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Radical Innovation Process in Sustainable Development and Knowledge Management: Toyota Prius Case Study

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Abstract. This article looks at the inter-linkages and causalities between innovation and knowledge management in terms of sustainable development goals through the case study method. Taking the case of the Toyota Prius, these concepts are further developed in detail. Recognising the fact that no organisational process can happen in a vacuum and that there are a host of extraneous factors that have a significant impact on the process, factors such as culture, vision, incentives are also examined here. Further, this article delves into some of the characteristics that successful organisations display and seeks to extrapolate from the specific to general implications for organisations that aim to be successfully innovative.

Key words: innovation, radical innovation, management process, knowledge management, sustainable development

1. Introduction

'In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge...these activities describe the 'knowledge-creating company' whose sole business is continuous innovation' Nonaka (1991). In the industrial economy, corporations have faced an 'experience curve' (Henderson, 1974), where a continuous improvement in process efficiency (a form of innovation) has seen as having a quantitative relationship with the number of times the process was undertaken. The belief in this phenomenon led firms to believe in the 'economic importance of market share and the opportunity to build balanced portfolios of business initiatives to more effectively leverage the economics of the experience curve' (Hagel et al, 2009). However, the diminishing marginal returns from this curve arising out of a hypercompetitive scenario imply that innovation in today's market cannot be incremental; it must be radical and transformative. Firms usually have highly successful continuous improvement programs, although they face challenges to



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make longer term innovation initiatives sustainable. Levitt and March (1988) show that organisational learning is widely considered to be routine based, where routines are the procedures and technologies around which organisations are constructed and through which they operate (Basadur & Gelade, 2006).

This article presents a knowledge-based view of radical innovation, which is described as a process in which the tacit knowledge in a firm is converted to explicit, codified knowledge. An enabling ecosystem is key to this process. As such, although there is heavy reliance on secondary data in the form of the case study method as a baseline from which to compare, contrast and understand deviations, there is also firm research grounding as the concepts that are proposed for discussion draw heavily from the works of Davenport and Prusak, DeLong and Fahey, Nonaka, Gelade, and Takeuchi. As primary data collection in the field of innovation is highly subjective and not amenable to mathematical modelling and the lessons to be learned in this field are largely from direct observation, the research methodology moves from hypotheses to clarification, explanation and critique through comparing and contrasting and finally arriving at a conclusion. It is an attempt to move from simple to complex ideas, while developing a proposition from first principles. Whilst it is true that adding cases to the overall project would improve the ability of the research to predict phenomena, there are instances, where single cases add to the iterations of “explanation and critique”.

Radical product innovations are products previously unavailable, products that improve performance significantly, or products removing some undesired quality (Hage and Hollingsworth, 2000). One such product is the Toyota Prius, a case that is explored in detail in the subsequent sections of this article. The case shows how such innovation requires the combination of people-centric decisions and disciplined subsumption to process. It also allows us to examine the following:

1. Linkages between the innovation process and knowledge management ecosystem of a firm. And our first hypothesis is that there is a direct causal link between the knowledge management activities undertaken by a firm in furthering the acquisition/creation of knowledge and the ability of the firm to innovate by transforming this knowledge into products, services or processes.

2. The role of culture, vision and organisation structure and process, as an overarching context in innovation. And our second hypothesis is that organisational culture impacts the innovation process by intervening at and influencing every stage of its interaction with the knowledge spiral (Nonaka and Takeuchi, 1995).

3. The role of vision and leadership in creating an environment for knowledge sharing. Here we hypothesise the following: the role of vision in an organisation is such that it creates an environment that best supports knowledge sharing and innovation.

2. Existing approaches

The knowledge management process in this article is said to originate with the knowledge spiral and the interaction of the Socialisation, Externalisation, Combination and Internalisation (SECI) process as described by Nonaka and Takeuchi (Nonaka and Takeuchi, 1995) in their seminal work on innovation in Japanese firms. Although this theory was first described in 1994, it is not only central to the book, but also allows for subsequent explorations include the relevance of culture, vision etc.

The SECI model has attracted little criticism in the scholarly literature. The case is based on a 1993 survey that Nonaka and Takeuchi conducted among Japanese executives as a method of validating their hitherto untested SECI model. (Nonaka et al, 1994). The 185-item long questionnaire was highly quantitative in that it was biased towards the “content of organizational knowledge creation”, as measured by the amount of time spent on specific activities (Nonaka et. al. 1994). Although this is a criticism accepted by the authors, they clarify that the results were specific to the Japanese culture and that the model remained validated. However, questions remain as to:

- whether complex interactions in the knowledge conversion process can be identified through self-assessment without a prior study of concepts involved, which would also further bias the minds of the people surveyed;

- what the measures of the variables detailed in the SECI process are. Nonaka's early work relates primarily to the creation of information (Nonaka & Yamanouchi 1989; Nonaka & Kenney 1991). The green shoots of the knowledge creation model can be seen in some of the earlier works, which remain data sources in the model;

- why there is a divergence between the questionnaire methodology i.e. the focus on content and the output i.e. the knowledge creation model which relates primarily to a process? It would be irrational to conclude that the one can verify the other;

- the statistical validity of all four states of knowledge creation is not reached in this survey, verifying the model only in the Socialisation and Combination phases. It is possible that since these two phases are primarily perception-based (tacit knowledge is the subject matter of the first and explicit knowledge of the second), managers could have a self-aggrandisement bias.

The authors illustrate the processes within the model through case studies of various organisations. The question that may be asked is, "Are these examples of knowledge creation *per se*, or have these cases been selected to prove the theory? Further, much of the data is secondary i.e. derived from Nonaka's previous works.

