WORKING PAPER 180

Integrative Mechanisms in "Imitative" R&D Projects

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December 2001

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Abstract

A considerable number of studies have been actualized on the integrative mechanisms in new product innovation. Most of these studies have focussed on functional integration, especially R&D-marketing interfaces, as a unit of analysis. Studies have pointed out that most innovations is old science rather than new discovery. The most notable Japanese products did not involve any discontinuous innovations, but imitative and incremental innovations However, not much is known about the use and effectiveness of interfacing mechanisms in imitative projects. The research on imitation management, especially at the project-level leaves much to be desired. The aim of the study is to understand various integrative mechanisms used and the challenges faced in adopting them in different imitation environments. Using case-study methodology sixteen successfully completed imitation projects from ten different companies were investigated from the view point of integrative mechanisms used. Based on project scope (complexity) and technological uncertainty, we classify imitative product developments into four types, type I, type II, type III and type IV. Based on the categorization and clustering we identified four interface mechanisms, viz., structural integration, cross-functional team, review systems, processes, and individual integrators. Type I projects with low technological uncertainty and scope appear to rely more on individual integrators. Type II projects related to high project scope and low technological uncertainty environments seem to rely on structural integration. Cross-functional teams and review mechanisms are used whenever the project complexity is high. Scope of the project seems to define the use of particular interface mechanisms rather than the technological uncertainty. Managerial challenges in using different integrative mechanisms is discussed.

Introduction

Researchers for long have been investigating the quality of interface management impacts on the success or otherwise of the innovation process (Cooper, 1999, Wang, 1997; Brockhoff et al , 1996; Adler, 1995, Gupta & Wilemon, 1990). These studies largely concentrated on R&D/marketing interface precluding the critical role performed by the interface mechanisms in imitative projects. Klevorick et al. (1995) point out that most innovations uses all sorts of science as a tool kit, most of which is old science rather than new discovery. The most notable Japanese products did not involve any discontinuous innovations, but imitative and incremental innovations (Sanderson & Uzumeri, 1995, Cusumano, Mylonadis & Rosenbloom, 1992). Cincinnati Milacron, the machine tool manufacturer adopted competitive benchmarking for injection molding machines to successfully regain market share (Bolton, 1993). Toyota's very successful premier car Lexus was an incremental replica of Mercedes (Chatterjee, 1998). The success of many others in the marketplace based on imitation, demonstrate how they win over other products based on original innovations (Schnaars, 1994). One firm will not always pursue innovative or imitator projects only. It is expected that firms would carry out both the types of projects in their life-cycle.

In an imitative project, the technology is new to the firm, but mastered by its competitors; the project's target market is new to the firm, but is an established territory of competitors. Imitative projects may therefore exhibit high technological (task) uncertainty and project complexity. Studies have shown successful imitation projects also require good planning and execution (Kim, 1998, Wang, 1997). In particular, large and complex imitative projects such as missile development may warrant elaborate interface mechanisms. Similar to a radical product development, an imitative project therefore requires effective communication, collaboration and integration between various departments and functions. Dougherty (1992) observed that integration between the departments tends to be hampered by development of `mental models' or thought worlds', associated with individual specialization and functional silos. To solve the problem a number of interface mechanisms have been proposed, that include project leadership, planning and coordination centers, horizontal structural mechanisms, and the use of information technology (Moenaert and Souder, 1990; Hitt et al., 1993). However, not much is known about the use and effectiveness of interfacing mechanisms in imitative projects. The research on imitation management, especially at the project-level leaves much to be desired. A need exist therefore to understand organizational linkages, and processes that are used to successfully implement imitative projects, and mechanisms employed for communication, allocation and control in imitative projects. The objective of the present study is to explore the unique contributions of interface mechanisms in successfully developing `imitative products. Towards this, we analyze imitators in India, a developing economy to understand functional interfaces and their contributions to technological capability building process.

The Integrative mechanisms in imitative projects: Literature review

Product development is a multi-stage process involving: idea generation, product concept, design, development, and implementation. An imitative product development involves all these stages, but the concerns, complexity and focus are different. Unlike idea generation stage in new product development, the technological uncertainty is low. However, an imitative product design stage should consider ways to get over the intellectual property of the pioneering firm. Challenges also exist on extending the features of the incumbent product, capturing new value propositions and extend the technological capabilities. While techniques such as quality-function deployment (Hauser and Clausing, 1988) are useful to integrate the requirements, an imitative product developments has other requirements too. A firm introducing an imitative product must not only secure information on relevant marketing and technological characteristics, but has to decide what features to incorporate (Cohen & Levinthal, 1990), evaluate the cost-feature additions in comparison to the pioneer and other incumbents and how to overcome imitation barriers caused by intellectual property rights (Shapiro and Khemani, 1987; Dunne et.al., 1988). Hence, interfunctional management becomes an important element of an imitative product conception and execution.

