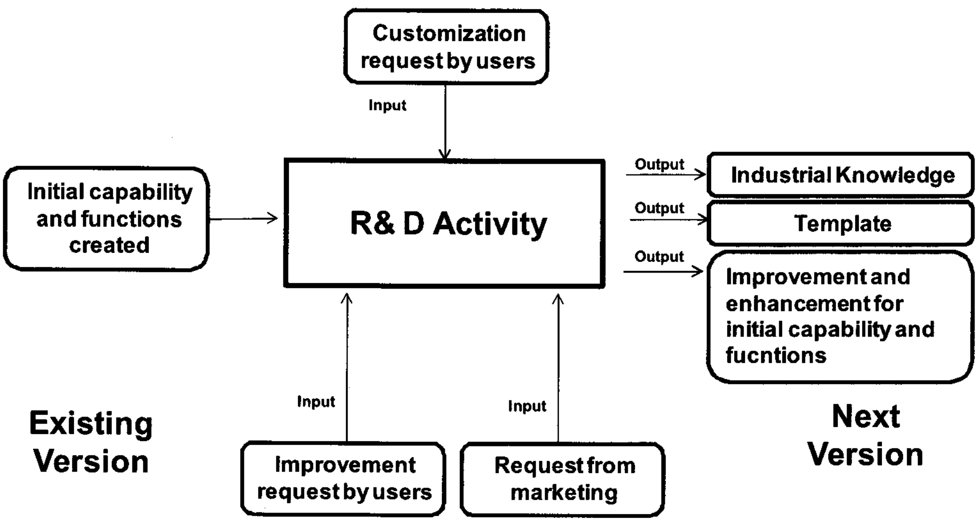



Figure 4 Process of Software Enhancement by Software Vendors

### 4.4.1 Design simplification through lean design approach

According to Narendra K. Jain, Deputy General Manager (Engines) at ERC. , the company "focused on simple designs and tried to incorporate innovations in that," (TML, 2008). This simple designs were those design free of designs with problems or unjustifiable costs. This is made possible through application of lean design principle. The application of lean design principle means remove the components with unnecessary functions or reduce functions of components (of the car) whose high cost per value is not justified and therefore need to be integrated with others. 8) As an example of removing components, it has removed power steering components and electronic window control components. As an example of simplified components, it used a single piece steel tube instead of using the the usual 2-piece steel rod of the rack-pinion system.

This application of the lean principle lead to the simplification of manufacturing process. For example of using engineering plastics, in the case of instrument panel, by using engineering plastics, the number of assembly work could be reduced. "Plastic panels have been innovatively designed to eliminate the need for screws and fit by just snapping on firmly.." (The Hindu Business Line, 2008). The cases of design simplications are suggested as the following.

Table 3 Design Simplification and Lean Manufacturing

| Category | | | | Item | Simplification | Reference |
|---|---|---|---|---|---|---|
| 1-a | 1-b | 2 | 3 | | | |
| X | | | | Airconditioning | Removal of components | Narayanan (2008) |
| X | | | | Power steering | Removal of components | |
| X | | | | Airbags | Removal of components | |
| | X | X | | Wheel Mounting | Normal wheel mounting has four pins while NANO has three | Wagh (2008) |
| X | X | X | | Steering | The usual 2-piece steel rod of the rack-pinion system was changed to a single piece steel tube saving weight and cost reduction at assembly and machining process | Business Week - May 9th, 2008 |
| X | X | | | Engine | Stripped down version of its standard Motronic DME (ECU), called Value Motronic. | Jaz(2008) |

8)Vivek Suhasrabuddhey, divisional manager, Small Car Project Office, said about design for manufacturing and assembling whereby the design efficiency of each of the assemblies was worked out as the following "Basically this means determining how many useful parts there are in the design. We involved the suppliers also in this exercise and they realised that some functions could be integrated in parts. That is how we got some cost benefit," TML (2008).

