"THE R & D / PRODUCTION INTERFACE"

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1. Introduction

Factors which explain the success or failure of an innovation project, or which throw light upon the differences between innovative and non-innovative companies have been a focus of interest since research on management of innovation was initiated. In the early landmark studies, e.g. Carter and Williams (1957), Myers and Marquis (1965), Langrish et al. (1971), the SAPPHO study (Rothwell et. al., 1974), or its followers e.g. the Hungarian SAPPHO (Rothwell, 1974), and the study in the Dutch Materials Handling Industry (TNO, 1975) one generally comes to the conclusion that efficient and effective R&D, the presence of specific factors e.g. an entrepreneurial and experienced project champion and a good cooperation between R&D. and other functional areas e.g. production or marketing favour the successful outcome of an innovation project.

There can be no doubt that the explanation provided by these and other studies (Cooper (1979), Gerstenfeld (1976), Hopkins (1980), Kulvik (1977), Roberts and Burke (1976), Rubenstein et al. (1977), Utterback et. al. (1976)) for successful and unsuccessful explanations are essentially of a pluralistic nature. Innovation is a complex socio-technico-economic process involving inter-organizational interactions. Success can seldom be explained in terms of one or two factors; on the contrary, most of these studies emphasize that successful innovators are better than their unsuccessful competitors across the board. The results concerning this better "across the board" performance can generally be classified in three broad categories:

(a) successful innovators pursue a better innovation strategy, choose the better market, know more about their market, etc.

(b) They perform the tasks involved in the innovation process better: they have a better and more unique product, launch it better, discover technical bugs during and after the introduction, have a better performing sales service, etc.

(c) They approach the innovation problem in a more integrated way, have a better interface between the different functional groups, see it as a company work effort rather than a task for R&D or Marketing,etc.

Concerning this last point, a considerable number of studies have been published about the interface between R&D and Marketing. (Souder et. al. (1977), Gupta et. al. (1985), Shanklin and Ryqns (1984), Bonnet (1985), Pearson et. al. (1984). These studies explore the need for an intense cooperation, measure the degree of intervention and integration in a wide range of field sites, and provide some ideas or frameworks for improving the R&D Marketing Interface. The interface between R&D and production has been given less attention. Apart from Bergen's study (Bergen, 1983), and the results of the IRI study group (Wolff, 1985), few empirical studies have been carried out on this problem. If one assumes that academic research is to some extent also market-driven, one would assume that either the link R&D/production is an unimportant one, or it causes no problems since it is generally well managed.

It will be argued here that attention to this R&D/production interface has to be increased and a model to analyse this interface will be presented.

2. The Need For a Good R&D/Production Interface

The ultimate goal of every innovation effort in general, and the improvement of the R&D/production interface in particular is to make an economic profit through building up a competitive advantage in the market place.

One of the elements which can provide such a competitive advantage is the appropriate choice of the combination of product and process technology. In theory, the process technology choice is a fairly simple concept. For every given product there exists a variety of interchangeable combinations of capital and labour, which are equally efficient depending on the relative prices of capital and labour. This assumes explicitly that alternative technologies exist, that they are available that decision makers know about the existence of these alternatives, (Tornatzky et. al., 1980), and that the choice can be made in an explicit economic model. Each of these assumptions proves in practice to be somewhat doubtful. Rosenberg (1976) suggests that the range of production possibilities for most products is limited to relatively major choices, modified or augmented somewhat by R&D. For all practical purposes, for example, there is currently only one way to refine oil, and it is very capital-intensive. In discrete parts manufacture there are greater possibilities for variations in the final products and generally less interdependence between the subcomponents of the production process. As a result, a greater variety of production alternatives becomes available. In assembly operations, technologies may vary from worker-paced to machine-paced assembly lines, or approach flexible manufacturing systems. However, even in such cases, the choice of product and process technology cannot be separated. The evolution of the technological life-cycle, competitive characteristics of the product (cost or performance oriented) determine a common product-process approach (Abernathy,1978).

