Implementing Computer Based Manufacturing Innovations

by Robert Drazin
and Robert Kazajian

Columbia Institute for Tele-Information
Graduate School of Business
Columbia University
809 Uris Hall
New York, NY 10027
(212)854-4222

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Robert Drazin
Robert J. Kazajian

Graduate School of Business, Columbia University
Graduate School of Business, University of Michigan

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ABSTRACT

The implementation of manufacturing process innovations is explored in a case study and associated theory development: The case study focuses on the processes and organizing approach used to develop a successful proprietary parts planning process. The issues of the case are analyzed using a framework that considers the nature of the innovation, organizational structure, staffing, leadership, and process.

Introduction

The past decade has been marked by a profound shift in the way U.S. firms do business. Spurred on by a loss of competitive strength to Europe and Japan (Business Week, June 30, 1980), we are currently witnessing a return to the fundamental principles of value added in the products we market. The major arena for this long awaited response is in manufacturing and the age of the Factory of the Future is now.

There is a necessity, as never before, for our plants and factories to achieve high performance levels on many criteria. No longer is cost reduction sufficient, we must now consider flexibility, quality, worker demands, and resource scarcity simultaneously (Skinner, 1982). These are combinations of outcomes previously believed to be difficult, if not impossible to pursue at the same time (Skinner, 1974). Significant technological advances, in the form of Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM), programable robots and material handling and planning systems offer the capabilities to achieve these goals. Efforts by capital equipment vendors, internal corporate development teams and universities have provided us with the basic knowledge. The problem now appears to be how to best implement these technologies in ongoing social settings.

The issues that are involved are primarily ones of information processing. Consider General Motors decision to manufacture the Saturn car to compete with the Japanese on quality, cost and high technology design. The development of this car is primarily a manufacturing process innovation. It required the merger of GM with EDS, a computer firm, because the new manufacturing process are essentially information processing based. The new manufacturing technologies, particularly in design, engineering and parts planning, require extensive data processing logic involving Artificial Intelligence at times.

What steps can the manufacturing manager take to control process innovation? The focus of the past twenty years of research on innovation has been on new product development (Cooper, 1983) and on managing the basic research process (Tushman, 1979). We need a guiding framework for managing process innovations, that recognizes their basic nature and how they differ from product or technology innovations.

It is our belief that manufacturing innovations can be aided by designing an organization that is appropriate for that purpose. Such a design should incorporate an up-to-date understanding of structure, rewards, team development and managerial process that lead to successful manufacturing innovation efforts.

This article describes the design of organizational mechanisms geared toward process innovation. A case history from the aeronautics industry is presented first to provide an illustration of the components of our framework. We then analyze the case by describing the key organizational choices the manager made and develop a theory of designing for process improvement.

I. A case of successful Manufacturing Process Innovation

The innovation in question is called Compu-Plan. Compu-Plan is a proprietary process planning system capable of analyzing the production of a product and then generating full process plans for fabricating machined parts and subassemblies. In contrast to existing computer based systems, which simply store standard process plans for later modification, Compu-Plan actually contains manufacturing logic. Compu-Plan determines the sequence of operations, selects the proper machine tools and calculates machining times.

The primary figure behind Compu-Plan is Bill Maxton. At the time Bill first conceived of a computer based parts planning process, he was an assistant manager in the planning control department of the manufacturing engineering division of a major aircraft producing firm. Based primarily on his innovative efforts in bringing computer technology to existing operations, Bill was appointed manager of the Computer Aided Manufacturing department. It was in this capacity that he began an earnest pursuit of launching Compu-Plan.

