Implementing University-Industry Joint Product Innovation Projects

By

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Biographical Sketch

Ganesh N. Prabhu is faculty in the Corporate Strategy and Policy area at the Indian Institute of Management at Bangalore where he teaches two doctoral level courses and a masters level course in strategic management as well as a masters level course in product design and development. He has a doctorate in business policy (1996) from the Indian Institute of Management at Ahmedabad and masters in rural management (1989) from the Institute of Rural Management at Anand, India. His current research interests are management of research collaborations and product development. He has published several papers in reputed journals including *International Journal of Technology Management, Technology Analysis and Strategic Management, Greener Management International* and *Asian Case Research Journal* and has contributed several articles to business newspapers and refereed books. He has presented papers in reputed international conferences and is a frequent referee for the *International Business Review*. Ganesh has two years of industrial experience in a major turnaround assignment and several short project assignments with the Indian National Dairy Development Board and has been on deputations or on projects with fifteen organizations.

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Abstract

I propose a grounded process model of product innovation projects that are initiated by industrial firms and implemented jointly with not-for-profit technology institutions such as technological universities and government research laboratories. The proposed model is limited to those joint product development projects between collaborators with complementary expertise, that are of strategic importance to both collaborators and involve the joint creation of new technology or significant improvement over present technology. The model contributes significantly to the literature on collaborative product development by depicting in detail the essential linkage *of antecedent conditions and motivations for the joint project initiation, to the* actual *project implementation process in which the two collaborators contribute complementary resources, and further to the project's expected consequences. The process model has been developed by synthesizing in-depth case studies of such university-industry joint product innovation projects, and aids understanding of effective processes for their initiation and implementation.*

Implementing University-Industry Joint Product Innovation Projects

Introduction

Technological collaboration between organizations for product innovation, is a topic of considerable interest and study in recent years. This interest has partially emerged from the recent increase in collaborative technology arrangements that have arisen between firms. Roberts [13] found that half of major US firms expected to increase their participation in joint ventures and alliances primarily for technology and over sixty percent of Japanese firms expected to be highly dependent on external technology sources. The same is true of Australian firms, where half of industrial research and development (R&D) investments are made in external organizations [15]. Bailetti and Callahan [2] found that technology based firms are increasingly using collaborative arrangements, for direct access to new technologies. This phenomenon is even more prominent in industries where new product development imperatives are high. For example, Bower [4] found that over a period of ten years the proportion of R&D projects sourced elsewhere by major American and European drug companies went up from four percent to twenty-nine percent.

According to Bailetti and Callahan [2], some factors which drive technology based firms to use collaboration for product innovation are: (a) significant technological discontinuities, (b) the convergence of technology and markets, (c) the rise of technological standards which significantly affect product markets, and (d) the scale increases required in R&D for global markets. Studies on technological collaborations for product innovation have however concentrated more on firm to firm collaborations, than the more synergistic university to firm collaborations. Alter and Hage [1] state that "there are no studies of problem solving in collective research involving multiple business firms and universities" [1, p.98].

Technology based firms that realize that they lack the technological knowledge and resources to develop certain new products on their own, can develop them by tapping on the complementary knowledge and resources of technological universities and other not-for-profit technological institutions[1] (TIs) through joint product development projects [3]. Some of these

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1 Technology institutions for the purpose of this research are independent, autonomous not-for-profit institutions involved in technological R&D including government laboratories, technological universities, technology education institutes, industry association laboratories and research foundations.

joint product development projects may involve the mere transfer and minor adaptation of existing technology available with the TI, to the firm's new product requirements. Others may involve the TI in the development of customized new applications of a known technology to the firm's specific product requirements. Still others may involve 'vertical' collaboration [9], in which the TI is contracted by the firm to independently conduct only upstream research and the firm follows up with independently conducting only downstream research on the upstream research output of the TI. However the focus in this article is not on such joint product development projects. I focus exclusively on those joint product development projects that involve collaborators with complementary expertise, are of strategic importance[2] to both collaborators, and require the simultaneous development of new technology or significant improvement on existing technology that eventually extends the technological horizon and knowledge base of both the collaborators. Such joint product development projects are usually more synergistic from the viewpoint of both collaborators. They arise when the firm approaches the TI with a proposal for a joint product development project (and the TI accepts it), that involves the joint creation of new technology or significant improvement over present technology, and also requires the use of their complementary knowledge, skills and equipment. This article is based exclusively on this type of TI-firm joint product development projects that I descriptively term as *joint product innovation* projects.

In general, previous research has concentrated primarily on identifying the antecedent conditions for initiating technology collaboration activities and on identifying their perceived or actual consequences. Bailetti and Callahan [2] assert that the focus of these technology collaboration studies "has been on the strategy and the reasons for entering a collaboration rather than its management" [2, p. 131]. Therefore, there is lack of adequate empirical research that gives insights into the important *process* of implementing and managing such technology collaboration activities once they are initiated. Also there is no clear linkage between the identified antecedent conditions, the process of managing the technology collaboration, and its identified consequences. In this article I propose a grounded model of the process of initiation and management of one type of TI-firm technology collaborative activity that I label as *joint product innovation* projects. The model contributes significantly to the technology collaboration literature by depicting in detail the essential linkage of antecedent conditions and motivations

2 Strategic importance – the joint product development project is linked to the strategy of the firm and used as a medium for achieving that strategy.

for the joint project initiation, to the actual project implementation process in which the two collaborators contribute complementary knowledge and resources to the joint project, and further to their expected consequences. It traces the web of inter-linked project processes and indicates their anticipated impacts on firm and TI activities. The process model has been developed by synthesizing in-depth case studies of such *joint product innovation* projects, and aids understanding of the effective processes required for initiating and implementing them.

Methodology

Given the lack of earlier process research on TI-firm *joint product innovation* projects, it was necessary to conduct a process study, using qualitative research methodology, to gather process data for developing the process model. Grounded [8] case research [16] is considered an appropriate [1, 11, 12, 17] and valid [14] approach for studying process issues. The longitudinal processual method of case research [5] was adopted to develop multiple qualitative process case studies on TI-firm *joint product innovation* projects. Multiple cases provide greater scope for attempting analytical generalization [16] compared to a single case. They also provide a useful vehicle for understanding the complexity and richness of the *joint product innovation* project initiation and implementation process, considering the paucity of previous process research. The broad research approach adopted was in the holistic tradition [6] of strategy process research in attempting 'to track simultaneously over time, multiple contextual factors, strategies, decision processes, administrative systems and outcomes' while focusing on a 'narrow strategic problem' [6, p.8].