The assumption of the economic model of technology choice about the process of decision making is equally oversimplified. Even when the model considers inputs beyond just capital and labour inputs, such as energy or know how, the level of which these inputs are considered are quite abstract. Labour is often undifferentiated as to skills, motivation, entrepreneurship, flexibility and creativity. Similarly, various characteristics of the capital equipment such as reliability, ease of use, maintainability and system compatibility are barely considered. Moreover, the basic assumption of profit maximization as the only significant decision criteria is equally untenable. Studies about the implementation of FMS systems (Gerwin and Tarendeau, (1984), Voss (1984)) or the use of process technology by multinationals in developing countries (Morley and Smith, 1974) indicate clearly that factors other than profit maximization are more important in the final decision.

If product and process technology are closely interwoven, if choice of technology is more than an economic trade-off, but involves elements such as organizational learning, confidence in suppliers, etc., the decision about process development and implementation is clearly one which requires a close interaction between the partners in technology. One could even go a step further and conceive of the idea that a separation between R&D (the "product" specialists) and production engineering (the "process" specialists) is an artificial separation. The importance of this product/process technology decision and its implications for the competitive position of the company would even ask for more than paying attention to a production/R&D interface, and would require the complete fusion of R&D and production in a technology function.

A second element which requires a close cooperation between R&D and production is related to the concept of the product life-cycle. In numerous publications (Bergen (1983), Twiss (1980), Souder (1984), Urban and Hauser (1980)) it is indicated that the cash flows generated during the life-cycle follow a pattern as depicted in figure 1. - It will be clear that this picture provides only a framework and is in no way a reflection of the cash flows of an actual project.-

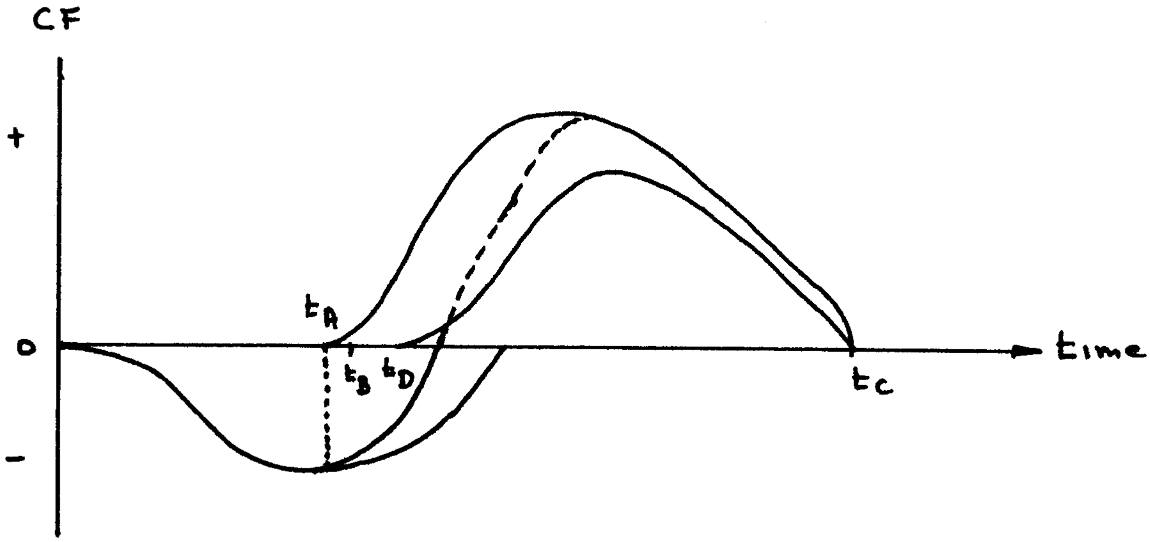

Figure 1: innovation project cash flows

The curves only show that investments increase when one comes nearer to the launch of the product in the production and the market and that if the product launch is successful, positive cash flows will show up from the moment that investments are less than incoming cash flows. From that moment (time t_B), the curve of the cumulated cash flow will start to go up. The figure also suggests that positive and negative cash flows are not in phase and that, taking into account that the average duration of innovation projects is approximately 8 years (Urban and Hauser, 1980), the company might have to finance the development over quite a long period. Finally, the picture suggests also that there is no direct relationship between the maximum cumulative negative cash flow and the final (positive) cumulative cash flow.