Through the above critique, the following aspects of the empirical basis for Nonaka's SECI model as detailed in his work of 1995 have been questioned. Large proportion of data was derived from an earlier work of his to do with the creation of information and although he has taken pains to clarify the difference between knowledge and information, one misses a coherent argument to show that knowledge and semantic information are one and the same to lend credence to the contention that his early work related to semantic (as against syntactic) information. Secondly, there is no statistical basis for his claim that the model finds empirical evidence in a survey. The survey does not validate two out of four phases of the knowledge creation spiral. Of the two that it does validate (socialisation and combination) one (combination) does not lend itself to analytical rigour, as it reveals itself to contain within it several processes and sub-processes which the authors have not explored. The survey also moves to validate the "content" of the processes, rather than focussing on the processes themselves, which are critical to the model in that it is a model of processes. Thirdly, the stages of combination and internalization need to have further clarity in description.

Thomas Davenport and Laurence Prusak (2000) build up a case for knowledge management from first principles. The authors view knowledge as being the only source of sustainable competitive advantage for an organisation. One of the key takeaways from the authors is that the human resource policies and culture of an organisation must dovetail with its desired goal of knowledge creation and utilisation. The authors underscore the need for a firm to consider its people as the most important organisational asset, especially as knowledge is viewed as internal to people. As a result, there is a definitive statement made about the linkages between a firm's human resources policies and its knowledge management strategy in that the former must assist in fostering the right culture for the latter to succeed (Davenport and Prusak, 2000).

Davenport and Prusak (1997) also illustrate the key pieces of the information ecology while at the same time providing a real-time measurement to readers of how their organisations function on various metrics.

Brown's and Duguid's (2000) central complaint is that excessive focus on technology has led firms to implement information systems with blinkers on. Such an approach is in their view unlikely to bring about the technology revolution as anticipated. Brown and Duguid view information as acquiring relevance only through social context. In exploring this idea, the authors view trust as central to any relationship and such a deep-rooted precondition for any kind of social interaction is unlikely to be captured by digital mechanisms as it cannot be expressed in logical terms. Similarly, the ideas of conversation and body language are explored by exposing the deficiency of technology in creating such conditions (information exchange is unlikely to be as free in a chat room as it will be in a face-to-face conversation). The delinking of social context from the actual interaction is a key flaw in networks operating on technology platforms and putting pictures of participants and other 'humanising tools' do very little to foster trust in interaction. The authors' differing specialities make for excellent

analysis, even though as they admit in their book, “there remain more questions than answers” (Brown and Duguid, 2000).

3. Commercial manufacturing and success of the Toyota Prius hybrid technology: a radical innovation case study

We used the case study method in this article because it allows to study the innovation-knowledge interactions in a realistic setting and to ask questions to understand the fundamental concepts behind the processes underway. Our article also attempts to integrate two very different sets of processes – one that takes place largely at an individual level and one that is an organisation-wide process. Further, though there is a rich theoretical basis for the study in the scholarly literature, the case method allows to validate the theory, developed earlier through the observation and commentary on facts.

3.1. Background

While technological changes occur through non-linear cycles of incremental and radical innovations (Nonaka and Peltokorpi, 2006); the emergence of a radical innovation has devastating effects on the old technological and even economic systems (Schumpeter, 1934). A recent radical innovation that is the research subject of this article is the commercial manufacturing and success of the world’s first vehicle driven by hybrid technology, called the Toyota Prius.

Toyota, incorporated in 1937, has emerged as one of the world’s largest automobile manufacturing companies, with global sales of 7.5 million units in 2009, meaning that somewhere in the world, one vehicle is sold by Toyota every five seconds. The company has been in the black every year since the early 1940’s. Although the company was considered successful in most ways by the early 1990s (the decade in which the Prius was launched), the lack of challenge was itself viewed by senior management as the next potential future challenge.

Although the senior team at Toyota had been aware of the demand for more efficient vehicles, the challenge we speak of above came from the demands of regulators for vehicles with lower emission levels and the hint of legislation around cleaner fuels. The organisation responded dynamically to this stimulus by not only deciding to radically alter its focus in favour of lower emission vehicles, but also develop the enabling technology ecosystem that would allow it to diffuse such an innovation within the market while retaining a leadership position. With the RAV-4 (a classic example of incremental innovation in knee-jerk response to legislation) a failure, the company embarked on a well-planned, systematic program of hybrid vehicle development, which resulted in the launch of the Prius in 1997.

Before launching into an analysis of the case, it is useful to provide some historical perspective and describe the way in which the Prius project developed within Toyota.

3.2. Conceptual origins, formation of the Project Team and hybrid development process

Toyota had as early as 1993 identified initiatives to enhance its future competitiveness and generate a strong source of differentiation. A high-level study group had been formed under the aegis of the Head of Research, with strong formal sanction and backing from top management. The choice of initiative leader was a young GM, who had a reputation for being aggressive and focussed. This individual, through his personal organisation-wide network selected a group of ten middle managers who formed the core group of the project. Toyota culture emphasises the use of projects to test the aptitude and capabilities of their managerial cadre and projects such as the Prius are routinely seen as a proving ground for future management. With the knowledge that the company was serious about developing such a vehicle, the core group met once a week to exchange ideas of a vehicle for the future, over and above their regular work. The first stage of the project functioned with a simple understanding – ‘that Toyota was seeking to move to the next level in automobile development’ (Nonaka and Toyama, 2003). Given this vision statement, the Group sought to develop both structured guidelines and a half-size blueprint of the potential vehicle, a clear indicator of the commitment levels of employees. Through the project, the team leader put stretch objectives in front of junior engineers, in an attempt to

cultivate leadership skills. The team came up with the following guidelines which could be said to constitute the guidelines under which the project would function:

1. Realise a large inner space by making the wheelbase as long as possible;
2. Place the seats at a higher position to make it easier to get in and out of the car;
3. Make the car more aerodynamic by making the body height about 1,500 mm;
4. Improve fuel efficiency by 50% in comparison to the vehicles in the same class;
5. Use a small engine and efficient automatic transmission' (Nonaka and Peltokorpi, 2006)

The group did not make mention about the development of a hybrid vehicle, since it was at this stage still in the idea generation phase.