Projects were selected from a list of TI-firm joint product development projects that was made available by a financial institution that funds such projects under a special technology development financing scheme. A variety of projects were selected to enable replication and comparison, thus building external validity [7] and expanding the domain of generalization [16]. The data collection was primarily through in-depth semi-structured and open-ended personal interviews of about an hour to two and half-hours with key project participants in multiple hierarchical levels and departments in both organizations. The open-ended questions allowed respondents to give descriptive answers and to elaborate wherever necessary. The interviews traced the project process from inception to completion and also covered background information on the organization, industry, and environment. To gather as much as possible the richness of the project process, new topics that emerged during the interviews were explored, and new questions were added for subsequent interviews [7]. All interviews were completely transcribed and supplemented by personal observations, written communications, records and reports [16].

This research was set in Eisenhardt's [7] framework for building theory using case study research. Steps on selection of cases, crafting data collection instruments, entering the field, analyzing data, shaping hypothesis and reaching both case and research closure, closely followed this framework. While working through the multiple projects, themes and issues gradually re-occurred and over the set of projects there was repetition of process details indicating that theoretical saturation [7] had been reached. When sufficient repetitions occurred to ensure external validity [7] no further projects were studied.

The Miles and Huberman [10] 'categorization and theme analysis' technique was then used to develop cases from the interview and background data. Draft cases were read, corrected and cleared by the firm in consultation with the TI. While structuring the written cases, the focus was on the development of causal patterns over time within cases and on the development of general patterns across cases. This analysis served as inputs for the inductive development of the proposed general process description and model. As this research was of an exploratory nature, I stopped after using the empirical base to identify the project process and to inductively develop a general process description and model. Further research is required for testing the adequacy of the variables included in the process model and the completeness and accuracy of the proposed process description and model.

Process Description and Model

The general process description presented in this section and the process model presented in Figure 1 are synthesized from the specific cases of TI-firm *joint product innovation* projects developed as described in the methodology section. These projects involved the development of a product or process along with the creation of new technology, or significant leap from present technology, and required the use of complementary knowledge, skills and equipment available with both the TI and the firm. In each project, the firm contracted the TI for jointly developing new technology by pooling their complementary capabilities and resources. The general description of the project process is presented in the form of a set of linked proposition like statements covering (a) the project antecedent conditions and the joint project initiation process, (b) the project implementation and learning process, and (c) the post project evaluations across organizations and the perceived consequences of the project by project participants.

Figure 1 about here

Project Antecedent Conditions and the Joint Project Initiation Process

In this section, the antecedent conditions for the TI-firm *joint product innovation* project, the considerations behind the firm's choice of this product development mode, and the joint project initiation process, are described. The antecedent conditions and choice process show the nature of the projects and contextual conditions that make this product development mode an appropriate choice for the firm. In parts, the process description is clarified and differentiated by providing corresponding examples of contrasting types of TI-firm joint product development projects.

To illustrate some important aspects of the process description, quotations and examples drawn from the *joint product innovation* project cases initiated by two medium sized firms with two different TIs, are interspersed with the process description. These case examples are presented in *italics* to visually differentiate them from the general process description. Examples from these project cases are also used as illustrations in the subsequent sub-sections of this process description.

The first firm named Secals is a special alloy steel foundry with its central office located in a major city. Its plant is located near a rural town about three hours by road from its central office. Secals collaborated on several product and process development projects with IISc, a premier technological university located in another major city about three hours by road from its plant and about six hours by road or an hour by air from its head office. The two *joint product innovation* projects I refer to here are (a) the development of new gating designs (NGD) for improved molten metal flow in complex foundry moulds and (b) the development of a sophisticated and customized decision support system (DSS) for material flow in the foundry. The second firm named Electronica is an electronics firm located in a major city that collaborated with a local TI named CDAC (a government supported not-for-profit advanced supercomputing technology development center) for the development of an advanced digital readout (DRO) device for use on computer numerical control machine tools. All three *joint product innovation* projects involved a significant leap from the state-of-art technology at that time and required the use of complementary knowledge, skills and equipment available with both the TI and the firm.

Importance of the Project for the Firm: The contemplated product development project is of strategic and possibly critical importance to the firm. The firm identifies persistent problems with the use of its present product or technology and realizes that it has to opt for developing an entirely or significantly new technology or product. Alternatively, it finds that its present technology is already obsolete or fast becoming so, and requires product development with new technology in order to retain or develop competitive advantage. This contrasts with TI-firm product development projects that are merely of commercial importance to the firm as the firm's objective is only to outsource its immediate and non-strategic technology needs from the TI and the project does not involve any significant change from existing technology.

The strategic importance of the project is clear in the Secals case. They had to develop new operational systems to handle their new six hundred ton capacity special alloy steel foundry that were entirely different from those used till then for their two hundred ton capacity scale of operations. Developing better gating designs and a new customized DSS system was essential for Secals to develop new and high quality casting products for more demanding applications in the international market. In the Electronica case, the development of an advanced type of DRO was important, as DROs were their major product and their old DRO design was no longer competitive on both cost and features when some of the national government protections on it were removed.

Technology Involved in the Project: The technology required for implementing the product development project lies in an area that is largely unfamiliar to both the firm and the TI, but each has some (though not all) of the expertise and equipment required for implementing the project. The required technology needs to be developed, is largely new and not known or available worldwide. To develop a new technological approach, the project requires both pure research and applied development, and work required is usually of a multi-disciplinary nature. This contrasts with other TI-firm joint product development projects in which the firm is working in a relatively familiar technology area and the project requires only customized application of a known technology to the specific project requirements.