| | | | | | | |
|---|---|---|---|---|---|---|
| X | X | | | | Components and sensor count (4 instead of normal 7 – 8 sensors) were substantially reduced with greater integration and many sensor functions are replaced by software emulators. | |
| | X | X | | Drive Line | Smaller diameter of shaft, made it lighter and saved on material costs. | Business Week ( May 9th, 2008) |
| X | | | | Drive shaft | Removal of components | The Hindu business line |
| X | | | | Bonnet Grill | Removal of components | |
| | X | | | Modular Design | Modular design allows the factory to produce kits that can be assembled by local maintenance shops and entrepreneurs who will then sell and service the car | Jaz(2008) |
| | X | | | Rear Engine Seating | The rear-engined layout also helped save costs and complexity given that the drive shafts didn't need complex joints as in a front engined, front-wheel drive car wherein these shafts also needed to swivel with the steering. | Source: engineering the Nano) |
| X | | | | Wiper | Two window wipers was changed to single wiper. | |
| | X | X | X | Engineering plastics | Application of engineering plastics in cabin desing and seats as much as possible with lean design such as deleting of screws for assembly | The Hindu Business Line(2008) |

Note : Category 1-a, and 1-b stand for number of components reduction from the previous TML models typically applied to the existing passengers cars in India, but has a difference as below: Category 1-a implies the reduction of the number of component from the unnecessary functions or agreed reduction of functions for NANO, and Category 1-b implies the reduction of the number of component from lean design activity. Category 2 implies reduction of assembly job or machining in the manufacturing process,