The second stage of the Prius project was led by an engineer who had significant experience in the testing arena and who had re-organised R&D laboratories for Toyota in the past. His experience had given him subject matter expertise on two counts – one, knowledge about Toyota's technologies and two, the ability to locate people in the organisation with the requisite subject matter expertise. Although management was initially concerned about letting a project management novice lead such a transformational project, they quickly came to see the benefits of having someone with technological expertise, social networks and the lack of the proverbial 'box' as being positives in developing a path-breaking vehicle. The second stage of the project was governed by the following strategic constraints:

1. To gain overall knowledge of the system and its components, all technology would be developed in-house with minimum collaboration with outside vendors. It was assumed that agents outside the company neither had the technological know-how, nor the shared vision with which to develop the product. This led to increased commitment, ownership and accountability within the firm.

2. Relatively unfettered access to resources and freedom from the constraints of regular production. In the words of Mr. Uchiyamada, project leader, he was 'given a free hand, unbound by any of the usual corporate and engineering constraints; freedom from component sharing and commonalities, marketing considerations and product hierarchy' (Nonaka and Peltokorpi, 2006).

3. Core product team to be solely dedicated to the new project. This enabled focus on goals and gave the project leader flexibility in team selection – each member brought to the table one recognised speciality.

4. The team was able to co-locate, a first at Toyota. This face-to-face interaction allowed for shorter feedback loops and lower lag times in the decision-making process.

Noteworthy here is also the 'rules of engagement' laid down by Mr. Uchiyamada to promote openness and cross-functional collaboration between his team members, as a response to potential derailers in the R&D process:

1. Technology should be assessed by everyone regardless of their specialty.
2. Technology should be the only point of argument, not rank or age.
3. All decisions are to be driven by what is best for the project, rather than each individual's home departments.

The first development iteration in the process was summarily rejected by management as it was focussed on incremental innovation by tweaking existing fuel-efficient engines. In an example of a macro-level iterative loop of judgemental evaluation in the idea generation process, management respecified project guidelines to force radical innovation into the project and additionally specified the optimistic vision of doubling the fuel-efficiency in a mass-produced vehicle, while at the same time demanding from the team a prototype for display at the Tokyo Motor Show in October 1995 and putting even more stringent timelines on the team by reducing the target market-introduction time by a year to December 1997.

The same loop occurred at the project level when the team decided to focus on the as-yet underdeveloped hybrid system, a field in which Toyota was significantly ahead of the market. After reviewing and evaluating over 80 plans for hybrid engines, the project team through a newly-developed analytical program accepted four for further study and selected the final plan to fit into its goal of synergising technology for mass production with the manufacturing and marketing processes needed to ensure that the car was ready for display at the Tokyo Motor Show in October 1995.

In response to this stimulus, the project leader undertook the following:

- Co-ordination with three experienced members – one each for the engine, chassis and production planning/marketing. This enabled the team to set parameters early and rectify errors quickly.
- Conduct the research and development processes in parallel with each other through relying on simultaneous engineering by activating a network across various product development groups.
- Approached senior management for additional oversight (Mr. Toshihiro Ohi) to speed up product launch. This led to the market-related processes of commercialisation, sales and public relations getting a boost in parallel with research and development.
- Sourced external knowledge for the first time in the design of the car, through a competition held to increase diversity in design concept.
- Overcame the battery technology obstacle through long-term collaboration in the form of a JV with Matsushita Batteries International (MBI), who had knowledge of developing batteries for electric-powered vehicles. Although this created problems initially as there existed differences between joint venture partners on quality control, shared vision and holistic understanding, these were overcome through seamless movement of management-level employees across organisations, open dialogues and communication of shared understanding. The JV engineers also participated in test drives to understand the operation of a hybrid in an actual context.

The Prius was successfully launched in December 1997 and became a commercial success due to its extensive press coverage, reasonable price and desire from customers to be early adopters of hybrid technology. The car has since gone on to win several accolades not only for production and design, but also technology and engineering. The internalisation of most knowledge has benefited Toyota greatly. Firstly, it has enabled Toyota to own more than 300 patents as part of the Prius. Secondly, the company has learnt from the Prius project how to control technology costs in the new product development process. Finally, the company has been able to leverage the knowledge created in this project across allied lines of manufacturing – alternative energy, diesel engines, gasoline engines and electronic vehicles, resulting in tremendous payoff in terms of shortened product development cycles and lower R&D costs.

The company launched the second-generation Prius in 2003, a vehicle that is regarded as a quantum leap over the first generation. In addition to improved design elements, the technology also produces higher acceleration than most conventional cars with larger capacities and has further cut down on emissions. Toyota is in the process of integrating hybrid technology into a number of other vehicles including conventional ‘gas-guzzler’ SUVs, trucks and commercial vehicles, and has also offered the technology to other automobile manufacturers, such as Nissan, Ford and GM to create an ecosystem around it.

4. Illustrative example

4.1. Framework for the analysis

The proposed framework through which the case may be viewed seeks to integrate the knowledge spiral i.e. the acquisition, integration and diffusion of knowledge with Nonaka’s Socialisation, Externalisation, Combination and Internalisation (SECI) Model of knowledge creation. The framework also looks at the culture within the firm and vision of senior management or leadership as providing a context within which the innovation – knowledge interaction process takes place (Fig.1). Research suggests that effective organisations display a high degree of three specific characteristics; 1) efficiency, 2) adaptability and 3) flexibility (Mott, 1972).