The new digital readout device (DRO) Electronica developed had features that are not *available in any competing product in the world. They used a new technology route for an old application. The new microprocessor based technology with an innovative combination of software-hardware integration gave those features rendered by the earlier primarily hardware-based technology as well as some new ones. Thus the device was competitive both on price and on features, and could therefore command a significant position in the market.*

Options for the Firm: Given this scenario of technological unfamiliarity and product development requirements, the firm typically explores three options: (a) *Implement a joint product innovation project with other firms.* This option is often constrained by the lack of suitable partners with complementary expertise. Competitive relationships can develop between the two firms with secrecy and lack of trust, leading to low confidence and low opportunity for learning and capability building. Overall this option involves high cost and high risk. (b) *Acquire new manpower and equipment for internal product innovation with self-learning and experimentation.* This is more time consuming and even more expensive compared to the first option. It has high risk and requires high internal investment. The firm usually has low confidence in its ability to do the project entirely on its own. However learning through self-experimentation is high even though it is expensive. (c) *Implement a joint product innovation project with a TI that has complementary knowledge and skills.* In this option there is no competitive relationship with the TI. Given the comparatively lower technology development charges by TIs in general, it is also likely to be lower in cost compared to the other options. The firm usually has higher confidence in its ability to jointly develop the new technology with the TI rather than on its own or with some other firm, and therefore the perceived risk is lower. There is also a possibility of interactive learning of complementary knowledge and skills during implementation.

A firm is likely to take the first option if secrecy is not a major issue or if the collaborating firm is not a direct competitor in the relevant product market. The second option is more likely to be chosen if absolute secrecy is essential for the project even at a high cost and the firm can easily acquire the required new resources. Here I consider the case, where, on weighing the three options the firm decides to opt for third one -- that of implementing the project in the TI-firm *joint product innovation* project mode. Given the technological nature of the project, this option emerges as the most appropriate one if both secrecy and cost are important considerations, and if a suitable TI with complementary expertise exists and is willing to take up the project.

Project Contract and Implementation Structure: The *joint product innovation* project contract requires the firm to jointly develop a new product or process with a TI, using each other's expertise, laboratory and infrastructure. The project eventually results in the joint creation of a new technology. The contract between the two organizations is usually open ended, allowing for expansion and changes in plans, as new knowledge created during the project leads to new technology development avenues. These is in contrast to those projects where the firm's major objective is to outsource specific and clearly definable technology requirements and it therefore enters into a specific, close ended and time bound contract with a TI.

Feasibility and Viability of this Project Implementation Structure: This *joint product innovation* project implementation structure is feasible if the TI and the firm both have clearly complementary equipment, infrastructure, skills and expertise, which cannot be acquired by each other. It is viable if the apriori perceived benefits of the new technology being developed far outweigh the investment and perceived high risk associated with it and there is an open ended agreement between the two organizations to seize new opportunities as they emerge during project implementation.

Motivations of the Firm: The *joint product innovation* project is essential for the firm to develop and retain technological and market leadership and for future growth, as present technology available worldwide becomes increasingly inadequate or inappropriate. The firm also needs to develop and learn the new technology for future projects.

In the Secals case, the objective of the new gating design (NGD) project was to move from human skill based controls to computer controls in an effort to reduce rejections and control this critical foundry process better. The study was undertaken to gain better understanding of the behavior of molten metal while pouring and the flow of molten metal through the gatings inside the moulds. Secals sought to translate this knowledge into better gating designs to give special castings of superior quality. The study used a combination of physical experimentation and computer simulation - a route that had not attempted before. Secals earlier had rejections of seven to eight percent which they were able to reduce with the *new and improved gating designs to five percent in their existing two hundred ton plant. They targeted a rejection rate of three percent for their new six hundred-ton plant.*

Similarly, Electronica decided to move from their conventional DRO to developing an entirely new DRO product with a new technology route. Their choice was a microprocessor based DRO in which additional features could be built in along with miniaturization, and higher reliability. The project team leader at CDAC believed that once the design and manufacturing costs were recovered, this product could give good returns. Electronica developed this product primarily for the international markets and it was price and features wise competitive and comparable to the best available in the world.

Constraints of the Firm: The firm identifies persistent problems with the use of its present technology. The new technology required for developing the new product or process is not available or accessible worldwide. It involves creation of new technology or a major technological leap for the firm, which it finds unable to take on its own as it lacks the skills, technology and equipment required for doing so.

For example, Electronica decided to go for microprocessor based DROs but they lacked the design capabilities, the equipment and both software and hardware knowledge of this technology as it was very different from the conventional electronics they were familiar with.

Firm's Choice of TI: Having decided to implement the project, the firm seeks a suitable TI to work with it on the *joint product innovation* project. Its first choice is usually a TI in its immediate vicinity (same city) as proximity facilitates the high interaction required for implementing the project. The initial contact is usually with a TI scientist personally known to the firm's project leader or chief executive. The firm's choice of TI is initially based on previous personal contact and fruitful earlier interaction if any, or on personal recommendations. Once negotiations are initiated, ease of interaction and interpersonal rapport built during negotiation play an important role in finalizing the contract.

This choice process is depicted in the Electronica case: The chief executive of Electronica had given a number of projects to TIs in the past. The TI scientist was usually someone known to him through personal contact or references. Electronica had been in contact with CDAC for a long time as both are headquartered in the same city. The chief executive of Electronica knew the project leader at CDAC personally. So when they needed *support in developing the new product with advanced electronics, CDAC was their first choice. Explaining the choice of CDAC, the team leader at Electronica said:*

> "We believe that they (CDAC) are the only capable people in ASIC (Applications Specific Integrated Circuitry) and FPGA (Field Programmable Gate Array) technologies"

In the Secals case, the chief executive of Secals had become acquainted with MNS (a senior professor of IISc and the eventual project leader and coordinator at IISc for the joint project) when he had come over to help Secals apply an IISc developed software that Secals had purchased. Explaining how IISc was chosen as partner, the chief executive of Secals said:

> "We had a close and fruitful interaction during the development of this package. We developed a lot of respect for (MNS) both as a person and as a professional. Then we appointed him as a consultant to us with the areas of technology upgradation, quality improvement and optimization as a broad mandate."

This initial consulting project with MNS eventually resulted in the initiation of the joint projects with IISc.