If now, for any reason, the launch of the product is postponed from t_A to t_D, and assuming that the end of the positive cash flows (t_C) is determined by exogenous factors, e.g. substitution products, new generations of technology, etc., or at least is independent of the launch date, then it is clear that the breakeven point will be delayed, or might never be reached. The curves suggest moreover that the delayed introduction has a more than linear effect, since it is the bigger positive cash flows (due to, for example, monopoly positions, or price-inelasticities at the beginning of the product launch) which will be missed.

The issue at stake here is the speed with which, once the product is designed, it can be transfered to production, and the rate at which the production can be built up. the objective of a good working R&D/production interface must be precisely to increase this speed of transfer and start-up and to decrease the delay of the product launch Bergen (1983) provides some data to illustrate these differences. he indicates that for the generation of a new instrument, such as a spectophotometre, it took British and American companies about two years to develop the product. this product was launched on the market by the U.S. companies, four months after the completion of the manufacturing drawings, while it took the British industry ten to fourteen months more than this. This, combined with a typical product life-cycle of five years on the market, after which advancing technology and the activities of the competitors, rendered them obsolete, creating reasons for believing that the U.K. scientific instruments industry has a handicap.

To the absolutely reduced cash flow generation due to delayed introduction, one can add the opportunity losses due to an inability to transfer from t_B onwards, resources from this project to new projects. As a consequence, lateness in the programme tends to be cumulative. Though in some cases, "me too" can be a conscious strategy, this logic suggests that it can be the consequence of a lack of choice due to an inability to reduce the speed of prototype transfer and production start-up.

This whole aspect tends to be aggravated if product life-cycles are shortening. The popular business press (Fortune, Business Week, etc.) tends to suggest that product life-cycles are shortening across the board. Concrete data to confirm this hypothesis is lacking, but the perceptions of some 600 of the world's largest manufacturers tend to support this view, (table 1).

TABLE 1: Change in the length of the product life-cycle over the last five years as perceived by large manufacturers (in % of total number of responses).

Trend	Europe 1983 (n=153)	Europe 1984 (n=154)	North America 1984 (n=214)	Japan 1984 (n=198)
Substantially decreased	3.4%	5.3%	8.1%	16.4%
Somewhat decreased	26.8	28.9	33.3	40.8
Remained about the same	56.0	50.8	43.6	28.6
Somewhat increased	12.0	7.9	13.3	7.1
Substantially increased	1.9	6.6	1.9	7.1

Source: De Meyer (1985)

Indeed, although in Europe, about 50% of the respondents perceived no changes in the length of product life-cycle of their products over the last five years, another 35% see a minimal to substantial decrease in it. For the U.S. and the Japanese manufacturers, respectively 40 and 50% of the respondents perceive a decrease of the life-cycle of their products. In such an environment, the fast transfer from prototype stage to production and introduction onto the market become all the more decisive in the survival of the company.

Yet another important element of the interface between R&D and production has to do with organizational learning. In describing the work of the IRI study group on the R&D/production interface, its chairman, K. McHenry summarizes his experience in three premises (Wolff, 1985):

1. The manufacturing/R&D interface is healthy only when technology transfer occurs in both directions ... I believe there is a lot R&D can learn from manufacturing and hence there has to be a two-way transfer.

2. The transfer to manufacturing is ony complete when the process is on-stream and reliably operating to produce a specification product that's being sold to the customers at a profit ...

3. the transfer back to R&D from manufacturing is only complete when R&D is able to improve the performance of its mission of providing technology for the firm's benefit.

The gist of these premises is that both parties can learn quite a lot from each other, and that in particular the double loop learning (Argyris, 1977) of the organization can benefit a lot from a close interaction between R&D and manufacturing. This idea is often summarized in the requirement of "design for makeability." i.e. make efficient manufacture an explicit element in the product design process. (Rothwell and Gardiner, 1983). Their description of a number of failures and successes of R&D/production integration leads to the following characteristics of this design for "makeability."