1) Efficiency can be viewed as the sole concern of a static organisation. It is the establishment of structure in the everyday functioning of the organisation and is determined by the series of routines that an organisation establishes for itself to most efficiently perform its core function. If carburettor-type engines were still purchased and the only purpose of a firm was to manufacture ad infinitum such engines, then it would centre all its activities around doing just that and would be efficient.

2) However, in the dynamic automobile market, since the carburettor was replaced by more technologically advanced engines, a purely efficient organisation would be out of business if it wasn't adaptable. Adaptability is the flipside of efficiency – while the latter implies mastery over a certain methodology/process, the former is the speed at which an organisation can change such a process. Mastery over the process of changing a process (Basadur and Gelade, 2006) allows the organisation to continually introduce new products and service, each governed by their own routines as well as improve on these routines to reduce cost, add quality etc. While adaptable organisations on the one hand anticipate and pre-empt changes in the marketplace, either in technology or customer expectations, they are also able to effectively acquire from external sources, the information or knowledge embodied in new technologies, ideas and methods required to respond to such changes. Adaptability in a line is the ability of the organisation to apprehend and react to anticipated change (Mott, 1972).

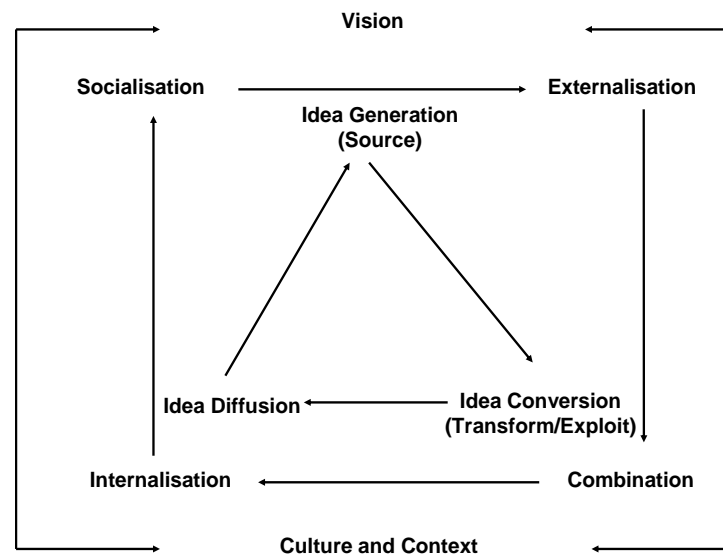


Fig.1. Knowledge creation model

3) We live in a hypercompetitive world, where “continuous changes in the state of knowledge produce new disequilibrium situations and therefore, new profit opportunities” (Jacobsen, 1992) at an ever-increasing rate. The Schumpeterian vision of competition as a ‘process of creative destruction’ requires for corporations to face what behavioural leadership literature calls the ‘adaptive challenge’ (Heifetz, 1998), which is a result of flexibility. While adaptability is continuous and proactive, flexibility is reactive and deals with the unforeseen.

Ikujiro Nonaka, in his pathbreaking work describes the knowledge creation process as occurring through the ‘dialectics of tacit and explicit knowledge’, (Nonaka, 1994) and considers knowledge as ‘a dynamic human process of justifying personal belief towards the truth’ (Nonaka and Takeuchi, 1995), which occurs through the modes of 1) Socialisation, 2) Externalisation, 3) Combination and 4) Internalisation. These four modes also deal with the conversion of individual or organisational tacit knowledge to explicit knowledge and then the reconversion of such codified knowledge into tacit knowledge at the organisational level. Each of these phases is explained as follows:

1) Socialisation is the sharing and creation of tacit knowledge through direct experience and is a function of the interactions between an individual and the environment. Direct experiences enable the accumulation and sharing of such knowledge. We know more than can be explicitly communicated through language (Polanyi, 1994). Since each person’s mind – coloured by its own biases – gives these experiences personal and highly subjective meanings, such knowledge is useless to the organisation unless externalised and explained. The socialisation phase in the Prius project can be viewed as a

concurrent phenomenon occurring at every stage of vehicle development through the influence exerted by the direct experience of every one of Polanyi's 'actors' on their interactions with the environment. While the project leadership viewed each one of their interactions with the various stakeholders in the process i.e. the team members, senior management and subsequently the different groups within the organisation that worked on the end state Prius, it is instructive to note that the choice of leaders (as well as team members) which through their accumulated personal meanings (Polanyi, 1962), defined the environment and thereby exerted significant influence on it. The Prius team leader, Mr Uchiyamada even laid down norms to govern the interactions of members in his team. Further, although the pressure by senior management on the project team to shorten deadlines after the Tokyo Motor Show prototype failure was a contradiction in terms, it was taken up as a challenge because of the sharing of vision and empathy between the team and the top management over the project. It is therefore, important for actors to embrace contradictions rather than confront them' (Varela and Shear, 1999).

2) Externalisation is a phase in which tacit knowledge is articulated or codified using widely accepted code such as language, flowcharts, diagrams etc. This is the phase in which tacit knowledge is shared either through analogies, or through metaphors or the process of two people interacting through dialogue or through reflection and where it gets translated into explicit knowledge (Nonaka, 1994). A key variable here is the 'diversity of knowledge, which increases the likelihood of the emergence of radical solutions' (Hage, 1999). The Prius project team had a significant abundance of both the diversity of knowledge and the enablers for the sharing tacit knowledge through dialogue. If conversations are understood as interactions between people, with some trying to convert others to their point of view by presenting logical, rational arguments, then dialogues in contrast as 'a stream of meaning flow among and through a group of people' are based on active listening and an openness to changing opinions (Bohm, 1990). Trust and care (Nonaka and Takeuchi, 1995) which are also key enablers in the process were present in ample measure. This is evident as not only did seniors (management and team leaders) display trust in their juniors by giving them free rein to perform, while simultaneously placing on their shoulders stretch responsibilities, but also the emphasis on quality in the process of re-inventing the product from the ground-up was indicative of their care towards the mission.