Effective liaisons between the external environment and internal units through both structural and other mechanisms accentuate organizational learning to be responsive to the environmental changes (e.g. Allen 1986; Tushman, 1979; Ancona and Caldwell, 1990). From knowledge management view, firms introducing imitative products may need to decode some tacit information and involve some experimentation, especially if they are the early followers, as the available generic information may not be sufficient enough to facilitate early commercialization. This is required for customizing the product, incorporating additional features to meet new/emerging needs and circumvent the IPR violations. An imitator must therefore maintain a highly sophisticated information infrastructure with widespread receptors and information-acquisition efforts. Successful imitation therefore requires considerable expertise to transfer and develop a borrowed (stolen) technology or concept, often necessitating substantial R & D and related competencies to integrate the new product into existing manufacturing system. Finally, an imitating firm must also open up and ascertain adequate distribution channels, other marketing activities in establishing close customer relations (Schnaars, 1994).

It is important to recognize that not all imitative project environments are same. They vary in project objectives, size, complexity, required technical and project management support systems and processes. Some projects may exhibit moderate technological uncertainty, but low project complexity. On the other hand, some projects may involve a complex collection of interrelated elements and systems with in a single product and, modifications required to beat the intellectual property violations. Such projects not only involve high technological uncertainty, but also high project complexity. Shenhar's (1993) work on classifying projects provides a framework for understanding imitative projects. He suggests classifying the projects based on two-dimensions: project scope (complexity) and technological uncertainty. Project complexity captures number of interactive elements and the interdepartmental coordination required for successful completion of the project. Technological uncertainty attempts to capture the knowhow part for executing the projects. These dimensions reflect Perrow's (1967) task variety and task analyzability characteristics that have been used by several innovation researchers to classify projects (Tushman and Nadler, 1978; Daft and Langel, 1986). Based on Shenhar (1993), we classify imitative product developments into four types, type I, type II, type III and type IV as shown in Figure 1. Type I imitative projects have low technological uncertainty and low project complexity. Examples include development of a off patent drug, where the generic knowledge about the drug is easily available and production does not violate any intellectual property. Type II imitative projects involve a single product consisting of multiple base technologies and high-integration of the subsystems. Improved software solutions including protocol stacks, communication technology products involving multiple vendors are examples of Type II projects. These projects have high management complexity, but low technological uncertainty.

Type III projects involves, high project uncertainty, typically of a single product. For example, development of a novel drug delivery of an incumbent drug would involve screening and developing effective technological options that would not expose the imitator from legal violations. Here the marketing's continuous monitoring of the environment for developments/ advancements in the drugs becomes significant due to the investments in the formulations, even for patented drugs. Firms though reverse engineer on patented drugs, investments in them are significant. Further, in pharmaceutical environments, achieving identical molecular structure of the drug of the inventor without any contra indications is simply not easy. These drugs though not new to the world, are new to the environment. Consequently, educating the customers and the legal authorities involves high investment. Because differentiation is not achieved in the drugs either in the form of efficacy, these firms have to compete either with newer applications or on brand names and/or through packaging or the form through which the drug is presented such as contours, and size or purity. With the available technical procedures and standards, most of the pharmaceutical companies achieve the requisite purity. The only other possibility is through dosage.

Type IV projects involve multiple element technology development, one requiring high integration of the subsystems and coordination of different activities. These projects may be the most complicated and risky, but they have the highest potential to provide quantum leap in effectiveness and enormous advantages for the organization. Examples include developments of new missile and communication systems such as radar. The projects exhibit what Emmanuelides (1993) terms as `internal uncertainty', stemming from non-routine nature of R & D and high-levels of technological and organizational interdependencies involved in their execution.

Successful imitation requires collaboration of several expertise that has to be integrated as a product. Several integration mechanisms can be used to attain this. Daft and Langel (1986), based on information processing perspective, argue that formal rules and regulations capable of handling large amount of information are effective in reducing uncertainty. Group meetings and integrator roles are effective in reducing level of ambiguity and confusion concerning the nature of activities. Further, they argue that planning mechanisms such as review systems assist in reduction of uncertainty and therefore should be useful in type III and IV projects. Although some researchers have examined the interface mechanisms used, and uncertainty management in innovative projects (e.g., Sicotte and Langley, 2000; Gales et.al, 1992), to our knowledge, this is the first study to evaluate the interface mechanisms in imitative projects. Studies analyzing the effectiveness of particular integrative mechanisms for uncertain imitative projects are required.

Methodology

The case approach is most deemed for this research problem, in that richly detailed information is likely to be obtained. This method allows for comparison across other research that examines the interface mechanisms used. We adopted an inductive approach for this study. Induction is a recommended approach wherever the understanding of the phenomenon is rather rudimentary. In this approach, inferences are drawn from the empirical evidences in the form of conclusions that explain the evidence. Induction may also explain facts other than those observed as evidences, therefore help in theorizing about the unobservable. The sites were generated based on several different characteristics, as recommended by Eisenhardt (1989). The case firms were from different product and market environments. We approached firms that were known to have implemented imitative R & D products during 1990-1995 and that had Department of Science & Technology (DST), Government of India recognized R & D laboratories and had won awards and recognition from the DST, for their contributions emanating from their respective R&D centers. The chosen firms operate in industries such as pharmaceuticals, metallurgical, machine tool, heavy electrical and chemical industry.