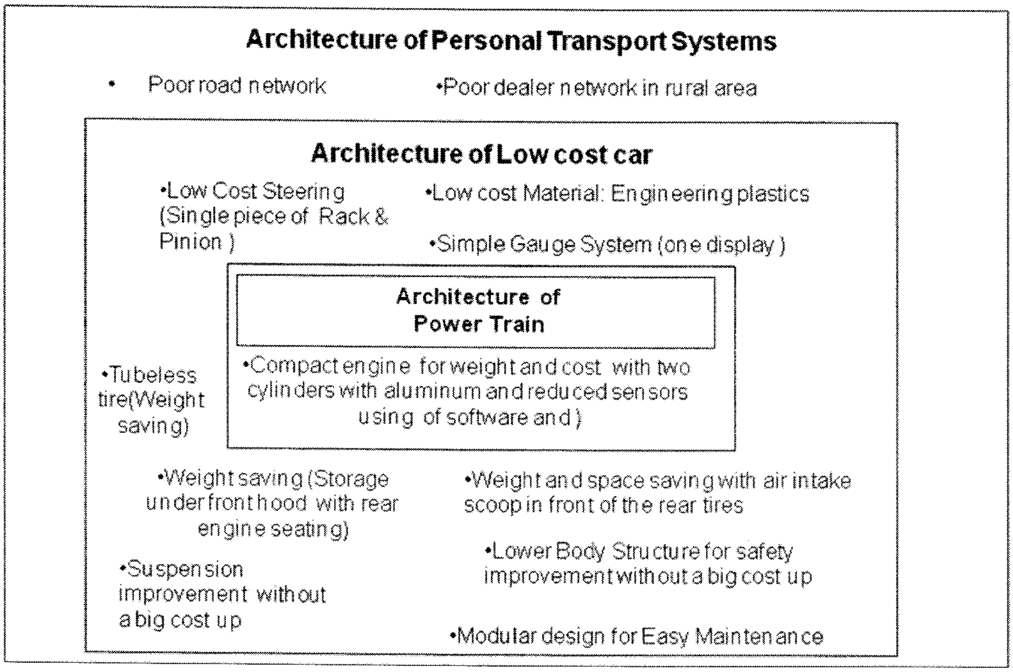


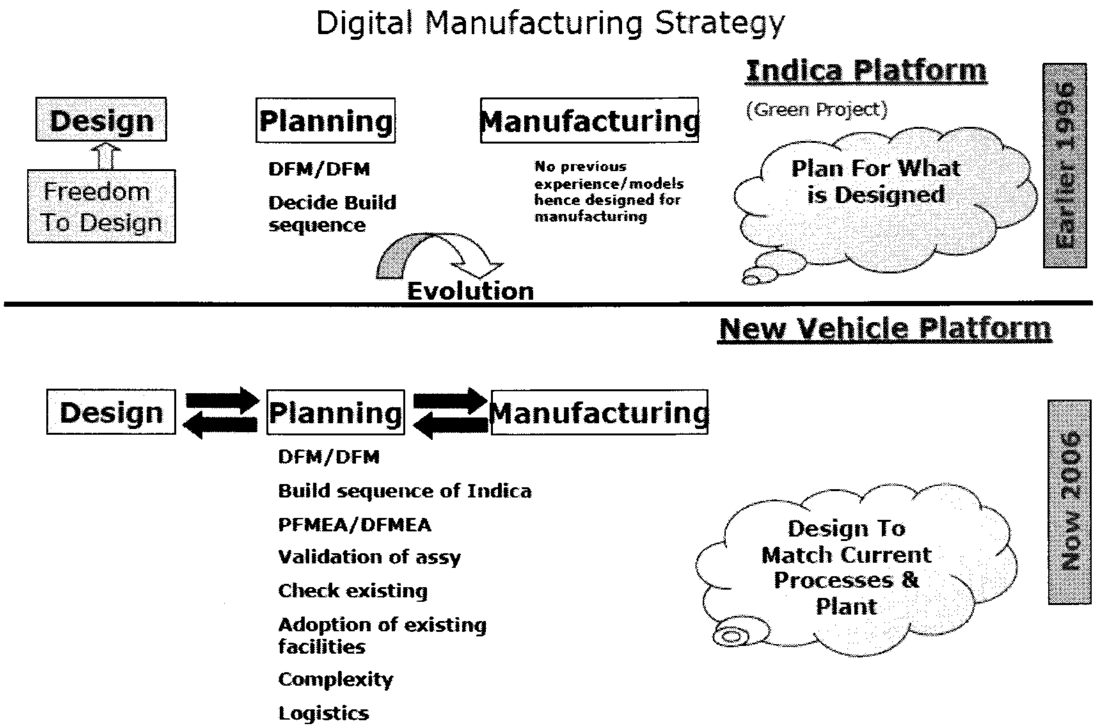
Figure 5 A Nested system of Product Architecture

4.4.2 Technology Enabled Process : play process based product development

<Design with play process>

Let's examine whether there has been substantial change in technology enabled processes.

As the report from users' conference 2006, it has been using digital tools in the design process: CATIA and Pro-Engineer(Rajurkar et al., 2006). The times of india (2008) reports the 'a great deal of digital validation at the design stage.' "Clever design, intelligent solutions with simplicity thrown in to achieve the functional aspects, weight reduction by way of ample digital analysis...were some of the means ..to get the project so clearly defined" (The Times of India, 2008). Narayanan (2008) reports 150 thermodynamic simulations by an engineer who developed an engine. According to the report from users' conference, there has been New Processes formulated in TML since 2000, after adoption of the digital tools: closer interaction between design and planning, planning and manufacturing (See Figure 6). This close interaction is made possible by play process: showing the 3 D digital mock ups and carrying out simulations results to the planning and manufacturing process.




Source : Rajurkar et al.(2006)

Figure 6. **New Process in TML since 2006.**

All of these show that there has been play processes in the product design and development stage. This study examined whether the application of digital innovation tools in the TML Nano significantly different from other car models, and the result shows that it is different. As seen in the figure 6, there has been more extensive use except for lean design for Body in White and lean design for engine. This shows that the TML Nano was made possible by extensive utilization of 3 D CAD, digital mock ups, digital design validation which includes play processes.