3) Combination phase is the stage that involved systematisation and application of explicit knowledge created in an organisational context. The codified knowledge created above is collated, integrated and subsequently diffused and transferred to become part of the organisation's routines and processes. The crystallisation of the externalised tacit knowledge in the forms of collective awareness and practical usage occurs in this phase. Sometimes, the sub-division of a concept into its constituent components allows firms to better evaluate and validate each piece for effectiveness as well as monitor and improve on it. In the Prius case, this is in the opinion of the writer, the single largest source of competitive advantage for Toyota. At every stage of the project, there was a division of vision into strategy, tactics and finally operations. The vision of the senior management to move to the next level in automobile development was translated into specific, measurable, actionable guidelines by the original concept team and subsequently into strategic constraints, against which progress could be monitored. The short and effective feedback loops thus generated were key to flexibility in rejecting ideas as well as adaptability in responding to the constraints imposed by management. Important to note here is the role of technology, hierarchy and organisation structure which enabled the efficient aggregation of knowledge residing within the firm to significantly speed up product development by placing well-networked actors in positions of responsibility. The effective utilisation of the over-300 Prius-related patents in other divisions of the firm and the documentation of the new process of product development also points to a system that effectively codified and shared learnings across the network.

4) Internalisation is the process of re-conversion of explicit knowledge to tacit knowledge in which knowledge created is put into practice and the experiences arising out of such practices become part of the organisational memory. Most organisations have difficulty in the implementation of newly

acquired knowledge in existing routines. Explicit knowledge, such as product/service concepts and manufacturing procedures, must be actualised through action, practice and reflection so that it can really become one's own knowledge (Nonaka and Toyama, 2003; Varela and Shear, 1999). The Prius method of product development has become a transformational praxis in which knowledge is applied and used in practical situations, becoming a base for new routines (Nonaka and Toyama, 2003). The second generation Prius is reflective not only of the speed with which Toyota took to the new R&D method, which was a by-product of a radical innovation, but also of the quantum of incremental innovation that it was able to achieve as is well documented in the technological superiority of the product over its predecessor. This framework models the stimulus for this product as being the tacit knowledge inherent in customer reactions to and purchasing patterns of the first-generation Prius, thereby leading to another round of the SECI spiral. This process recurs as organisations innovate.

The framework also models the recursive process of innovation, which may be understood as 'the beginning of a process of value creation which, subject to the firm's own attributes and market conditions, may result in an improvement in the performance of the innovating business (Roper, Du and Love, 2006). Knowledge or productivity spillovers may also then lead to improvements in the performance of other co-related or co-located firms (Klette et al., 2000). The implication is that although the innovation process begins with the sourcing of knowledge – or what is referred to as 'Idea Generation' in our framework – and continues with the transformation and exploitation of such knowledge what is modelled as the idea conversion phase, it does not end until the innovation (or idea) is diffused in the environment. Hence, although knowledge is the unifying factor linking the various components of the innovation value chain together, the motivation to engage in the risky, uncertain and costly activity, which is innovation (Love and Roper, 2001) arises from competitive pressures and opportunities. Modelling the value chain underlines the complexity of conversion of explicit knowledge into value additive activities which act upon the various factors of production in an organisation to improve, or in the case of the Prius, radically alter product or process output.

4.2. Innovation process in terms of the value chain

Stage 1 – Idea Generation

This is the stage which Simon (1977) refers to as 'opportunistic surveillance' or the proactive acquisition and generation of new information and the sensing of trends, opportunities and problems. Roper et al. (2006) identify five different types of sources of knowledge that generate inputs for innovation.

- Investments in in-house R&D, in line with the standard 'make' option in terms of the literature on technology sourcing (Shelanski and Klein, 1995).
- Forward linkages to customers generate formal or informal inputs for innovation.
- Backward linkages to either suppliers or external consultants, a fact emphasised by Horn (2005).
- Linkages to either competitors (Hemphill, 2003) or collaborative agreements to acquire knowledge such as joint ventures.
- Linkages to public universities or research centres.

The choice of avenue is constrained by a firm's existing resource base and the environment in which it operates. It also stands to reason that a firm will source knowledge that it can most easily assimilate or conceptualise into new challenges or ideas. In the initial phases of the Prius project, Toyota decided to rely solely on in-house development for the following reasons:

- To enable it to control all aspects of the system and its constituent elements. One beneficial aspect of this was that the firm developed a wealth of tacit knowledge from the project that was then codified and channelled to other divisions of the firm. The move yielded great benefits to the firm by allowing it to modify the hybrid system in a short time when the second-generation Prius was to be launched,
- To own all technology (300+ patents) relating to the Prius which could then optimise return on investment in the long run.

- To ensure unification of the project team under a shared vision, which would flow from Toyota's senior management and would be in consonance with the company's unique culture.

However, considering the changing project constraints, the company was forced to forego the internal idea generation model in favour of generating ideas from external sources in the field of design and battery development. This was driven by:

- The similarity of in-house designs to extant Toyota designs, which the team felt was being unduly influenced by the status quo. There was also the acceptance that design was a factor Toyota could be relatively open to change on, without compromising the vision of the Prius.

- Battery development expertise was not as developed within Toyota as it was in its JV partner, Matsushita. Though the JV had teething problems, corrective action was taken quickly enough to unite the JV partners under a common vision.