TI's Considerations: The TI contacted by the firm for proposing the *joint product innovation* project could be a technological university, a government research institution, a research foundation or an industry research association. The differences in the charters of these different types of TIs may effect their considerations in accepting proposed joint product development projects. Technological universities conduct both basic and applied research with only one of their multiple and often diverse objectives being to develop technology for industrial application. These are likely to accept a wide range of joint product development projects if they match the research interests of individual faculty members. Specialized government research laboratories are usually charter bound to work for their relevant local industry and are therefore very likely to accept joint product development projects that help them meet their charter, if such projects fall within their specialization area. Research foundations may work on specific sectors or on wider interdisciplinary developmental issues and are likely to take up only those joint product development projects that match their funding specifications. Industry research associations usually work only with their member firms and may take up any such project proposed by them.

The TI scientist when approached by the firm with the project idea accepts it for a variety of reasons. Though personal recommendations and friendly obligations towards the firm are important, acceptance is more due to the inherent interest and excitement generated by the innovative nature of the project, that has unique features and high potential to contribute to the scientist's and TI's research interest and program. The project is seen as providing the TI scientist the scope to learn, add to the TI's resources, do something unique at the cutting edge of technology in the field, have the potential of being published, and most importantly be personally and academically exciting. This interest and excitement spurs the TI scientist to act as an initiator and coordinator within the TI, in getting other TI scientists with the required complementary expertise interested in the project. These scientists too get interested in the project for the similar reasons and are incorporated into the project team. The TI agrees to implement the project if it fall within the TI's areas of research and available facilities and also fall within its experience base and time constraints.

These considerations are shown in statements in the Secals case: During their earlier consulting interaction, MNS had suggested areas of improvement at Secals and later when Secals decided to undertake such improvements, he was contacted to suggest suitable persons to undertake the suggested work. MNS was able to identify appropriate scientists within IISc. The chief executive of Secals and MNS then went together to meet these scientists and requested then to join the project team. MNS also played the facilitator's role at IISc and coordinated with the other professors within IISc, with the chief executive of Secals at their central office and the general manager of the plant where the project was implemented. Explaining his interest in industry projects, MNS said:

> "The inflow from the industry is not much but the interaction is highly valued. We often get insights into real life problems that are often at the cutting edge of research work here and anywhere in the world.......... Technical consultancy needs high involvement and takes a lot of our time. On the other hand it is intellectually stimulating, sharpens our intellect, gives us new topics for research, and feeds on to our academic work."

In the Electronica case the project team leader at CDAC said:

> "From CDAC and my own point of view, the attraction was of quantity and there was a potential for export. It is going to be a good product in the international market........ Also in the electronic industry change is very rapid with low product life cycles, whereas this product is likely to have a long lifetime of five to ten years, before it gets obsolete. Design involves a lot of effort and money. To make it worthwhile and satisfying the product should not become obsolete before completion. The longer it lasts in the market, the more the satisfaction as a designer. Personally, my interest was in the export potential and mental satisfaction as a designer. The project should give a successful product and a stable good product. Most importantly, appreciation is in the product being used by a

large number of customers."

Importance Level of the Project to the TI: The *joint product innovation* project is of strategic importance to the TI in the sense that it overlaps with the areas of work that the TI has mapped for itself as its thrust areas for the future. It is also seen as an opportunity to work at the cutting edge of technology in the field, with high contribution potential for the TI's research interests and program. This contrasts with joint product development projects that are only of commercial importance to the TI as they merely require application of known technology and are therefore used as a means of providing industrial training to the TI's students or junior scientists.

The importance of the project is shown in the statements of MNS of IISc who worked on the new gating design project in the Secals case:

> "There has been a lot of work in the science of the flow of metals but the translation of this work to the field is a highly challenging task. So we took up this opportunity. Building the complex shaped moulds itself is a challenge in mechanical engineering. For me this study is a wonderful opportunity and some of it is path-breaking work internationally."

Familiarity of TI with the Project Technology Area: The *joint product innovation* project technology area is new and unfamiliar to the TI but it has some of the basic skills and knowledge required for developing the new technology. This contrasts with joint projects in which the TI works in a familiar technology area to develop part of a new product or process through customized application of a known technology.

For example in the Secals case, MNS of IISc drew on his experience in this area, to try a new simulation method that to his knowledge had not been attempted before. He explained:

> "We have tried a middle path in this project by doing part physical simulation using plastic and fiber reinforced plastic moulds and part computer simulation using mathematical analysis with the (new) software we have developed."

Technological Nature of the Project: A *joint product innovation* project involves the creation of new technology, as the presently used and available technology is inadequate to solve the firm's technological problems. Therefore the work involved in the project is in the realm of both pure research and applied development. This contrasts with projects that require only customized development and application of a known technology.

The technological nature of the project is shown in the Electronica case: The DRO is an electro-mechanical device that uses both electronic and mechanical components integrated with each other. Till this project Electronica manufactured DROs using the conventional hardware route - conventional electronics integrated with mechanical movements. The new DRO developed in this project replaced a large part of the hardware by software and achieved miniaturization and integration by the use of customized integrated circuits. The product innovation involved designing the new integrated circuit chip and building in more programmability with software to hardware interface. It also included the design of the device layout and design integration to achieve system wide optimization.

Project Implementation and Learning Process

The project implementation process in a *joint product innovation* project is described in this section and illustrated through the Secals and Electronica cases. The project work at both the TI and the firm involves developing new technology for immediate and future application, along with capability and facility development. The project as initially proposed is usually narrow in scope, but its scope expands and evolves over time based on project developments during implementation and the development of rapport between the two organizations. Interactive work is high with high frequency of meetings and communications, working together and good interpersonal rapport. This is in contrast with joint product development projects in which there is a temporal sequence in activity -- the TI independently conducts upstream research and the firm then independently conducts downstream research on receiving the technical output of the upstream research from the TI during a short technology transfer phase.

Project Implementation: The *joint product innovation* project moves interactively between R&D work at the TI, TI-firm joint technology creation and R&D work at the firm, as described below and depicted in Figure 1.

Work at the TI: In a *joint product innovation* project, project work at the TI involves developing new technology for immediate and future application with capability and facility development. The work is divided among the TI scientists/engineers based on their expertise areas. However they have several meetings throughout the project to coordinate and support each other. This is essential in cases where the parameters of each scientist's work are interdependent with those of the other scientists working on the project.

Work at the Firm: Similarly at the firm, project work in a *joint product innovation* project involves developing new technology for immediate and future applications with capability and facility development. A coordinator is designated at the firm who coordinates various scientists/engineers at the firm. There are several meetings throughout the project for coordination and mutual support.