<Seamless linkage between design into manufacuturing>

The design process has based upon seamless interaction with manufacturing process. In the case of TML Nano, even though the manufacturing facilities have not been established, the design process has been implemented with simulation of manufacturing processes. . Already majority of companies has been developing production engineering in parallel with car product development and thereby could reduce product development proceses (Negish, 2001; 2002). In the same way, the plant of the NANO has been designed and simulated in advance to minimize any waste (Rajurkar,2008; )[9] In addition, the whole plant could be played using the PLM system as have been cited by Charles comment.[10]

TML is known to have applied intensively from the design to manufacturing and even for maintenance validation process(Khedkar,2008) and as cites from Times of India(2008): "A great deal of digital validation occurred at every stage of the design and build process, ensuring that corrective measures if needed, could be taken quickly in the normal process."(Times of India 2008). Rajurkar et al. (2006) reports the use of PLM including digital mock up tools and also digital manufacturing tool from DELMIA for assembly process validation, plant layout and the welding process of Body in White. Also the survey result reports there are digital validation for 'Final Assembly' and for 'Body in White.' Trivedi (2008) reports about TML that Delmia ,solution for digital manufacturing, was deployed over 4 months work for sub-one ton truck called Ace in 2005, then to a new version of the Indica, and then to the Nano. It did not only helped plan manufacturing processes and design a plant's layout, but also virtually simulates the repercussions of those plans. Digital manufacturing covers product design, plant layout, time measurement, process planning, ergonomics, robotics and simulation of the whole plant. Umamaheshwaran, CTO (engineering automation), TML The CTO, says that privdosly the company used the prototypes in manufacturing designing and planning phase. In this case, when the changes needed to be made towards the prototypes, the cost were high "Using DM, on simulated basis, the costs of making such changes are much lower. You can actually see and walkthrough your facility even before you have laid the first foundation stone. You can simulate all the operations even before the first of machines are installed." (Trivedi 2008). This shows how the manufactured process can be played even before the serious resource allocation for production.

All of the above evidence shows that there has been the process which examines the impact of the design at manufacuturing stage. This means that the design was validate by the play process. The manufacturing process can also valudated even thotugh the production has not started through the digital process.

### 4.4.3 External sources of knowledge

The technology enabled processes, which has been made possible through adoption of digital innovation technology, require know how of setting up product development process utilizing digital innovation technology. TML, in shifting product development process into digital process, it had to rely on external sources of knowledge. This has been made mainly by interacting with INCAT, which belong to the Tata group, which has been global leading provider of product development IT services such as Product & Information

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9) an Interview with CEO Bernard Charles of Dassault Systemes by The Economic Times as cited in Mitra [2008].

10)*"The whole plant has been designed and simulated in advance so that there's no wastage. Also, with franchisees, they can replicate the same plant across the country," says Charles* (All sentences from an Mitra [2008], " " is an Interview with CEO Bernard Charles of Dassault Systemes by The Economic Times as cited in Mitra [2008]).

Lifecycle Management (digital innovation tools: PLMs) and also the provider of engineering and design service. The company used to be British engineering company until 2005, having the world's premier automotive, aerospace and consumer durable manufacturers as customers, employing globally 3000 employees over US, Germany and India. INCAT also supports PLM products from leading solution providers in the world such as Dassault Systems, UGS and Autodesk.( United States Securities and Exchange Commission 2008). INCAT has been involved with the development of NANO as shown by the proceeding at Detroit USA by Khedkar(2008) and other documents(Jadhav,2008;Khedkar(2008). Considering that the INCAT used to be british engineering company and the major provider to world leading automobile makers, the involvement of INCAT into TML Nano project can be regarded as the transfer of the technological capability accumulated in advanced countries.