These firms are considered as highly competitive in their industries and some are held in the industry as market and technology leaders. For these firms, conducting R&D internally continues to be an important source for technical expertise. Because these firms pursued strategies such as outsourcing of R&D capabilities through licenses, joint ventures and alliances until 1991 – the pre-liberalized era. Among the sample, some of the firms had obtained ISO certification for their R&D units. The aim was to systematize the process of conducting R&D for realizing innovations in products and processes, resulting in better revenues. Although the specific basis is confidential, total annual sales of the firms at the time of data collection ranged from US$ 70,000 through $1250 million.

Data

The unit of analysis for this study was an imitative product project. This is because a project enshrines a set of processes and activities directed towards a common goal and it is therefore easier to capture the mechanism used and the underlying dynamics at several stages. Projects are also areas for conflict between the need for innovation and retention of the existing state. For example, development of an imitative product may disrupt existing manufacturing layout, schedules, and capacities.

The data for this study was collected by employing multiple methods that included interview schedules, questionnaire, and analysis of archival records available in various departments of each organization. Secondary sources such as newspaper and journal publications were also referred wherever available. The archival records served as a rich source for data concerning the project initiation, investments, configuration changes, linkages brought at several stages and the product performance. Wherever possible, project design reviews and related documents were referred. However, in most cases the reviews were more for official purposes only, lacking descriptions of the exact happenings. Hence, it was necessary to solicit information from important executives who had played important roles in the technology development projects.

The data was collected from CEO, all the functional heads, project leaders and project members in each of the organization. Primarily, interviews were conducted by employing a semi-structured interview schedule. The interviews conducted by the first author averaged about one-hour with each subject. At least four senior executives from various disciplines were interviewed individually to get multiple views and to reduce personal bias. Whenever a substantial difference in the response occurred, the process was repeated but in a group. This variety and breadth is believed to be sufficient for exploratory purposes, thus allowing exploration of the different integration mechanisms to be grounded in the data.

The cases were analyzed using pattern matching and explanation building, as suggested by Yin (1989). We used checklists, and event listings applied within and across the cases as suggested by Miles and Huberman (1984). In order to create a 'categorization and theme' without imposing an interpretation of the events the following strategy was adopted. Four independent experts (two each from industry and academia), each of whom was well acquainted with qualitative techniques and possessed doctoral-level training in management, met together at numerous coding sessions to identify the variety of integration mechanisms used. The second step was to narrow down the list but still capture qualitatively different mechanisms. Similar approaches were clustered to minimize classification error. The following section presents details of the organizations studied, the cases and the interface mechanisms observed in our sample.

Results and discussion

This section provides the findings, beginning with a summary of the firm characteristics. The fieldwork consisted of case studies in ten companies. In all cases, the projects have been successfully completed and implementation has been in force. The firms are major players in their segments with average market shares of 30 percent. Table 1, provides the summary characteristics of the sixteen projects studied. The case-projects used a portfolio of interface mechanisms. Based on the categorization and clustering we identified four interface mechanisms, viz., structural integration, cross-functional team, review systems, processes, and individual integrators. We describe each of the mechanism, and how they are implemented in the following paragraphs.

Structural integration was achieved through functional differentiated units integrated through formal process for product concept review, assessment of design for manufacturing and assembly, and logistical considerations. Structural mechanisms ranged from temporary assignments (loaning of a technical expert to another group) and functional authority in a matrix type of functional arrangement. Towards this, each of the units acts as an independent organization with its own internal structure and interfacing structures were defined for design and implementation purposes. These mechanisms by improving the amount and quality of information enable quicker information and resource transfer (Larsen and Gobelli, 1988). We present an example of a firm that had adopted structural mechanism for imitative project.

The Steel Company of India (hereinafter, SCI), one of the top ten steel producers in the World, in 1987 faced competitive threats from large importers. The competition was supplying generic steel to the auto majors which would serve several applications (automotive body and other components) and could meet, and perhaps surpass the quality requirements of the auto companies. SCI which had a long term contract with several of the auto manufacturers found its products rejected on quality and related parameters.

SCI had its manufacturing and marketing offices spread across the country. The marketing group, constituting several end-use groups sets its own targets and sales figures. The R&D with *over 15 divisions is located centrally as the corporate industrial R&D, but physically separated much away from the manufacturing plants. The steel manufacturing plants distributed across nine different locations with each plant focusing on products segments such as automobile sector, power sector, construction sector etc. The three functional units are however, well integrated structurally and through corporate vision. For example, the liaison between the R&D, marketing and manufacturing is fittingly structured through the Application Engineers (AEs). The R&D set-ups at each of the manufacturing locations reinforce the coordination. More important are the norms that strengthen the bond - one, every scientist of the R&D should spend 100 working days in the steel plants; two, the AEs of the R&D and the CMO along with the plant engineers should arrive at action points by concurrence to work effectively every year. In this, the AEs of the R&D have experience in marketing and as well in manufacturing. Further is the committee on product development, constituting specialists from manufacturing, R&D and CMO. This committee meets usually, twice in a month to discuss the status of the product development activities, strengthening the bond. In fact, the creative abrasion, the principle of intentionally combining people with different skills, values, ideas and knowledge to generate creative solutions (Dorothy and Sensiper, 1998), seems to occur so naturally in SCI.*