Interactive and Joint Work: There is close and frequent interaction between the TI and firm project teams in a *joint product innovation* project. The project work may involve members of the firm's project team personnel working at the TI's premises and vice-versa. Even while working separately, they communicate their work to each other as often as required, so that each knows intimately about what the other is doing. Since the problem is unique for both partners, and each has complementary knowledge and expertise, this interaction is instrumental in transferring their knowledge to each other. New technology is interactively created, with joint and almost equal learning for both the TI and firm participants, as they work together and learn together while implementing the project. Meetings are frequent, intense, usually of long duration, characterized by a high degree of openness, and equal acceptance of failure and success.

This project implementation structure contrasts with joint product development projects in which there is a clear temporal sequence and separation of activity between the firm and TI and where interaction is low -- clearly limited to the short duration during the project initiation stage and for receiving the technical output of upstream research from the TI.

The interaction during project implementation is depicted in the Electronica case: Before the project started Electronica and CDAC had several rounds of discussion to develop a project proposal. Then they jointly developed a "wish list" of specifications that contained all the features that were desirable if there were no constraints. This "wish list" was narrowed down through discussion to those that were possible. Following this they froze specifications for the product on twenty odd features. They mutually discussed the pros and cons. Later CDAC used computer simulations to show Electronica how the product would work and look. CDAC's interaction was with all the people at Electronica who were involved *in the project. They interacted with Electronica's marketing people on color selection and the key operating sequence. CDAC built in variations on the keyboard based on their inputs. CDAC had to check with Electronica's production people to make sure that the device was suitable for production. The discussions between Electronica and CDAC were of technical nature. Electronica's initial design was modified by CDAC who redesigned it for better system level integration.*

In the Secals case, MNS of IISc described the nature of interaction:

"The interaction is continuous in this project. Within IISc and with Secals we have regular meetings of an hour or so in which we check the data, collect information, review progress, find and rectify problems. (Their chief executive) comes over to IISc regularly. I go once to twice a month and they also come over equally often. Also faxes are sent to keep each other informed........ We pass on notes to them, make presentations with transparencies. Also they give us feedback. It is highly interactive with demonstrations of packages etc. We send regular communication, show processes on video and photographs. They ask questions and put forward their views, send me their drawings. We analyze and codify them and sent them back. So the technology transfer and training is fairly extensive and intense over time."

The chief executive of Secals described the interaction:

"We have had several brainstorming sessions with the IISc professors. I visit IISc about once a month and personally review the projects. The IISc people come and spend time at our plant."

Learning Process Within the TI: In a *joint product innovation* project, the learning within the TI is through the high interaction between the scientists/engineers. They learn from each other and through the experience of new technology creation that involves considerable experiential and tacit learning. They are also exposed to the latest industrial practice. The TI scientists discover new unexplored practical and theoretical problems for future research, which are at the cutting edge of their field. These can become topics for future research using the firm as a research base.

In the Secals case a scientist at IISc talking about his learning from the DSS project said:

"Some of our project learning does develop into research areas and also feeds on to our teaching. We have used the software that we have developed for Secals in demonstrations to our students. We have developed notes for teaching students the process of developing solutions to these generic problems. A Ph.D. student of ours has developed an expert system for scheduling the tool room. We may find further research potential in this area also in future."

Learning Process Within the Firm: The learning within the firm in a *joint product* *innovation* project is through the high interaction between the scientists/engineers. They learn from each other and through the experience of new technology creation involving considerable experiential and tacit learning. They also learn from exposure to the latest technical literature in their area.

Talking about the learning within the firm, the project leader at Electronica said:

> "We have learnt a new technology through this project, which we can use for other devices and new products."

A scientist at IISc working on the DSS project remarked about the learning and changes at Secals during the project:

> "They (Secals) did not have an optimization orientation and worked more on an adhoc basis. They were preoccupied in their day to day decisions. With this work they have now grasped the concept of database use through computers. It has given them a new way of looking at their production and thinking and visualizing possibilities of improvement."

Joint Learning Process: The joint learning in a *joint product innovation* project is by teaching each other complementary past knowledge and creating new knowledge together. The learning is equal for both the firm and the TI. The project results in capability development within the TI and the firm. Apart from developing the new product or process during the project, both gain substantial technical, experiential and tacit learning through the project. These are seen by both TI and firm participants to have benefits in future. This contrasts with the learning process in vertical [9] TI-firm joint product development projects in which leaning takes place largely within each organization, and transfer of knowledge is limited the technical output of upstream research from the TI to the firm, without any transfer of tacit or experiential knowledge.

In the Electronica case, the engineers from the firm were involved in teaching CDAC people the basic technology of the DRO device, making them understand the software requirements and the product-user interface. The chief executive of Electronica said:

> "It was really an interactive type of project"

The financial institution representative handling the project said:

> "The learning for Electronica was that their engineers had an opportunity to interact with engineers at CDAC who are working at higher levels of sophistication. They could see the benefits of software use. Also they had exposure to FPGA technology."

A design engineer at the Secals plant said:

> "There were some designs we had developed but had not tried during our regular work. Now we

have got the opportunity to try various things under professor's guidance. We are using his experience. This interaction has helped us in going for more experimentation."

Expansion of Project Scope: While the major objective of the *joint product innovation* project is clearly to move to a new technological level, there is apriori no clearly definable end result. The project scope often expands as new avenues emerge with the generation of new knowledge and develops over time through the interaction process. The firm is open about exploring new technology avenues as they emerge during the course of project implementation, if they are within its investment ability and risk bearing capacity. The TI is also willing to explore such new avenues, within constraints of time and resources, as their interest grows with the expanding scope of the project. The firm's choice of developing the project scope is based on the ease of interaction with the TI, the development of interpersonal rapport, the results of the project till that stage, and the nature of the emerging areas. This contrasts with TI-firm joint product development projects that require work in known technology areas. In such cases contracts are more likely to be well defined, specific and not expand or change in scope over the project duration.

MNS of IISc explained how the Secals project expanded in scope over time:

"For me the importance of this project was high and has changed over the project duration. We do learn from the project and perceptions change due to improved understanding. The important initial steps are project identification and definition. During the phases of project definition, classification and then focus the attention keeps changing. The problem has grown in importance over time - it has become more exciting when you see and explore something that has not been done before."