In addition to this, the TML's Nano development process has been implemented in the situation where Tata Group's engineers abroad continuously flow in and out. Tata group employs roughly 8000 automotive designers and engineers within Tata Goup and have been moving hundreds of engineers in the world to India and the other way round. For example an exchange programme includes 200 TML engineers from the group's Europe technical centre stay at India's R&D center and also a vast number of Indian engineers spend time at the Europe centre (Talgeri 2008). This implies that there has been inflow of designers and engineers available in Tata's group world wide. All of these are the external sources of knowledge within Tata Group.

Outside the Tata group, there are various type of companies. One is the company providing softwares related to PLM. Dassault systemes and UGS together with INCAT have been providing consulting services and softwares since 2005. These companies provide services related to installation and interfaces and the processes for running the softwares.

Table 4 Suppliers involved in the product development project

| External suppliers | Busines Field | Compone nts | System | Source |
|---|---|---|---|---|
| TTL INCAT* | Consulting | N/A | PLM, Product Design and Engineering | |
| Dassault Systems and SIMENS PLM** | Software and consulting | N/A | PLM, Digital Innovation technology, Industrial Knowledge | Home page in Internet |
| Bosch | Engineering ( for multi-point fuelling system and also the electronic management system) | Engine | N/A | The Times of India,2008 |

| | | | | |
|---|---|---|---|---|
| Rane | Steering gears, columns and seat belt | Parts | N/A | Economic Times ,2008 |
| Italy's Institute of Development | Design of the styling of Nano | N/A | Styling | Tata ,2008 |
| Munro & Associates Co. | Consulting for lean design and engineering | N/A | Engineering | Munro,2008 |
| Sona Koyo and Rane Group | Devlepment of hollow steering shafts | Parts | N/A | |
| Emcon | Exhaust supplier Design of exhaust system | Parts | N/A | Nanarayanan,2008 |
| MRF | Development of tyres to bear extra weight on rear wheels. | Parts | N/A | |
| Lumax | Development of tail light fixtures | Parts | N/A | Gopalan and Mitra,2008 |
| GKN | Driveshafts | Parts | N/A | The Times of India,2008 |

**Note : *TATA, **Non-TATA & DIT, Rest of the companies are non-TATA group, Non DIT supplier**

There are other consulting company for helping the company with the design process. There was Munro & associates have been proviving design services (Munro,2008). There was a case, of reducing 300 $ per car through lean design principle to the TML Nano (Munro, 2008). The application work was achieved with 3 D digital technology and softwares and prototypes. The company has been involved with TML on the whole car for the design. It analyzed engines, transmissions, the entire interior, suspension, steering, BIW, closures and could achieve over $300/vehicle in cost reduction (Email Interview 2 January 2009). The company was also involved in the process of validating the process.

There were other kinds of companies who developed components for TML Nano as a supplier. For further details, please look at Table 4.

From all the discussion, it can be seen that the TML relied on INCAT, Dassault Systemes and UGS for software and product development IT services. The design process of the TML Nano have been implemented by the support of the product development IT service and design service from the companies in side the group which ware global actors. There also have been support from the suppliers who have been involved in the component development for TML Nano.

### 4.4.4 The reduced burden of technological capability

The empirical results discussed shows the answer to how the company could develop the disruptive innovation model.

The firs is that by applying the lean design approach, the reduced components due to simplication and removal of unnecessary components lowered the complexity of the product development. The more complex the component, the higher possibility of failure (risky) in integration of components into a product. This integration of components into a product requires in house accumulation of capability because integration capability cannot be learned or transplanted without experience of learning by doing. In the case of aero space and automobile industry which consists of more than 10,000 components, the integration capability is important for gaining competitiveness. TML, being the laggard company as an automobile company, TML has a long way to go in accumulating integration capability of middle range or higher end automobile makers which consists of sophisticated components. However the lower end automobile which is made with simplified number of components do not demand as high integration capability as other automobiles. Therefore the product development process was not as risky (prone to failure) as in other higher range of cars in spite of the company's relatively poorly accumulated capability. or other competitors in development stages and integrating designs and manufacturing process: (i) due to the reduction of functions, the company do not have to the technological capability to develop the component providing the function or the company do not have to integrate the used-to-be components into the whole design (ii) through the reduction of the number of components, the company do not have to develop interfaces with larger number of components into the product or do not have to solve problems of the conflicts or interventions among larger number of components.