Formal cross-functional teams, is yet another structural mechanism that has been extensively used by firms, especially when the product development had significant technological complexity. Adler (1995) argues that cross-functional teams are optimal for high novelty projects, but less effective for routine ones. Several studies have reported the value of cross-functional teams, especially R&D, marketing and manufacturing functions. We found the cross-functional teams employed by Indian Pharmaceutical firms offering new insights into imitation projects and cross-functional integration. The non-availability of product patent legislation in India till recently, encouraged Indian pharmaceutical firms including MNCs in India to conduct R&D (reverse engineering) on the drugs available in the market. These firms tweak the drug formulations and eventually produce the drugs and sell it in a brand name. Product changes, especially for the new generation drugs, have been prompted by the drug price control mechanism. Firms modify their formulation – say change an ingredient, thus bring the product outside the gambits of the drug controller and earn better revenues. The major goal for some of the Indian firms is to improve the drug delivery system and find many new applications for the drugs that are to go off patent soon. The improvement strategies involve drug delivery systems and expansion to multi-media. The emphasis in drug delivery systems is in improving the effectiveness of an existing drug (say in terms of dosage, length of treatment, bio-degradability). Many Indian pharmaceutical firms, with a proven track in reverse engineering of a patented drug, see this strategy as risk-free strategy. Drug delivery improvements do not impinge the product patents and the cost of stage I and II trials for an improved drug cost almost 1/10 of a new drug. Importantly, an improved version of an existing drug also assures reasonable market success, unlike a new molecule. Multimedia applications refer to leveraging product know how in a particular form to another. Application from a tablet to injectibles or vice versa, and shift from ointment to lotion are the examples of multi-media strategies.

The cross-functional team of the Pharmaceutical firm studied searched for legal and technological limits, identified opportunities and designed new products. The firm had a production or implementation team that carried out the manufacturing and delivery activities of the imitative projects. The core team prepared product blueprints, evaluated customer responses and developed products without any violation of intellectual property rights. Often, the teams selected a product for its weak legal defense, such a product getting out of patent term, or product improvements that could grant them design or utility model rights. Given below is an example of a firm that had adopted a cross-functional team.

Priya Pharma came into existence during the year 1970. Over the years it has grown to a size exceeding US$ 100 million, with recent acquisitions in US (Accumed Inc), Britain (Wallis Labs) and with manufacturing plant set-ups in China, Eastern Europe and Kenya. It constitutes five divisions such as, mother and childcare division, super specialty division, pharma, veterinary and hospitals. Pelox is the first large-scale innovation for Priya pharma. The marketing unit of Priya pharma based on field observations found that the doctors were in need of the drug in the injection form for faster remedies. A cross-functional team was formed which identified the process and product details that would not impinge on the existing patents. Trail samples were sent to doctors and to the surprise of Priya pharma, the reception for the drug was not very encouraging. The doctors were experiencing difficulties in using the injection because the dosage of the injection is 5 mg, which has to be cut and added to 100 ml of Dextrose. In India, dextrose is available in 500-ml pack and when it is diluted in 500 ml the effect is lost. The doctors, in order to avoid wastage, had to wait until 400 ml of solution is first used to mix the injection. The problem with the drug was that it could not be mixed with normal saline. Because, the mixture turns to sodium chloride then it hastens. By mistake, if somebody introduces this injection in normal saline, it could lead to unnecessary complications. The core team of R&D, manufacturing and marketing brainstormed over the issue and identified an escape route would be to develop a premixed composite in injectible form. Inputs of legal experts revealed combination drugs could get approval as a process patent. The core team identified Ciprofloxicin and Dextrose combination for 100-ml bottles. It took two years for the core team to design, stabilize and get the product approved by the drug controller of India. Once approved the drug was transferred to the production group.

The third type of integrative mechanism observed was related to review systems and processes. The firms used formal configuration control and design review processes and had substantial involvement of external experts for product review, and milestone reviews. Product design review was a formal process with each different platform or product groups making their resource and idea presentation. Group of senior managers from each functional unit was ordained as the project leader and was asked to choose the technical supports from the units. Once the teams were formed, a preliminary design review was conducted more in the form of brainstorming, identifying business opportunities and legal threats. Customer and procurement considerations were discussed and the product concept was thoroughly reviewed. Each project leader reported the developments through formal project completion and resource analysis. Periodic reviews were done based for both major and minor milestones. A support group directly reporting to the CEO coordinated the reviews and the review documents were circulated for information and action. Formal configuration control board consisting of design, manufacturing and marketing chiefs reviewed deviations and alterations. The following case presents the use of review process for an imitative product.

The Power Equipment Company (PEC) is one of the successful public-sector undertakings in India, employing over 63, 000 employees at fourteen different locations in the country. PEC *manufactures 180 products and the sale amounts to $ 1.5 billion. The product management system in PEC was initiated as early as 1975. As a part of the system, two committees, product and technical committees were formed. In the product committee, some members play the role of gatekeepers, monitoring the environment globally for knowledge spillovers and advancements. These members serving as a source of areas to concentrate for the R&D, identified fuel cell technologies as the project, which could be a forerunner to programs for development of megawatt-level power plants based on fuel cells. Towards this, the product management system established a* ***ba*** *(Nonaka and Takeuchi, 1995) which included members from the two manufacturing plants, R&D, marketing, corporate planning and corporate engineering. Thus, it was essentially a wide based cross-functional committee that started engaging in-group brainstorming. The fuel cell technology project had a manager, as the policy of PEC was to have a manager for each product in all its units. The product manager was responsible for the overall growth of that product: the turnover, the engineering aspects and subsequently incorporating new features in the product. The technical committee which includes R&D engineers evaluated the project and approved the fuel cell technology project. The product committee and the technical committee first discussed with the manufacturing plant managers before proposing the idea along with the possibilities in marketing to the general manager of the R&D for approval.*