Interest Level and Relationship: The *joint product innovation* project is characterized by high personal and organizational interest in both the firm and the TI project teams. This leads to a high degree of interest and initiative from the two chief executives or project team leaders to initiate, lead and directly manage the project. Project participants are also highly enthusiastic about the project, as they see considerable scope in it to learn new skills, as well as benefit from being involved in a project that is at the cutting edge of technological innovation. The TI-firm relationship is primarily relational and to a lesser extent contractual. Good interpersonal rapport develops between the TI and firm participants. High reliance is placed on trust and enthusiasm to carry forward and control the project in the face of high technical risk and uncertainty. Both TI and firm participants usually go far beyond their initially written contractual agreements in their effort to do the best for the project. High personal rapport usually develops between the two coordinators -- while emerging from earlier interactions, it is sustained and built during the course of the project. This contrasts with TI-firm joint product development projects that require work in known technology areas with clearly defined contracts in which the relationship is likely to be primarily contractual.

The TI-firm relationship in the Electronica case developed far beyond the formally agreed and written down division of work in their Memorandum of Understanding (MOU) Though it was formally a turnkey project for CDAC, yet Electronica engineers worked at the CDAC premises with them. Electronica had full access to CDAC scientists and their laboratories and were in constant touch with CDAC. The Electronica project leader visited CDAC every two days to assist and make clarifications. He also worked jointly with a CDAC engineer on software design. They two teams had regular meetings to discuss all aspects of the project. Operational level meetings were atleast once a week while at the business level, meetings were once a month. The project leader at CDAC said:

> "We did not go strictly by the paper work and written contract. It is very difficult to work if you follow only the contract as given on paper. We have to go by the intention of the contract and not on the literal interpretation of the words on paper. Once we signed the contract we did not talk in terms of money. We did not take a 'business' point of view. We were flexible in taking up jobs within the project as they came up. We were also willing to do some extra work. Infact there was a last minute design change (which came up because there were some field problems, which were not anticipated in advance)........ Their people implemented this design change with fifteen man-days work over here. At the end when the know-how transfer took place we also downloaded some development activity on to them...... We also trained them in assembling the device, even though this was not there in the initial contract. We took it up as we wanted to do a complete job."

Problems and their Resolution: Problems in the *joint product innovation* project are usually related to the initial ambiguity in the project definition and its change over time. Problems also arise from communication gaps and delays. Given the rapport between the two project leaders, they take a proactive role in preventing such problems and in bringing about their amicable resolution as soon as possible when they do occur. This contrasts with joint product development projects that are strictly governed by formal contracts in which problem resolution usually requires formal arbitration mechanisms.

Post Project Evaluations and Consequences of the Project

This final section of the process description of *joint product innovation* projects covers the parameters on which the firm and TI evaluate each other after the joint product innovation project is completed. It also covers the consequences of the project and each organization's individual vision of the consequences of the project for future interaction between the two organizations.

Evaluations: On completion of a *joint product innovation* project, evaluation of the TI by the firm is based on its perception of the knowledge base of the TI project participants, the quality and ease of interaction with them, their ability to understand the complexity of the technological problem faced by the firm, and their ability to develop new technology suited to the firm's special requirements, apart from their effectiveness in jointly implementing the project. The firm is positive about collaborating with the TI in future if these expectations are met. Similarly, evaluation of the firm by the TI, is based on the clarity of the firm's project participants in communicating their requirements and expectations, their interest in the project, their ability to contribute in a complementary manner to the new technology innovation effort, their openness and understanding in accepting failure as a part of success in the R&D process, and the ease of interaction. The TI is positive about collaborating with the firm in future, if these expectations are met.

Some of the comments made by project participants in explaining the success of their project are illustrative of this evaluation of each other. In the Electronica case, the project leader at CDAC said:

> "The success of this project was due to (Electronica's chief executive) being clear on what he needs, being receptive to ideas and being open and willing to see reality. He understands the process of design well and could appreciate the intricacies and the threats. We could tell him exactly what was happening. We did not have to hide anything."

In the Secals project a scientist at IISc said:

> "In my opinion this project has worked out well because Secals has a mature view of industrial R&D. They are not like other firms which expect immediate solutions to their problems. They are patient and understanding. They understand that failures are a part of success; that trial and error is required for such work. All my suggestions have not worked but they have not complained."

The chief executive of Secals said:

> "Though theoretical work is involved, the IISc people have by and large kept their feet firmly on the ground."

Other Outcomes of the Project: In a *joint product innovation* project, apart from the development of a new product or process, a major outcome for both the TI and the firm is a technological leap leading to new ways of thinking. In the TI, the technological leap results in the emergence of new related research areas to explore - as new knowledge is gained, the TI sees new interesting research areas and seizes them if time and resources permit. Similarly, as new knowledge is gained, the firm sees new technology innovation opportunities and seizes them if affordable. These new opportunities are either immediately seized by the project team, or kept in reserve for future work, if resources required are not currently available. Overall these positive outcomes of the project leads to willingness in both the firm and the TI to explore new emerging opportunities together.

A scientist at IISc working on the Secals DSS project said:

"The study of this problem can give us useful insights into developing solutions for this class of problems which have not been tackled before. It is possible that even the simple heuristic method we have developed may be a new method not yet dealt with in published literature. The academic interest is in developing new workshop flow models. Though there are a large number of dissertations on flow shops, they are all on machine shop applications. These are not applicable to the foundry industry. We (at IISc) are likely to work further in this area."

An IISc colleague of his also working on the DSS project for Secals said:

"My interest has enhanced over the duration of the project. We have created several new ideas for student projects. Over the project duration, this work has fascinated and interested me more. I see new work areas emerging from this interaction and our understanding of such production systems."

Unanticipated Benefits: In a *joint product innovation* project, participants can discover unanticipated benefits from the project. The project often opens new technological frontiers, with the firm thinking in previously unexplored ways. This can result in projects that incorporate the new technology in areas well outside the scope of the initial project. Similarly, the interaction with the TI also exposes the firm to the latest technical literature in its field. This may lead it to rethink on technology related decisions in other areas that are entirely unconnected with the project. There may also be an overall technological upgradation as the new technology and skills diffuse throughout the firm. The TI can also discover such unanticipated benefits.