The second is the play process. By utilizing play process, available due to digital innovation technology, could provide the TML opportunity to avoid trials and errors in spite of low technical cahability. Because they can check future problems and the low value designs through visual examination in cyber space and simulated results. For example of the link between the design and manufacturing, This kind of validation of manufacturability of the design and planning manufacturing processes are critically important to those companies like TML who do not have much experience in developing products. According to Umamaheshwaran, CTO , "We cant't imagine what would take place at a new plant, if we did not have DM[digital manufacturing] tools. Two years before the first stone of a plant is laid, we already start working on it.... You can simulate all the operations even before the first of machines are installed," (Trivedi, 2008). According to Nitin Rajurkar, General manager at technology & production services "Earlier, only after we had made prototypes did we realize that we had overlooked some practical problems. ... But it was too late to do anything then. Now, we are able to figure out such problems at the desktop and take corrective measures." These simulation saves "a large number of prototypes" to test a new product and saving a lot of testing activities. He adds that through review of simulation movies by different teams and share comments about the designed manufacturing processes. This ability to simulate facilities and processes has reduced the cost of physical rework and there 30 percent reduction in manufacturing and facilities planning times, with a 20 percent reduction in cost of the manufacturing planning process. (Trivedi 2008). The fact that the company could reduce the time means that the company could forecast problems and solve problems in advance and therefore saving time. This implies that the company who are lack of technological competence to forecast from the lack of accumulated competence, could reduce risks of failure by solving problems earlier. This means that this kind of tools complement its weakness in technological capability. In those cases other than TML Nano, the results of the usage of digital innovation tools, which helps the validation of designs and manufacturability of the design could end up with the savings of costs (CIMdata, 2006; Dassault Systemes, 2005). All of these imply that the TML could have been exposed to risks of failures leading to trials and error processs if there had not been for the digital innovation tools which helps the company to play with the design and the planned manufacturing process.

The third is the linkages. By utilizing external suppliers who could provide complementary capabilities, the company could overcome the weakness of the capability. The global leading product development IT service companies and the leading digital innovation tool providers, other consulting firms and suppliers helped the TML's produces of product development.

Table 5 Reduced risk in product development

| Category | Role and Contribution | Effect |
|---|---|---|
| Lean design | Product: Product with Reduced components and functionality | Lower the risks of technical failures in the process of integrating large number of components in development process and manufacturing process |
| Enabled process by digital innovaton technology | Process: Play process for front loaded problem solving and lean design | Help firms to check risks of unexpected problems in R&D and manufacturing processes |
| Complentary competence from external suppliers | Linkage: | Help avoiding unexpected problems if carried out by the company alone. External companies help firms to develop components which could not be developed efficiently in house |

### 4.4.5 R&D activities for core technological competences

At the heart of innovation activites of TML Nano is the R&D for supporting simplified design of the car to reduce car and weight. The core of R&D activities were those related to the engine design activities. The design activities of an engine occupies one of the important activities in product development process. The detailed design of engine is one of the main 11 stages of product development process, lying between finalization of styling & packaging and detailed design of transmission, defined by the team leader Wagh.[11)]

In order to reduce the cost of the car, the car design is oriented to reducing the size of

11) Interview with Girish Wagh- Head of Tata Nano project

the car while providing space to other components and interior space. The engine design was crucially influential in determining the size and saving the space. The two piston engine saved space and the location of the piston at the back of the seat helped reducing size of the car. As the decision making to put two piston engine designed to fit in the space behind the rear seat provided the major turning point in designing process, providing more space room (Tata Motors 2008). In order to make the engine fitted to the rear seat, additional R&D was required. The available engine's speed was too lown therefore the enhancement of the engine was required. The two piston engine, which used to be not used for the car, has a vibration level not satisfactory. So the company had to carry out in house R&D to reduce the vibration of the engine. The two piston engine with enhanced speed and reduced vibration was the engine which could make the TML Nano differentiated from other similar cars.