In the project initiation phase, a document namely, Project Initiation Report (PIR) was prepared as per the norm by the members of the product committee with directions from the members of the technical committee. Thus, the technical committee was actually a support committee to prodict committee. The PIR was then sent to the chairmen of Technical and Product Committee. The chairmen, who are typically the senior managers, reviewed the consistency of the report in terms of the immediate plant needs and organisational goals. Subsequently, the chairmen sent the PIR to the Planning Department, wherein the head of the divisions conducted the feasibility analysis in-detail. Finally, the project was taken for approval to the R&D Chief and later to the Corporate Office, i.e., the Director's Office. Here the Central Corporate Engineering analyzed and provided recommendations in terms of its potential outcomes to the director. The PIR was then cross-signed by the Director Finance. The total approval process thus was very long, consuming as much as four months. Nevertheless, the scientists in the R&D agreed that this process had resulted in a robust screening system during the project initiation phase.

In reviewing the projects, the system was that the R&D Director would go to different units to review the R&D projects. R&D was conducted not only in the Corporate R&D Center but also in the plant units to ensure a close co-ordination between the plants and the R&D. Whenever a project was undertaken, a comprehensive report on that particular project was formulated to identify the unknown areas and the procedures to tackle them. In this, preferably well-established modules, already available, were used. However, for the fuel cell technology project, certain modules had to be developed, for which members representing areas of chemical, electrical, and electronics were identified and a multi-disciplinary group was formed. This multi-disciplinary group was asked to take up the development of modules. Regularly, this group met: once in a fortnight to review the progress, and to devise plans to interface with the other groups. One person was identified as a project leader, to perform the review every 15 days. Since every 15 days the review was conducted, a lot of interface developed. Howbeit, all the group members from all the departments were present to discuss *the progress of the project. The general manager of the manufacturing plant conducted the review once a month. The respective departmental heads discussed every month. The unit heads discussed once in two months.*

The technology group that was established primarily to fill the technology gaps developed a quality plan, which contributed significantly to the success of the project. The quality plan was drawn with the help of all the participating groups in addition to the quality control and quality assurance groups. This system lead to the production of the desired parts and having checks as per the quality assurance plan. Thus, this system ensured that the deviation is brought close to the accepted plan. At all these stages, a constant discussion with the customer representative was held at the plant, which is normally represented by a five-member team. The clients visited quite regularly and continued their comments. These procedures let to the successful development of 2 kW phosphoric acid fuel cell module. This product has undergone several long duration operational trials, setting a foundation for megawatt-level power plants based on fuel cells.

The fourth type of mechanism was the use of individual integrators. Firms formally assigned individuals as integrators, recognizing the technical and managerial skills the individual possessed. In our sample, this strategy was used for large interrelated projects involving integration across several units, such as missile development. Presented below is an example of an imitative product development wherein individual integrator was used.

During the early 1992, failure of engine connecting rods in operations was a concern for the automobile major M & M. The engineering division was asked to analyze the structural and morphological properties. This was a major concern because of customer dissatisfaction and high warranty cost associated with it. Literature review showed that the failures took place due to tensile stresses on the connecting rod, which can be eliminated by inducing `counter' compressive stresses within the connecting rod. The induction of compressive stresses can be done by `shot-peering' operation on the connecting rods. Shot pining is a process that is very similar to shot blasting, wherein small steel balls are stroked on the job at a very high speed in a shot blasting. The functional differentiation between the two processes is that shot blasting is done for removal of excess material remaining on fayed components leading to better finish and to a certain extent removal of residual stresses developed during forging. Shot pining on the other hand is done to deliberately introduce compressive stresses within the part. Shot peering however is a more controlled process wherein the balls size, angle of impingement, velocity of shots and timing of shot peering are to be strictly controlled. Any deviation from set values for above parameters could result in premature failures. The two major American companies that have perfected the technology quoted very high price for technology transfer and given the local demand the prices according to M & M were exorbitant. In addition, no other firm in the Indian automobile sector had any knowledge of pining, although some vendors had attempted pining of leaf springs. M&M entrusted the design and development of the product to a technocrat, who approached Indian Institute of Technology-Mumbai mechanical engineering division for technical support. The contact was facilitated because some of the R & D engineers were from IIT-B themselves. This provided an easy rapport with the faculty and the engineers who were familiar with the systems of the institute, and could access their entire requirement without much difficulty. Based on the technical information received, M & M engineers screened a couple of *their vendors who had the technical capability to absorb this technology. Many of the suppliers were not convinced about the benefits one would gain from shot peering. M & M collected the investment information from Bharat Forge concerning the process.*

The cost estimates were quite discouraging and getting a sanction for this project without confirming the benefits it would accrue was highly impossible. Hence, M & M got four connecting rods shot peered from M/s Bharat Forge and checked it against shot blasted connecting rods for compressive stresses on a x-ray diffraction on the machine available at College of Engineering, Pune. The shot-peered connecting rods showed four times the compressive stresses than those, on a shot blasted part. The findings were in line with those mentioned in the technical papers. Nevertheless, to take a second opinion, these parts were sent to their consultants in Austria who certified that the load to failure was higher in shot peered parts. Based on the test results, M & M introduced shot peering on connecting rods and the annual expected benefits from this process is about 19 lakhs in terms of replacement costs alone.