- a greater propensity to link product design to the requirements of the production sequence;

- inclusion of the requirement for efficient manufacture in the initial design specification,

- the constant questioning of traditional production methods;

- increased propensity to produce ranges of machines with a high commonality of parts;

- recognition of the importance of linking product/market strategies to the requirement for efficient manufacture;

- an increased manufacturing flexibilty or the capacity of the production sequence to accomodate changes in product characteristics.

To conclude, there is a clear need to improve the interface between Manufacturing and Research and Development (1) to increase the total amount of cash flow generation and to advance the moment when positive cash flows will start to flow in; (2) to cope with shortening product life-cycles; (3) to build in a "design for makeability" attitude and (4) to provide a better balanced choice of product/process combination.

The latter element would even call for distancing the concept of an interface, and for the creation of a technology function which bridges the application of technology choice and implementation in product and process.

3. The Barriers Between Production and Research and Development

The barriers between Production and Research and Development usually find their roots in what Lawrence and Lorsch (1967) described as the differentiation between different parts of the organization. As one will recall, they made a distinction between three groups in the company - sales, production and design; and came to the conclusion that these groups differ on a number of dimensions such as time horizon, orientation towards others and orientation within the group, degree of formalization of authority structures, etc. These different orientations are an immediate source of lack of understanding and conflict.

These ideas have been supported by Prakke's study (1973) which shows that R&D managers consider a long term orientation to be a lot more important than managers of other functional areas. Faas (1982) reports that the R&D managers he interviewed consider that their role is perceived by their non-R&D colleagues as that of a saviour, who can intervene on condition that there are enough resources available, while they perceive themselves as the structural backbone of the company. Conflicts around budgets, allocation of resources etc. are consequently inevitable.

The translation gap between R&D and manufacturing has been described thus: "within its bounds occurs the inevitable confrontation of human resistance to change, urgency to meet product schedules, new technology infusion into products, interdisciplinary language problems, continuing design alterations, and corporate cash commitments. (Wolff, 1985). McHenry notes in the same article that manufacturing resistance will increase in the following order:

1. Making changes in an existing process to make existing products;

2. Introducing a new technology to make existing products;

3. Improvement of an existing process to make new products;

4. Introduction of a new technology to make new products.

It is striking that he thinks that introducing a new process technology creates less resistance than introducing a new product. The reason for this is that for the new product the request often comes from a third party, Marketing, which adds to the complexity of the change.

Roberts and Frohman (1978) indicate that the transfer at the interface between R&D and manufacturing requires the transfer not only of knowledge, but also of enthusiasm and authority over resources. Enthusiasm is preemptively a characteristic of people, which is difficult to transfer if the people themselves are not transferred. Moreover, knowledge exists of two components: the "hard" knowledge or the information which is registered in design specifications, drawings and memo's and the "soft" knowledge or the information about technological choices which have been made in the past, or about development routes which have been considered but abandoned and which are never put on paper, and remain embedded in peoples' minds. All this suggests that one of the barriers at the level of R&D/manufacturing interface is inherent in the impossibility of organizing it with systems and procedures.

4. A Framework For Improvement

Suggestons for improvement have often been the reflection of the remedies proposed by Lawrence and Lorsch (1969) or Galbraith (1973) to integrate between different functions. Twiss (1980) suggests for instance the adoption of liason groups, cross transfer of personnel task groups and new product departments. Roberts and Frohman, (1978) propose on the basis of their own experiences, the creation of "bridges" along three dimensions:

a. the procedurial bridges, including joint planning, joint manning and joint appraisal of innovation projects;

b. the "human" bridges, through lateral rotation, stimulation of informal contacts, the creation of liason roles or groups;

c. the "organizational" bridges, or specialized transfer teams, internal venture teams, stimulation of internal entrepreneurship.