For example, the chief executive of Secals said:

"There have been spin offs in areas outside the project scope. I am getting science into the foundry.

People are now more aware of information technology. They are now computer trained...... In general the level of technology has gone up in our foundry and the way people think has changed."

MNS who worked on the new gating design project for Secals said:

"We have a Ph.D. student working on simulation and modeling work. One of my students did a project at Secals, which was not specifically in the protocol of this set of projects. We also derived benefits such as access to information through these projects."

Future: If post project evaluations by both TI and firm about each other are positive then continuous future interaction is expected in jointly exploring new problem areas and in developing pioneering new technology. On successful conclusion of the *joint product innovation* project, the firm is usually willing to work on future collaborations with the TI, and often proposes subsequent projects. The TI is also positive about collaborating with the firm, and accepts such projects if it has the time and resources to implement them. Even otherwise, the TI is usually positive about working with the firm in future. This contrasts with vertical [9] joint product development contracts in which technical failures usually lead to negative evaluations of each other, possibly ending the TI-firm relationship.

On successful completion of the DRO project, the chief executive of Electronica was interested in launching more projects with CDAC. However the project leader at CDAC was reluctant to accept new projects, as CDAC was temporarily short on manpower at that time. He therefore told the chief executive of Electronica that though it was not immediately possible, CDAC could do some projects for Electronica at a later date. He emphasized that CDAC was interested and keen on maintaining its link with Electronica.

Talking about the future of their link with IISc, the chief executive of Secals said:

"In future we would like to continue our interaction with IISc. There are a lot of benefits. There is a wealth of knowledge in IISc. We can check out the state of art in all areas of science and technology. We can speak to them and know what is happening in many areas. To meet our technology gap we do intent to go to them in future. We find the interaction creative and fruitful."

MNS of IISc said:

"In future, I hope to interact with them in a long term enduring way. I see tremendous possibilities in general and continuous growth of such work."

Another scientist at IISc said:

"I am keen on doing projects there. I am sure that synergies will develop. Their support for the project has been very good. (Their chief executive) has a very good vision."

Summary

The most important features of the process description and model of *joint product innovation* projects presented above are summarized in the two tables that follow. Table 1 summarizes project attributes related to the antecedent conditions of TI-firm *joint product innovation* projects and the joint project initiation process. It covers the importance level of the project to the firm and the TI, their respective familiarity with the technology area, their respective considerations, motivations and constraints in choosing each other as collaborators and finally the conditions that make this project implementation mode a feasible and viable option.

Table 2 summarizes project attributes related to the implementation process that follows the *joint product innovation* project's formal acceptance by both collaborators. It covers the essential nature of project activities and learning in the two collaborating organizations. It also covers the learning during the project for the collaborators, the actual and anticipated outputs, and their post-project evaluations of each other.

Tables 1 and 2 about here

Limitations

This research on TI-firm *joint product innovation* projects was to some extent limited by the refusal of several potential firms and TIs to allow a detailed process study on their projects. This was primarily due to the secrecy involved in their new product development projects, given the patentable nature of the project outputs and the high level of competition in their industries. Even the firms and TIs which eventually agreed to the study were reluctant to reveal complete details of the actual technology involved. While it is likely that complete technical details of the projects may have helped sharpen some parts of the process description, this was not a serious limitation as the project participants showed no reluctance in describing in great detail the project implementation and interaction process that was more relevant to the focus of this study.

As the interviews relied largely on open ended questions requiring descriptive answers from project participants, there were some differences in both the quality and nature of responses, reflecting individual differences in the ability and willingness of the participants to patiently articulate their project experiences. Therefore all project cases could not be equally well developed due to the differences in the background and interview information made available. Another limiting factor was the natural reluctance of some project participants to discuss those projects that eventually became technical failures. Surprisingly however, there were several participants who candidly discussed such failures.

As this research was of an exploratory nature, I stopped after developing the empirical base and using it for identifying the project process leading to a proposed general process description and model. While sufficient cases were developed in this research to ensure external validity of the model developed, further large sample research is required to test the validity and robustness of the model. Overall these limitations have not adversely affected the quality and scope of this research.

Conclusions

This research contributes to the literature on the management of research collaborations in general, as well as TI-firm *joint product innovation* projects in particular. It complements the content studies of research collaborations that provide an overview of the firm and TI motivations and explain the existence of such collaborations, but are not designed to describe the initiation and *implementation process* that is key to developing policy mechanisms that initiate and facilitate them.

As indicated earlier, previous research has concentrated only on identifying the antecedent conditions and consequences of TI-firm joint product development activity, while neglecting to describe and analyze the important *process* of initiating and implementing such activity. This research contributes towards meeting this gap in the literature by providing a model of the *process* of initiation and implementation of *one* type of TI-firm joint product development activity – those joint projects that are of strategic importance to both collaborators and also involve the creation of new technology or significant improvement over present technology. In doing so, this research contributes significantly, by providing a clear link between the identified project antecedent conditions, the process of initiation and implementation of the project, and further to its identified consequences – a link that is clearly missing in the extant literature on technological collaboration. It therefore provides both methodology and direction for future research in establishing this important link in other types of TI-firm joint product development projects and other forms of technological collaboration in general.

This research leads to several interesting avenues for future research. Proposed directions for future research are: (a) testing the accuracy and completeness of the developed process model and its identified stages and sub-processes, (b) testing the adequacy of the variables included in the process model, (b) developing similar process models of other types of joint product development projects, (c) comparison of the model with other models of joint activity between organizations, and (d) developing scales and operationalizing the various components of the model.

This research can also enable practitioners and policy makers to first, understand effective processes for initiating such collaborative projects, and second to modify structural conditions to initiate an effective implementation process in them. Firms can examine the process model and description to draw lessons on creating the appropriate ground conditions that facilitate the initiation of such collaborative projects. The process model is also useful in understanding how multiple factors at the individual, organizational and inter-organizational level combine to initiate and implement such research collaborations. It can also provide practical insights for firms, TIs and policy makers to facilitate and strengthen TI-firm interaction in general, and to initiate, execute and sustain a progressive program of such projects.