The key words of the patent title shows that patenting activities were focused on two cylinder engine and steering. R&D for steering was interpreted to have been required to make the car to be steered with limited number of components and space. Also the adoption of the two cylinder engine required further research to keep balance in order to mimimize the vibration. The R&D data shows that R&D expenditures have seared from 1.9% in the fiscal year of 2006 to 2.7% of 2008 (United States Securities and Exchange Commission 2008). The analysis of patent data implies that the process of reducing cost of the car with simplified design required R&D activities to support the design. These R&D activities are those R&D which provides components difffernetiated from other small car makers.

Simplified design does not mean reducing R&D activities.

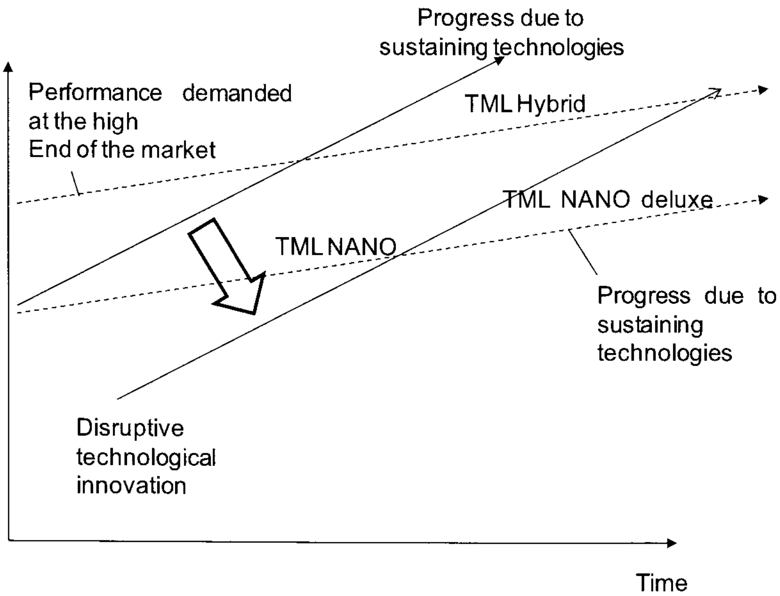
Table 6 Contents of patents filed in PTC by TML

| Key word of Title page word | Number of Patents | Remarks |
|---|---|---|
| Two(twin) Cylinder engine | 3 | To reduce the vibration of the engine |
| Steering | 3 | |
| Belt | 2 | |
| Lower body structure | 1 | |
| Bearing for crankshaft | 1 | |
| Transmission | 1 | |
| Suspension | 1 | |

**Source: WIPO PCT data base http://www.wipo.int/**

### 4.4.6 The disruptive innovation model : low cost innovation model

The disruptive innovation by TML Nano is the disruptive innovation through process innovation by application of lean design principle and utilizing digital innovation technology. With the innovation, the company could provide the lower end market product, which used to be not existent. Accoridng to the CEO, the Nano is not just a 2,500 $ car but a platform that will be used to develop further high-end models. The company already has developed the luxury version of the Nano. It is not developing electric and hybrid cars, using the Nano and its future variants as a base according to the CEO. The CEO's remark can be plotted on Figure 7. Based on the disruptive innovaton model of the low cost innovation, TML can produce higher performance cars with higher price (Narayanan 2008). Whether this model shall be enjoyed by TML or not shall depend on its performance in the market. At least, the CEO's remark showed the new model of distuptive innovaton models on the basis of low cost innovation processes.