Stage 2 – Idea Conversion

This link in the chain is essentially the stage at which knowledge sourced in Stage 1 is utilised to act upon the various factors of production and is converted into outputs in the process of innovation. A quantitative approach led by Geroski (1990) and Harris and Trainor (1995) has led to this being modelled as a 'knowledge production function'. While in the first part of this stage, the firm researches, develops and optimises new product or process solutions, in the latter half, it also implements these solutions. New information is leveraged in increasing the variety of options – or what Guilford (1967) referred to as divergent production – as well as in achieving best outcomes and reaching decisions to reduce the variety of options in a process referred to as evaluation. Osborn (1953) believes it is the task of the organisation to 'defer judgement' i.e. separate the process of non-judgementally creating options from the process of judgementally evaluating them (Joyner and Tunstall, 1970).

This stage is evident at every point in time detailed above. The change in the Prius project mission, guidelines and constraints from the time of initiation to the final delivery of the Prius constitute a complex iterative loop in which 'the generation of information from given information where the emphasis is upon variety and quality of output from the same source' (Guilford, 1967) precedes 'reaching decisions or making judgments concerning criterion satisfaction of information' (Guilford, 1967).

It is observed that like individuals, organisations also go through a 'learning cycle' (Kolb, 1976) and need to recognise the complementary relationship between the experiential and theoretical learning systems. Most organisations view knowledge management as the first two parts of Nonaka's model (i.e. knowledge sharing), labour to convert tacit process or product knowledge into codified data or information in electronic form and develop information sharing systems to spread this knowledge to various parts of the firm. An increase in the availability of information does not in any way have a bearing upon the use to which it is put. It is proficiency in Kolb's 'active experimentation' stage that endows a firm with tighter feedback loops and make it truly efficient.

Stage 3 – Idea Diffusion

Diffusion is a measure of the scope of impact of the implemented idea and translates into the total value realised from the innovation (Ruggles and Little, 1997). The most common metric through which diffusion is measured is market impact, either through revenue, market share or share of mind. Internally however, especially in the case of process change, diffusion occurs in the form of awareness about new processes and their benefits as well as their overall applicability in other sections of the organisation. It is in this phase that successful business practices are transferred from one part of the organisation to the other, a process akin to organisational sharing of lessons learned.

Diffusion in the case must be viewed in both an internal and external context:

- Sharing 'lessons learned' through technology transfer to other lines of business within the firm.

- Transferring technology to other firms within the market. As the Executive Vice President, Akihito Saito explained in an interview, "We believe that the proliferation of technologies is essential. Proliferation is not something that Toyota can achieve on its own, and when considering the global

environment, it is important that auto makers from around the world work together. That is why we are considering disclosing technologies” (Hage and Meeus, 2006). The company hopes to create economies of scale that would have beneficial impacts on inputs, industry-wide innovation (to develop external sources of ideas), as well as potentially impact governing legislation in a way that could positively develop the market.

5. Discussion

The Prius case represents Toyota as the epitome of a ‘knowledge creating company’ (Nonaka, 1991), an organisation that has a demonstrated ability to combine newly acquired knowledge with its existing bank, to innovate and create new products (and in the process knowledge) and to disseminate this knowledge throughout the firm. In the view of the author, it is worth noting that this process would be impossible without a supportive ‘ecosystem’.

Organisations have different goals, social contexts, histories, value systems and reward structures (Brown and Duguid 2000). Fruin (1997) believes that ‘Western management is mostly concerned with efficient use of tangible resources, etc. These are things that can be counted, routinely depreciated and easily valued; balance sheets where people are a residual resource, not a core one’. This leads to an over-emphasis on technological aspects of the programme, while excluding the human aspects relating to ‘right staffing’ from the point of view of knowledge, all of which are compounded by inappropriate technologies. This ‘Taylor-like’ view of the firm ascribes it value purely as a system that processes data and regards all knowledge as data – codified processes, goals and targets, with equally structured methods of measurement and evaluation. In the words of De Long and Fahey (1998), this implies ‘raw or unabridged descriptions or observations about states of past, present or future worlds, and information as patterns that individuals find or imbue in data’. But it is not objective information that formed the basis of effective innovation at Toyota. It was the combination of highly subjective tacit knowledge borne out of human reflection and experience that the firm was able to leverage. Culture, therefore, imbues an organisation with organic characteristics, much in contrast to Western management thought. It makes the organisation a collective of individual identities, existing for a purpose beyond the mundane and upholding a set of ideals.

Newman and Conrad (1999) are of the opinion that the most powerful type of ‘agent’ that acts upon an organisation’s ‘artefacts’ (or whatever it uses to represent meaning and understanding) is the organisation itself. Such agents are best embodied in the firm’s ‘unwritten rules and organisational culture’ (Newman and Conrad, 1999). As Schienstock (2000) notes, ‘organisation culture influences the meanings and functions attributed to modern ICTs, while the material structures of ICTs shape the emerging organisation culture’. In the language of socio-technical systems analysis, culture and technology are co-constitutive: mutual shaping takes place.

The KM consulting literature is awash with techno centric nostrums, from intranets through knowledge bases to data warehousing and mining, but noticeably deficient in addressing the messy matter of culture. At times, the concept is almost reified, being treated as something that can be measured and manipulated with precision (Haney and Norika, 2000). In academia, the concept, although of great importance has not been given the focus it deserves.

De Long and Fahey(1998) believe that culture mediates between two kinds of knowledge – the organisational and individual, by defining the distribution between them. A culture of openness and sharing promotes knowledge diffusion within an organisation by encouraging people to share their unique, largely experiential insights gained from their years performing a particular job. Convincing an employee to contribute human knowledge to creating a structured knowledge database – say asking sales people to update their Customer Relationship Management systems - which will have common control is easy when the feeling of loss of ownership of such knowledge is not only supported by a company’s norms, but may also be critical to the ‘work of the firm’.

Culture, therefore, also performs another function in light of the above and in the context of the case being examined, in that it shapes values, norms and practices. At a very subliminal level, culture defines values, which are unspoken understandings of not only the goal, but also the methodology that

should be employed to attain it. These are extremely difficult to articulate and are far less amenable to change than norms, which put values into action and are manifested in practices. Practices are the most apparent symbols of culture in that they represent the most direct influencers of knowledge acquisition and sharing.