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Table 1. Antecedent conditions and joint project initiation process

Project Characteristics	TI - Firm *Joint Product Innovation* Project
1. Importance level of the project for the firm	Strategic importance: firm needs to develop and learn new technology as old technology is obsolete
2. Firm's familiarity with the technology area	Technology area is new for the firm
3. Need for the firm to outsource technology	Firm lacks part of the knowledge and appropriate manpower and/or equipment
4. Firm's major motivations	New technology required as technology available worldwide is inadequate or inappropriate
5. Firm's major constraints	Persistent problems with present technology, cannot take the required technology leap on its own
6. Firm's choice of TI is primarily based on	Personal contact, earlier fruitful interaction, ease of interaction, interpersonal rapport, recommendations, rapport develops over the negotiation period
7. Importance level of the project for the TI	Strategic importance, seen as an opportunity to work at the cutting edge of technology in the field
8. TI's familiarity with the technology area	Technology area is new for the TI
9. TI's considerations	Creative nature of the project, high research potential, scope to add to the TI's resources, publishable nature, academically exciting
10. TI's selection criteria	Project must fall within areas of research and available facilities, fall within its experience base, friendly obligation, time constraints
11. Project process mode is feasible if	There are clearly complementary skills and equipment or infrastructure existing in both the TI and the firm that cannot be easily acquired by each other
12. Project process mode is viable if	There is an open ended agreement between the firm and TI to seize emerging opportunities, apriori perceived benefits outweigh the high risks
13. Project implementation structure	Joint development of the new product or process, use of each other's laboratory and infrastructure, joint creation of new technology

Table 2. Project implementation process, learning and evaluation

Project Characteristics	TI - Firm *Joint Product Innovation* Project
1. Project implementation process	R&D work at the TI interactively moving with joint product innovation interactively moving with R&D work at the firm, expansion in scope of the project over time
2. Initial activity at the TI	Developing facilities, capabilities and new technology for product innovation
3. Initial activity together	Joint product innovation, high interaction, frequent meetings
4. Initial activity at the firm	Developing new technology for immediate and future application
5. Technology transfer activity	Throughout the evolution of the project and in both directions - firm to TI as well as TI to firm
6. Later activity at the TI	Working on the expanding scope of the project and exploring new areas of research that emerge from the project
7. Later activity together	Joint product innovation, high interaction, frequent meetings
8. Later activity at the firm	Working on the expanding scope of the project and exploring the new areas of application that emerge from the project
9. Problems and their resolution	Problems related to the ambiguousness of the project definition and its change over time, communication gaps and project delays, project leaders take a proactive role in their prevention and in their rapid amicable resolution
10. Learning at the TI	Through high interaction between scientists, learning from each other, new knowledge creation, new experience, tacit learning, exposure to practice
11. Learning during the technology transfer	Through teaching each other complementary past knowledge, creating new knowledge together, learning together, equal learning for both the firm and the TI
12. Learning at the firm	Through high interaction between engineers, learning from each other, new knowledge creation, new experience, tacit learning, exposure to research literature in their field
13. Evaluation of the TI by the is firm based on	The TI's knowledge base, quality and ease of interaction, ability to understand problem complexity, ability to develop and implement new technological solutions
14. Evaluation of the firm by the TI is based on	The firm's clarity in communicating their requirements and expectations, ease of interaction, interest and ability to contribute complementary resources effectively, openness and patience

Figure 1 **Process Diagram of TI-Firm *Joint Product Innovation* Project**

Project Implementation Structure	**Project Structure Feasible if**	**Project Structure Viable if**
TI and firm jointly developing new product or process, use of each other's laboratory and infrastructure, joint creation of new technology	There is clearly complementary skills and equipment/ infrastructure in both firm and TI which cannot be easily acquired by each other	There is an open ended agreement to seize emerging opportunities, apriori perceived benefits outweigh high risk and investment

Project Initiation Phase

Project of Strategic Importance to the Firm	**Project of Strategic Importance to the TI**
Firm's Motivations creation of new technology required for market leadership and future growth as technology available worldwide is inadequate or inappropriate	**TI's Expectations** creative nature of project, high research potential, scope to add to TI's resources, publishable nature of work, academically exciting
Firm's Constraints faces persistent problems with present technology, inadequate knowledge, skill and equipment hence cannot take technology leap on its own	**TI's Criteria** project must fall within areas of research and available facilities, fall within experience base, friendly obligation, time constraint
Technology Area Unfamiliar to the Firm	*Technology Area Unfamiliar to the TI*

↓ ↓

Firm's Choice of TI is based on
personal contact, earlier fruitful interaction, ease of interaction, interpersonal rapport, recommendations, negotiation process

→

Project Accepted by TI based on
its ability and availability of resources to handle project, project selection criteria, norms of TI, assessment of firm's interest in project

Next page →

↑ ↑

Positive Evaluation of TI by Firm Based on Earlier Interaction

Positive Evaluation of Firm by TI Based on Earlier Interaction

Figure 1 (cont.) **Process Diagram of TI-Firm *Joint Product Innovation* Project**

Project Implementation Phase and Outcomes

Project Process: Work at TI ↔ Joint Technology Creation ↔ Work at Firm

At the TI →	**Work at the TI** developing new technology for immediate and future application, capability and facility development →	**Learning at the TI** high interaction between scientists, learning from each other, new knowledge creation, new experience, tacit learning, exposure to practice →	**Output for the TI** technological leap, new ways of thinking and new research areas to explore emerge
At the Interface →	**Interactive Work** working together, high interaction, good interpersonal rapport, high frequency of meeting, communication →	**Learning Together** teaching each other complementary past knowledge, creating new knowledge together, learning together, equal learning for both the firm and the TI →	**Together** Willingness to explore new opportunities, expansion in the scope of the project
At the Firm →	**Work at the Firm** developing new technology for immediate and future application, capability and facility development →	**Learning at the Firm** high interaction between engineers, learning from each other, new knowledge creation, new experience, tacit learning, exposure to research literature in their field →	**Output for the Firm** technological leap, new ways of thinking and applying new knowledge emerge

Problems and their Resolution

Problems related to the ambiguousness of the project definition and its change over time, communication gaps and project delays, project leaders take a proactive role in preventing such problems and in their rapid amicable resolution when they do occur