Bergen (1983) blames the differences between the U.K. and the Federal Republic of Germany on the lack of adequate engineering training in the U.K. Consequently he suggests that the government has a crucial role in changing the British educational system to produce more innovative engineers, who are more aware of product and production engineering. He also emphasizes the commitment of FRG engineers to engineering systems and standards which have been more productive than the U.K. penchant for individualist innovation.

We would like to propose here a framework to stimulate an improved R&D/production interface (as suggested in figure 2).

The ultimate goal of a strong R&D/production interface is obviously the short and long term performance of the company. In this specific case this means the return on investment of the innovation project on its own as short term goal, the contribution to the competitive position of the company as a long term goal. This latter contribution is of course a fairly general concept, but it can in the case of the R&D/production interface, be operationalised indirectly through the evolution of the company's market share over a long period of time, the spin-off effects in terms of process improvements and product changes for other product lines of the company, and the cash flows created immediately after the product introduction, and which are available for other innovation projects. It can be taken for granted that all these long term contributions are not solely due to a better R&D/production interface. Good marketing, the professional launching of the product, the uniqueness of the product's performance characteristics are probably as important to protect and improve the market share. But the interaction of production with other functions in the company will definitely contribute to it. And again, the positive cash flows realized immediately after the product introduction are obviously related to the characteristics of the product and the professionalism of the product launch. But here one can argue that a badly performing R&D/manufacturing interface will definitely delay product introduction. As was discussed above, this does not mean a mere delay in the cash flows, but implies that part of the cash flows will be lost. In this case the R&D/manufacturing interface is directly responsible for creating the opportunity to generate this cash flow.