The cases were classified into the four groups as elucidated earlier and the interface mechanism used was observed for each case. Table 2 presents the project types and the interface mechanism observed. Type I projects with low technological uncertainty and scope appear to rely more on individual integrators. Type II projects related to high project scope and low technological uncertainty environments seem to rely on structural integration. Cross-functional teams and review mechanisms are used whenever the project complexity is high. Scope of the project seems to define the use of particular interface mechanisms rather than the technological uncertainty. The reader should bear in mind, this observation is based on a small group sample, and generalization requires large group observations.

Managerial Challenges in using different Interface Mechanisms

The integration mechanisms identified had some limitations. Some were costly to implement and/or required large organizational support in term of planning, structural support, documentation and review. Discussions with the senior managers of the organization revealed some of the disadvantages for each of the interfaces, as summarized below.

Cross-Functional Team

Cross-functional teams overlay traditional functional groups. They are intended to provide high level of face-to-face contact, mutual adjustment and horizontal communication (Hitt et al., 1993). However, it did pose some problems to the organizations studied. Developing and sustaining a cross-functional team can be time-consuming and costly. Often, managers face problems of dual lines of authority, and ambiguity of responsibilities. The chemicals manufacturing plant in our sample for the development of a copycat adhesive invested about four person-months to develop and hold a cross-functional group. It faced rough weather when it came to reporting and incentives. Scientists on loans from R & D group to application group faced conflict of interest between senior managers from the two functional units. A similar tale was observed in an integration agency that was developing high-end navigation systems. The firm formed a cross-functional team involving members from several organizations. However, coordination and control of the project was a major challenge, especially with respect to information exchange on design changes and schedules and initial allocation of priorities of various milestones. Adding to the managerial complexity is the agency cost: costs of monitoring, and bonding. Monitoring refers to ensuring a project team undertakes activities without deviating from norms. Bonding costs are associated with continued participation of the employee until the completion of the stages/project, therefore associated with learning and attrition. In addition, the distributed nature of the project across many units affects the priority and opportunism (self-interest seeking with guile). Opportunism in complex projects could be multifold: project managers of a sub-system may compromise on the specifications to ensure local optimization, which may affect global optimization & integration at later stage. A major problem faced by these projects is with respect to system integration.

Firms had developed some innovative solutions to counter these. In the case of the heavy machinery firm, *if a particular scientist is required for two different technological activities coming under different PMs or Program Directors, the rule of Common cause shall be evoked. For example, within a project if Scientist X is required for two different activities under project managers # A and B, the allocation shall be based on priority. The priorities shall be based on slack available for each of the project activities, and their risk exposures. The Program Director shall facilitate effective allocation of the scientific resources amongst different modules. Scientists who are loaned from a Work Center or other lab during various stages shall report to the concerned Project Director and this clause shall be explicitly stated in the MoU. Further, if a Scientist has been loaned to a group for project information processing purposes the scientist would report to the concerned project manager. Towards assessing the contributions of the employee, a 180-degree of performance evaluation system was in force.*

Individual Integrators

Individual integrators with authority and personal credibility are effective in imitative projects with high technological scope and low technical uncertainty. Individual integrators in such situations act as single contact mechanism reducing the lead-times and decision-decay that happens in case of multiple-intermediaries. Individual integrators motivate team members to work together, resolve the differences and act as a power bridge between the project teams and senior management (Brown and Eisenhardt, 1995). Pillai & Rao (2000) show how effectively integrators employed for the development of missiles in India. Certain cultures may also favor individual integrators. According to Hofstede (1980), certain societies allow people possess unequal physical and intellectual capabilities. India, France and Japan are supposed to favor this behavior. In our case analysis, we observed that the individual integrators through their persuasive powers and willingness to commit to the project, they assist in creating convergence and enthusiasm around common goals.

Most managers felt the individual integrator becomes largely personalized approach to new product development unless systems and processes are brought in tandem. A senior manager from the industrial valve-manufacturing firm said…integrator *had several years of production experience. It was quite easy for him to establish communication across different functional units. It made a lot of difference to the projects. However, as a manager, he relied less on systems and processes. Once he left for another assignment, our applied R & D suffered, because* *we had become too personalized in our approach. It took quite an effort for us to bring some processes and systems into the place.* The other drawback of individual integrators from the project management perspective is that the individual integrators emerging as power centers, sometimes extending the development phases for personal interest.

Planning and review systems

Empirical studies have shown project planning and process management is effective integration mechanisms contributing to improved project performance (Zirger and Maidique, 1990). Daft and Lengel (1986) suggest that planning and process management is most useful under conditions of high uncertainty and eqivocality. The review system, which is formal, albeit time consuming, and to an extent harnessing bureaucracy, brings in multi-functional expertise together resulting in effective project outcomes. Most respondents felt that prior experience of the team in planning and review systems impacted the outcome of the project, especially in the case of Type IV projects where the data were at best estimates. An ability to work with estimates and corrective measures was crucial for the success of the project planning review systems. Another drawback is that it brings in bureaucracy. The organizations had a project management group to support project information processing and monitoring. The major responsibilities of the group were: maintaining the centralized database of requests, activities and schedules, monitoring progress and reporting milestones, and updating schedules.