All throughout the Prius project, Toyota emphasised high levels of quality control, which was a key value as defined by Toyota's culture. When this value was under threat in the Matsushita EV, the company immediately took corrective action to acquire the right knowledge and bring battery quality up to acceptable levels. Understanding. Culture also defined what knowledge was important, a trigger for initially developing all technology used in the Prius in-house.

The Toyota organisational culture also played an important role in influencing the knowledge and innovation systems within the firm. The culture at Toyota is quintessentially Japanese. On the one hand, while this implies a great regard for hierarchy, adherence to organisational directives, which are viewed as coming from senior management, (who the organisation looks up to as a collection of ideals worth emulating), it also means that the stimulus for a new idea need not come from management theory. It may come from analogy and metaphor, poetry and enigma. The duality of culture necessitated Mr. Uchiyamada to lay down the 'rules of engagement' for his team. He recognised that a radical innovation of this sort would require people to shed their cultural baggage and interact as objective knowledge agents to the degree and extent possible and therefore attempted to create a culture of openness and a shared motto for the team i.e. technology above all else.

Brown (1978) believes in the existence of a duality of objective structures and subjective consciousness in Anglo-American social theory. In a perfectly rational environment, organisations would be little more than optimisation functions, with a deterministic relationship between inputs and outputs. However, in reality, they comprise of subjective actors, who do not necessarily maximise organisational utility, but personal utility. It is this dichotomy between the subjective struggle of an individual with the objective environment that makes it impossible to subject organisations to 'objective positivism' (Hayek, 1948).

Nonaka and Konno (1998) view organisations as 'intertwined collections of meaning structures' i.e. they regard the individual in his/her purest form as a collection of relationships at any given point of time. Polanyi (1952) believes that individuals 'seek to gain the essence of their surrounding reality through 'action-reflection' dialectics. Therefore, it can be assumed that knowledge creation is purely through the process of human interaction – a process that is at the same time, rational and subjective and filled with contradictions. A case in point is the concept of 'stretch'. Ethical idealists such as Rescher believe that individuals, though rational, have a desire to attain a higher goal or ideal and it is the job of the organisation and its management to bring together circumstances that are serendipitous to such striving i.e. it must create or at times bring together *ba* (Nonaka et al., 2000). Management can create *ba* through several means

a) Connecting various *ba* in series. Barabasi (2002) estimates that 20 per cent of actors hold 80 per cent of network connections. Mr. Uchiyamada in the Prius case was cognisant of this fact and was in fact picked because of his wide technical network by senior management. The appointment of Mr. Ohi to the project was also largely driven by his wide networks and personal equity within the Toyota system.

b) Activating and energising *ba* (Nonaka, the knowledge creating company). By setting radical goals such as 100% increase in fuel efficiency, Toyota leadership led the project into thinking around completely different lines i.e. they provided the context for radical innovation, thereby collapsing silos and inter-departmental (not to mention inter-personal) barriers. Re-emphasis on how important this project was to the future of the company kept the context relevant and the motivations high.

Toyota faced an 'adaptive challenge' (source). Given an unstable and unpredictable future, the corporation realised that it had to venture into it by relying on imagery rather than logical extrapolation, by appealing to the emotions within its employees, rather than their logical faculties. Thurow (1996) believes that the greater the degree of unpredictability of the future, the greater is the reliance on painting a 'desired reality' (Senge, 1990) by senior leadership. 'At the very top, creating

and driving a consistent vision of the company's or group's purpose is the primary skill that provides the glue for all its highly disaggregated units' (Quinn, 1992). In the opinion of this writer, vision is the key enabler of both the knowledge spiral and the innovation value chain and also of the interactions between them. While it influences knowledge creation and idea generation, it is also key to the process of the integration of such knowledge into the organisation.

According to Vleck and Davidson (1992), vision helps people transcend the trivia of everyday efforts by generating a tension between 'the actual performance of the organisation and the desired future expressed through a clear and unambiguous vision (Kanter et al., 1992). Hence, it is evident that one of the largest and most important functions of vision is to make employees feel larger than their 'business as usual' activities and to focus them on the tasks at hand by painting a picture of where these tasks fit in to the larger goal of the firm.

Senior management at Toyota can be considered visionary in that they undertook activities that led to the generation of an impetus for change. By specifying not only the general principles and measurement metrics under which the project would function, but also the operational guidelines for implementation of the vision, management set down the rules of engagement for the project team – both through positive and negative affirmations. The same percolated down through each successive layer of management as well ensuring that it was a 'shared vision'. In fact, it was the soundness of vision that instructed each successive layer what was asked of them (i.e. their roles) and what they could do within those roles. For example, the project team was given a free hand in executing the project, with all possible resources at their availability. They were also allowed (a luxury in the automobile world) to function independent of all existing hierarchies (both product and organisational) and constraints.

6. Conclusion

The term innovation implies the process of changing or recreating something. In today's business world it implies the creation and deployment of new products and services as well as efficiency enhancing activities such as process and organisation improvements, a starting point for which is the harvesting and harnessing of existing knowledge. The innovation that was the Toyota Prius was path-breaking in several ways:

1) It was a completely new product line and was an image-changing product for the automobile manufacturer.

2) The innovation was not limited to any one set of components, such as the chassis or the engine, but was embodied in most individual systems such as engine, motor, braking etc. and their combination into the hybrid form, thereby ensuring the development and ownership of several technologies that were later applied in other product lines.

3) The method in which the Prius project proceeded was completely new and indeed laid the foundation for a fundamentally new process. While existing projects took an average time of four years from the drawing board to dealer showrooms, the Prius was completed in fifteen months. This was further commendable given that almost all technologies used in the car were developed within the firm.