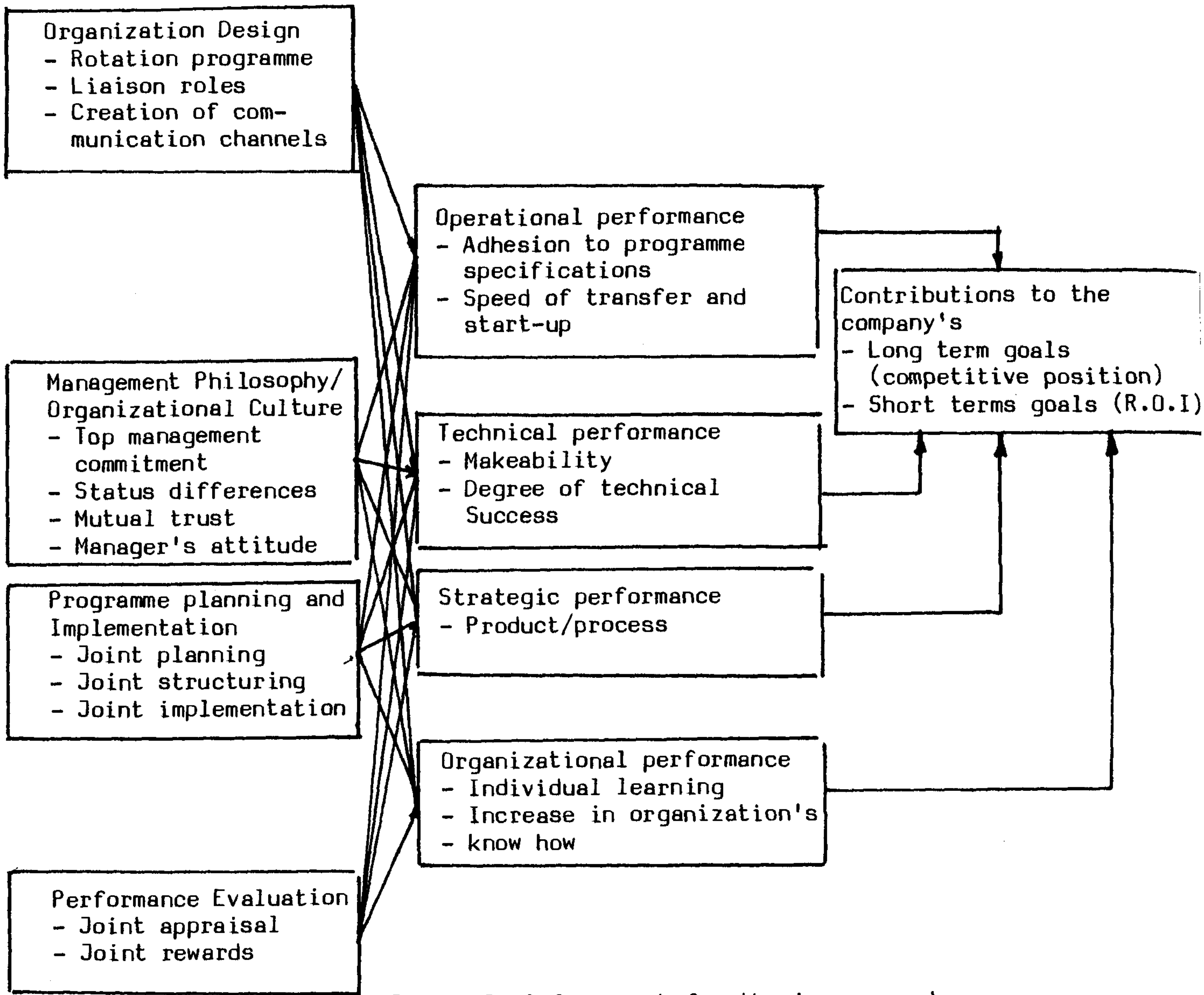

Figure 2: A framework for the improvement of the R & D/production Interface

This contribution to the company's objectives is a consequence of the performance of the R&D/production interface. Reflections on why one needs to pay attention to this interface provides insight into these performance dimensions. The first dimension reflects the operational performance:

a. how well was the company able to adhere to the original project planning, or in other words, how large was the project slippage related to the transfer and the production start up and,

b. what was the absolute "speed" of the transfer and the start up as compared with the overall project duration.

A second dimension is what one could call the strategic performance, i.e. how well do product and process fit in with each other. This is again a subjective measure, since the degree of fitting in between the product and the process is difficult to measure. One approach here could be to compare the product's relative position vis-a-vis its competitors in terms of production efficiency, flexibility, quality and reliability to the goals set at the start of the innovation project.

A third dimension relates to the technical performance, i.e. what is (a) its makeability, which could be reflected in the number of engineering change orders, released after the transfer from R&D to production and (b) the technical success, or to what extent the technical performance of the production process meets the expectations.

The fourth dimension determining the contribution to the company's performance reflects the learning process: to what extent did technologists and the R&D organization learn something from the product transfer and start-up.

These four dimensions in their turn can be controlled by a number of operating variables which again can be classified in four groups.

The group of variables most often mentioned in literature, (Roberts and Frohman, (1978), Lawrence and Lorsch (1969)) are the ones related to the organizational structure: rotation programmes, liason roles, creation of communication channels. The second group is related to the management philosophy and the company culture. Bergen (1983) stresses the differences between the German Ing. Grad. and the U.K. engineers and provides supporting data to the hypothesis that projects managed by German Ing. Grad., who went through an apprenticeship in production, have a better chance of success. In these projects there was also a higher absence of status consciousness.

In his study of the R&D/marketing interface, Gupta (1985) indicates a number of factors which influence the quality of this interface which can generally be related to the confidence which the R&D and Marketing Manager have in each other. It is hypothesized here that a similar trust factor is present at the R&D/production interface.

A third group of variables is related to the planning and implementation of the innovation programme. Bergen (1983) emphasizes the need for participation of manufacturing in the product design and the clarity of the common problem definition joint planning, structuring and implementation of the innovation project.

The fourth and last group of variables is related to the performance evaluation of the project members. As Roberts and Frohman (1978) suggest: a joint appraisal and reward system for the technologists at both sides of the interface, will definitely stimulate cooperation.

5. A Research Proposal

We propose to verify this framework on a small sample study of about fifty projects. In principle we aim at ten companies in two industries, (one process, one discrete products oriented) in which five projects of transfer would be studied.