The system design, especially specification management is a major determinant of success for a complex project. In this context the sample organizations had a formal design review on receipt of qualification requirements (QR) from the user. The system group consisting of cross-functional experts identified the need, and stated the product architecture options. Typically, the broad architecture were described and the system (sub-system) requirements were defined by the technology specialists in accordance with operational concepts and requirement specifications to be generated. Acceptability, ease of implementation, and testability were the criterion guiding the sub-system plans. Formal reviews to be carried out on suggested input/outputs, controls and testing procedures by selected moderators. These moderators were technical experts who are not involved in system design. They were to approve only if all design issues were satisfied or the risk associated with an issue, has been mitigated. Risk profiles and expenditure statements to be attached to the approved base line design (CDR). In all the firms interviewed, the design process was intense and with clear deadlines. In all the organizations studied, specification development and control were very formal process. Project Managers could not make any changes in the base line design without the formal approval of the Configuration Control Board.

Structural elements

The structural elements are costly and ineffective for fast changing technologies. In one of the failed project we studied, the firm had adopted a structural approach to product development. The product technology under development required specialists from several disciplines and needed extension of knowledge base in certain areas. During the project execution the firm had to face unpredictable changes such user requirements and design specifications. Insufficient information on locations of partners and their capability also had an impact on the pace of design and development. Moreover, coordination and control of the project was a major challenge, especially with respect to information exchange on design changes and schedules and initial allocation of priorities of various milestones Complete reliance on the structural arrangement did not alleviate motivational problems especially where successes are few and occur at late stages of the project. Therefore, we believe the structure proposed should be amenable to multiple types of coordination (both horizontal and vertical): informal interactions for specific problem solving; and a formal interaction connecting wide network of operating units.

The organizational support systems though are similar across project environments; differences in interface management do exist. For instance, in the pharma project environment a sequential approach is seen that is in the form of compartmentalization of activities for product development. Later stage there is a cross-functional team approach. Here one individual is dedicated to one project only, at every point of time. In the metallurgical industry, a one-function approach is adopted. The R&D, however, do not interact much with the direct customer in the pharmaceutical industry, as is the case with other industries. Likewise new product developments, imitative products also involve three stages: conceptualization, development and commercialization. Interface management also appeared to be different across the product development stages. In conceptualization stage, the interface was more between marketing and R & D, and the focal issue was dominantly on tangibles. In development phase, the interface included manufacturing and the salient issues were largely tangibles (product features such as quality, reliability, efficiency) with little emphasis on intangibles (delivery schedules). At the commercialization stage, the interface was primarily between marketing and manufacturing with little inputs from R & D per se. The focal issues were largely on intangibles and little on tangibles since the customers at this stage were already familiar with the product. None of the firms studied were using formal manufacturing sign-off process. One of the executives commented that `we prefer informal process for managing design to development conversion'.

CONCLUSIONS

This research involved an empirical examination of the interface mechanisms used in imitation projects in the context of developing countries. Our study makes several important contributions to the literature on interface management in general and mechanisms for imitation projects in particular. First, Our study on imitation product environments indicates individual integrators, cross functional teams, structural integration and process and review mechanisms are critical for tight inter-functional coupling. Nihtila (1999) found that integration mechanisms in new product project environments are enhanced through four mechanisms: standards, procedures and plans; milestone and design review practice; individual integrators; and cross-functional teams. Thus, for both radical and imitative products, the systems which are required for conceiving, developing, and commercializing appears to be not much different. Further, in all our cases, the innovations were driven by the market demands/needs. Consequently, even for these market-pull products the efforts of marketing to scan the market environment continuously, coordinate with R&D, and manufacturing is quite high. Thus, pioneer or follower, technology or market-pull, a tight inter-functional coupling for achieving market success is warranted. The integration mechanisms studied in the ten companies yielded insights to the complexity of interface mechanisms used and the challenges faced by the organizations implementing these for imitation projects. By doing this, it is hoped to contribute to understanding of how integrations is realized in me-too or imitation projects.

Second, the results indicate that different project environments rely on different interface mechanisms. Despite a network of intertwined mechanisms, it appears that scope of the project seems to define the use of particular interface mechanisms rather than the technological uncertainty. Type II I and Type IV projects seem to rely more on cross-functional team and review systems as interface mechanisms to direct and control resources over the project life-cycle. Future research is required to verify the linkages between project scope, technological uncertainty and a particular interface mechanism.

The limitation of the study emanates from the research design adopted. Case studies describe history and retrospective in nature. Survey based research and longitudinal analysis could reveal variations in the use of interface mechanisms holding for the evolution of the project management capability of the firm. This would allow for greater breadth of data and predictions of the project interface mechanisms. Lack of a control group and selection of only successful projects is the other limitation of the study. The decision to study successful projects was made to ensure a rich description of experiences but also considerations of access to data.