With the Prius case as a backdrop, we may conclude the following:

1. Knowledge acquisition, knowledge integration and knowledge application are three key areas in which an innovative organisation excels.

While knowledge management activities are value-additive to firms in that they enhance the innovation ecosystem of a firm, their impact on innovation is not deterministic since there are different methods of harnessing knowledge to improve efficiencies. Each of these methods depends on subjective individuals in as much as they depend on objective organisation structures for their execution. The link between innovation and knowledge management hinges around Nonaka's SECI process of conversion of tacit knowledge to explicit knowledge on the one hand, while on the other hand it is defined by the innovation value chain of the organisation i.e. the efficiency of the firm at generating, converting and diffusing ideas. It is in fact the interplay between the knowledge spiral and

the innovation value chain that define an innovative organisation. The primary goal of the innovation process is to take an idea as input and transform it from a tacit state to a product or service as an output, which must be value accretive to stakeholders in the firm, who may be customers, owners/shareholders, suppliers or even employees. While the former portion is influenced by the robustness of the knowledge management process and culture in an organisation, the latter is a function of the efficiency of the innovation value chain. Since all markets are not necessarily external to an organisation, a secondary goal of the innovation process is to generate an idea that further improves the way ideas are generated. Argyris and Schon (1978) define two levels at which organisations learn and improve routines. Single-loop learning implies rectification of an error, without the rectification of the associated policy, norm or framework. Double-loop learning occurs when both the routine is changed and the framework modified. Hence, innovative firms are efficient at both kinds of organisational learning.

Toyota was clearly proficient at double-loop learning in that the organisation created and replicated new methodology in product development almost immediately after the Prius launch and also documented experiences or what the Prius team ‘knew’ to serve as a learning tool for future teams. At a project level, both the idea generation and conversion processes were robust. Team members were encouraged to generate ideas based purely on a project goal and were also mandated to evaluate ideas thrown up by the group regardless of the seniority of people who generated them or the speciality of the generator/evaluator.

2. Organisation structures need to be targeted at promoting efficient knowledge sharing across networks.

If as per Drucker (1993), the sole aim of knowledge is to create further knowledge, then the efficacy of a knowledge management system needs to be viewed in the context of the speed with which knowledge embodied in products and services is steered from the stage of realisation to the stage of commercial exploitation i.e. the time-frame within which products are created and delivered to the market, which remains the most objective evaluator of knowledge. While noting that the idea generating capacity of a firm is constrained by structural factors such as organisational capabilities, availability of resources etc. it may be necessary to outsource the developmental elements of the innovation cycle (Ruggles and Little, 1997). Since the basic concept behind idea creation is the feedback loops between knowledge externalisation/knowledge combination and the evaluation phase of the idea conversion process and that face-to-face interaction is a primary enabler in the tacit-explicit knowledge conversion process, modern corporations create ‘research labs’ to foster innovation. “The model for such units tends to be fairly simple: bring together smart people, give them good equipment and sufficient resources and then leave them alone to create.” (Hagel and Seely Brown, 2009). However, modern geographically diversified corporates feel the need to improve their knowledge management systems and better leverage their intellectual assets. This is the genesis of what modern management literature refers to Communities of Practice or CoPs (Lave and Wenger 1991). Lave and Wenger saw knowledge creation and acquisition as a social process where people participate in group learning at different levels. Most CoPs are advanced networks that evolve over time through mutual engagement, shared interest and trust between members of the network. As Seely Brown (2004) points out, such networks reduce the “interaction cost” of new knowledge creation and dissemination.

The case study presents incontrovertible evidence of company structure being an enabler of the processes surrounding the interaction of knowledge management systems with the innovation cycle. A critical success factor for the Prius was the integration of various technologies and dependencies on the hybrid platform, which was brought about by cross-functional collaboration and diverse team constitution. As against the extant method of serial processing, in which the R&D teams submitted ‘orders’ to component development units, product development here functioned in parallel, a necessity of the complex technological asks of hybrid vehicle design. Further, instead of creating networks specifically to meet the Prius ask, Toyota initially staffed and then subsequently supplemented the project team with individuals who had the necessary personal equity and networks within the system to facilitate mutual understanding.

3. The role of culture and vision in driving efficient knowledge management cannot be underestimated.

The article views knowledge creation as a synthesis between subjective actors who follow the SECI knowledge spiral and a context in which they operate. Culture shapes norms, values and behaviours, which through routine and process act upon the various factors of production to generate output. Further, assuming that senior management needs to create an enabling system for innovation, effective vision needs to be linked to organisational structure and process in that it allows employees to operationalise the vision of the firm. Senge (1990) believes that a visionary leader “must operate at levels of patterns of change as well as events”. Vision aligns the organisation around the achievement of innovation goals and also specifies what the future goal for the innovation is. In doing so, it directs the individual’s information searching behaviour and integrates associative and goal-oriented thinking (Johanssen, 1998). The link between current mundane activities and a desired future, enables the generation of Senge’s ‘creative tension’ or the articulation of dissatisfaction with the status quo, which then spurs employees to move from current reality to desired reality.

Toyota management imbued their vision into the project team, whether by articulating the Prius project as a categorical imperative, by bringing closer the delivery deadline by a year and forcing the product team to find innovative ways to cut down development time, or by selecting the right people with the right networks and promoting interaction and direction within the organisation.

The importance of the societal cultural context is best understood through the words of Mr. Fujio Cho, then president of Toyota, who said, “It bothers me when I’m told that in the 100 years of automobile development, Japan has not contributed anything...Toyota will make every effort so that we can hear that Japan’s technology has contributed this much to the environment.” Toyota operationalised this cultural directive is by creating an organisational environment which rewarded performance, promoted information sharing and valued trust.

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