In the description of the model it was indicated how most of the dimensions and variables would be operationalized. For most of these operationalized variables the measurement instruments exist or they are obvious.

The data will be collected through the interviewing of at least two persons (one from R&D, one from production) on the basis of a semi-open questionnaire which is reproduced in appendix 1.

Appendix 1: Questionnaire

A. Description of the Project:

- goal
- partners involved
- technical problems to be solved
- history of the project
- outcome

B. Project Contribution

- R.O.I. if known / other financial evaluation measures
- spin-offs and eventually their return on investments
- improvement in competitive position: leade turn over the competitors, increase in market share, etc

C. Operational Performance

- comparison of budget and time planning with the actual performance (are deadlines met, budget limits exceeded, etc.)
- lead time in the transfer between R & D and productive
- number and type of crises during the transfer stage

D. Technical Performance

- number of ECO's after the transfer
- general appreciation of the makeability
- number of manual operation (assy) required
- number of pilot plants needed
- time span of pilot plant or prototype production

E. Strategic Performance

- availability of process at product introduction stage
- fit between process and market

F. Organizational Performance

- experience curve effects in product introduction

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LIST OF INSEAD RESEARCH WORKING PAPERS

80/01 "Identifying cognitive style determinants of retail patronage, by Christian PINSON, Arun K. JAIN and Naresh K. MALHOTRA, January 1980.

80/02 "Dimensions culturelles des conceptions de management - une analyse comparative internationale", par André LAURENT Février 1980.

80/03 "Cognitive style and effective communication", by Arun K. JAIN, Naresh K. MALHOTRA and Christian PINSON, Dec. 1979.

80/04 "Accomodative cognitive style differences in consumer reduction of alternatives", by Naresh K. MALHOTRA, Christian PINSON and Arun K. JAIN, October 1979.

80/05 "Stability and reliability of Part-Worth utility in conjoint analysis : a longitudinal investigation", by Arun K. JAIN, Naresh K. MALHOTRA and Christian PINSON, September 1979.

80/06 "The expected future spot exchange rate, the forward rate, and the trade balance", by Charles A. WYPLOSZ, March 1980.

80/07 "Decline and adjustment: Public intervention strategies in the European clothing industries", by José de la TORRE, July 1980.

80/08 "The uncommon market: European policies towards a crisis industry - clothing in the 1970's", by José de la TORRE and Michel BACCHETTA, May 1980.

80/09 "Stratport: a decision support system for strategic planning", by Jean-Claude LARRECHE and V. SRINIVASAN, April 1980, Revised October 1980.

80/10 "A new approach to market segmentation strategy: a banking application", by Arun K. JAIN, Christian PINSON and Naresh K. MALHOTRA, March 1980.

80/11 "The exchange and interest rate term structure under risk aversion and rational expectations", by Charles A. WYPLOSZ, Revised Version, September 1980.

80/12 "Individual cognitive differences in MDS analysis of perceptions", by Arun K. JAIN, Naresh K. MALHOTRA and Christian PINSON, July 6-12, 1980.

80/13 "STRATPORT: A Model for the evaluation and formulation of Business Portfolio Strategies", by Jean-Claude LARRECHE and V. SRINIVASAN, April 1980, Revised November 1980.

80/14 "Les styles cognitifs : une nouvelle approche de la segmentation des marchés, by Christian PINSON, Naresh K. MALHOTRA and Arun K. JAIN, Septembre 1980.

80/15 "Cognitive styles: A new approach to market segmentation", by Christian PINSON, Naresh K. MALHOTRA and Arun K. JAIN, March 1980.

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81/02 "Alternative approaches to the theory of the banking firm: a note" by Herwig LANGOHR, September 1980.

81/03 "Why does beta shift when the length of securities returns varies?" by Gabriel HAWAWINI, December 1980.

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81/05 "On some propositions regarding the behavior of the labor-managed firm under uncertainty" by Gabriel HAWAWINI, Jan. 1981.

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81/07 "New evidence on beta stationarity and forecast for Belgian common stocks" by Gabriel A. HAWAWINI and Pierre A. MICHEL, February 1981.

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