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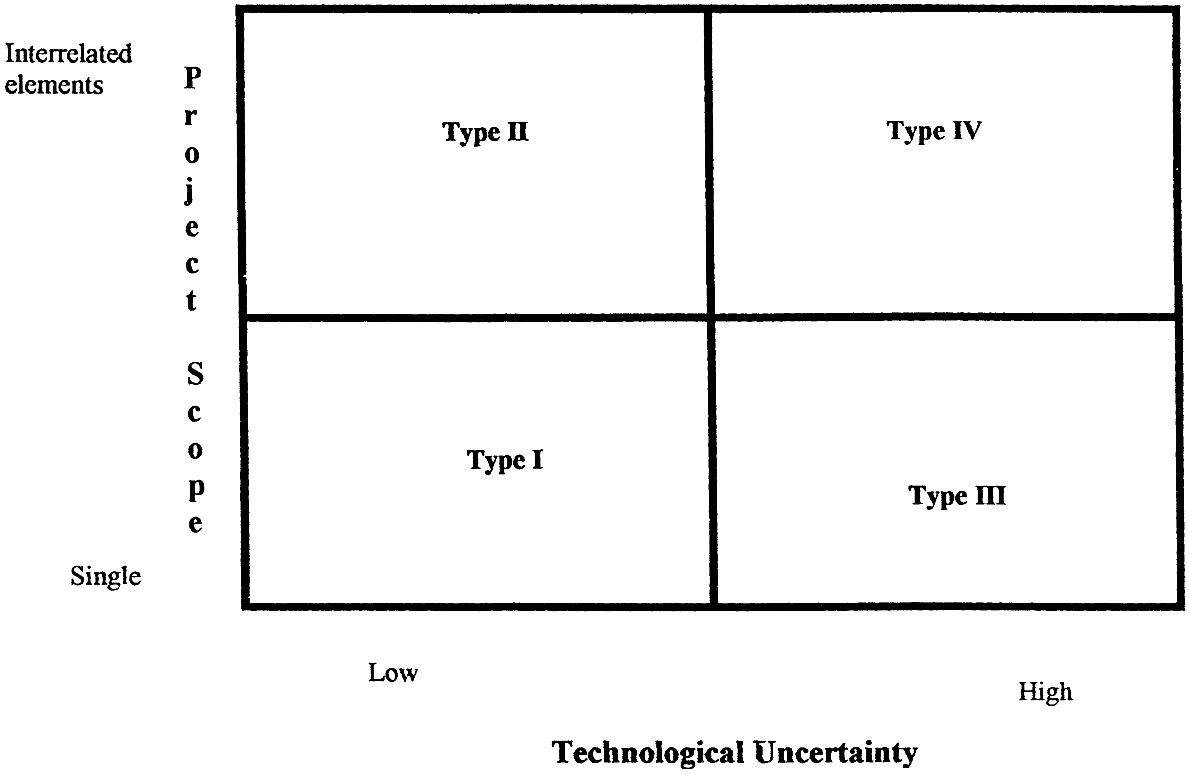
Interrelated elements
Project Scope
Single
Type II
Type IV
Type I
Type III
Low
High
Technological Uncertainty

Table 1: Details of the Case-projects

Company	Characteristics	Description
1 Projects A & B	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Pharmaceutical company with 15,000 employees Project 1: New Drug delivery system t. Project 2: alternate delivery mechanism Small (9-17) cross-functional team A- 5 and B-2 A- 38,000 and B-14000
2	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Heavy Machinery manufacturer with 34,000 employees Project 1: Coal Hauler, Project 2: Dozer 320 HP Structural Integrated application team of 12 12 months, and 6 months 7000 and 5000
3	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Power equipment manufacturer with 12,000 employees Heavy electrical machinery – Project A & B Team of 8 engineers, cross-functional 13 Months and 9 months 19000 and 9000
4	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Automotive equipment manufacturer Connecting rod Team of 6 engineers, Individual integrators 11 months 10, 000
5	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Industrial valves manufacturer with 500 employees High-pressure reverse flow valve 15 Application engineers, Individual integrator 9 Months 15,000
6	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Automotive manufacturer with 8000 employees Environmental friendly scooter Team of 12 engineers, Cross-functional team 8 Months 20,000
7	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Chemical and Pesticides firm with 3000 employees Project 1: epoxy-adhesive, Project 2: New compound Engineering team of 6 7 Months and 5 Months 11000 and 6000
8	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Drugs and Pharmaceuticals with 2000 employees Project 1: New molecule. Project 2: Novel drug delivery systems Cross-functional team of 20 19 Months and 7 Months 30,000 and 6000
9	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Electronics instrument manufacturer with 600 employees Project 1: Precipitate analyzer, Project 2: robotic arm Team of 25 engineers 23 months and 11 months 30,000 and 12,000
10	Business Type of product Project Team Project Duration (month) Cost in thousand (US$)	Heavy Electrical Machinery Transformer Application engineering cross-functional team of 20 20 Months 14,000

Table 2: Use of Integrative mechanism by project type

	Type of Project			
	Type I	Type II	Type III	Type IV
Total Projects	5	4	3	4
Type of mechanism				
Individual Integrators	80%			
Cross-functional team	20%	25%	67%	
Structural Integration		50%	33%	25%
Process &review systems		25%		75%