Source: Christensen (1997, p. xvi) and interviwed report by Narayanan (2008)
Figure 7 The Impact of sustaining and disruptive technological change

## 5. Conclusion

The answer to the research question in this paper is that it is lean design processes combined with digital innovation tools and utilization of external sources of knowledge that enabled the company to attempts the disruptive innovation in spite of full fledged technological capability. The TML Nano, the cheapest car in the world, can be a case of the low cost disruptive innovation model targeting at low income customers which have not been treated as potential customers. In the product development process, there has been massive exploration of designs in product development process. Even though the TML does not have full fledged technological capability to develop a 'new to the world product', the company could develop the car because (i) the TML Nano did not require as demanding integration capability as comparable cars due to the simplified design (ii) the process enabled by digital innovation technology help TML , who are weak in accumulated experience of developing various car models, to avoid trials and error process and to identify high cost designs that need to be eliminated, (iii) utilizing external sources of knowledge.

Contribution to the disruptive innovation theory is that this study investigated how the firms in India in spite of its weak competence, would reduce risks in product development processes in low cost disruptive innovation. The case shows the exploratory pattern of low cost disruptive innovation : the low cost innovation is made possible by application of lean design principle and utilization of digital innovation technology and utilization of external sources of technology for complementary technology.

The implication of this study is that the study showed that the company in developing countries can try the new to the world innovation, which is disruptive innovation, even though they do not have full fledged technological capability. In the current literature on technological capability accumulation (Lall 1990; Kim 1990, 1997; Lee et al., 1988), those firms with full fledged technological capability implement disruptive innovation The previous model of catching up, there world frontier innovation is made by those companies who successfully succeeded in catching up in accumulating technological capability. This shows that the exiting framework of explaining technological catching up needs to be changed. The disruptive innovation by the firms in developing countries can be an important new emerging pattern.

Low cost disruptive innovation in this case is the disruptive innovation on the basis of process changes. The TML Nano case implies that the companies in India and China who would still be not with full fledged technological capability are likely to generate the disruptive innovation if the company is innovative enough to apply lean design principle and utilize digital innovation technology and utilize external sources of knowledge. As the China and India emerge as a huge market with fast growth, the low cost innovation including low cost disruptive innovation is expected to emerge. Further researches on low cost disruptive innovation are required to elucidate the mechanism of disruptive low cost innovation clearly.

Research issues about the disruptive innovation in the developing country would provide the lot of insights to other developing countries. One of the rich area for the disruptive innovation would be the disruptive innovation utilizing the process enabled by the advanced digital innovation technology. The play process available to the developing country would provide rich experience of learning which has not been possible without and error.

**Further research issue**

The disruptive innovation of TML Nano has been made possible by the top managements' innovative approach. There has been CEO's deep involvement and the seamless interaction in top down and horizontal interactions. There has been fearless culture in challenging to develop a new technology and product. However this study could not investigate in details about the management processes and organizational changes and cultures. The possibility of exploring theses aspects are expected to further illucidate low cost disruptive innovations. The impact of low cost disruptive innovation on the other advanced countries is expected to be high because the low cost disruptive innovation shall create the cheaply priced new markets and undermine the current markets.

**Limits**

The TML's case for overcoming the limit of capability could have been exaggeredd because this study focused on the process enabled by the digital innovation technology. However aother possible explanation could have been rapid generation of technological capability required to develop the new car by TML and this aspect has not been investigated. Another possibility in the development of TML Nano was that there could have been intensive transfer of technological capabilities from those advanced firms such as INCAT in Tata group. However this aspect has not been investigated. This aspect needs further investigation.

Another limit of this research is that the TML Nano is not the product which has been sold in the market. Therefore it is not time to success or failure of innovation because successful innovation includes success in market. That is the main reason why this study focused on the issue on how the company could finish a the process of developing a disruptive innovation product The mass production of the TML Nano has been delayed due to political problems in choosing a factory site, although the production with small volume is started.

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