Parts process planning had always been a target opportunity at the company. Under the old system, individuals, called parts planners, took the designs of aircraft components and translated them into the appropriate routing and operation stages. Most of this very essential work was largely accomplished via the traditions of how each part planner had learned the skill. Several factors underscored the need for change in this area:

- the function of process planning is labor intensive with process planners paid at the highest hourly labor grade.
- process planners take 7-8 years to train as the function is very much tailored to the requirements of a specific manufacturing site.
- every part invented for a new airplane requires planning for production and changes are frequent, resulting in re-work.
- parts planning is a highly idiosyncratic function. If you give 10 planners the same drawing you will get back

10 different plans. Inconsistency across plans leads to a proliferation of unnecessary variety, waste and inefficiency.

- finally, the core of planners at the company were all older, many with 25 plus years experience. The company faced the prospect of losing its knowledge base with a series of close retirements.

With the parts planning process justifiably targeted for innovation, a project team was started. Bill Maxton consciously attempted to include a variety of skills, backgrounds and ages. His first step was to enlist several experienced, respected parts planners, who had years of on-the-job experience and could serve as the data base for the existing methodology. They were chosen not only for their knowledge and competence, but also with an eye toward implementation and acceptance as well. It was felt that other planners would see the merits of change if these individuals were involved and positive in their outlook. One of these planners was considered the company's "300 year old man."

A second addition to the team was a group of three advanced co-op students from the local technical university. Their primary purpose in the project was to interview parts planners about what they did and why. Bill explained their involvement as being those who "didn't know it could be done."

Other members of the team included Chris Johannsen, a recent college graduate with excellent analytical skills. While he joined the project 9 months later than the others, Chris quickly established himself as a technical leader by breaking a major early hurdle in coding and logic. Also at this time it was felt that a full-time programmer was needed on the project. Bill convinced the Data Processing people to hire a Fortran programmer and assign her full-time to the Compu-Plan group. This resource completed the team and provided all of the elements to develop a first application.

Another key figure, not part of the team itself, was Alex Taylor, Vice-President of Operations, who ran manufacturing during the period of Compu-Plan's development. Alex was described as a believer in MBWA - management by walking around - would make periodic tours around the floors. On one such tour Alex and Bill discussed the beginning of the Compu-Plan idea. From then on Taylor supported the project both directly, through his attention and indirectly through provided key resources and support decisions.

The first area Bill instructed the group to work on was the most difficult, machined parts. It was felt that if this could get accomplished, a total was possible. The first nine months of the project focused on conceptual and background research. Various existing schemes including CAMI-CAPP, OPITZ and others were reviewed and found to be stimulating but deficient. Chris Johannsen's breakthrough in coding and logic design allowed the group to proceed toward the goal of first application. However, problems were encountered which hindered the progress of the team.

The first source of strain came between the project team and the Data Processing (DP) division which controlled the computing and programming resources. Overtures were being made to the recently hired programmer to return to DP (who were paying her salary), and become more functionally oriented. Members of the Compu-Plan team felt that the project's capability and potential was becoming known, DP was trying to get a piece of the action. Bill Maxton intervened to retain control of the programmer but this solution was short-lived. Just about the time when Compu-Plan was scheduled to first go line the programmer quit. Rumor had it that she felt ignored and unappreciated and wanted to start her own firm using the Compu-Plan idea. This caused a six month delay. In the rush to demonstrate the program there was little attempt at documentation. Bill Maxton added four full-time programmers who work with the CAM department (not DP).

Another problem arose at a meeting of manufacturing managers from all the plants. Maxton's claims about Compu-Plan were met with disbelief. In fact at the meeting, Maxton was all but called a liar. These challenges led the team to plan a series of demonstrations which were very successful in establishing Compu-Plan's early credibility.

Several factors associated with how the project was handled also contributed to its successful implementation, and the avoidance of resistance which might have developed. First and most obvious was the structure of the team. Maxton managed to get a good mix of experience and energy. By using experienced, respected planners to develop a new planning technology, they established much better credibility.

Additionally, the project was managed incrementally. In the very early stages, Tulkoff set small intermediate goals to establish success. Once the methodology was established, applications were put up sequentially and always parallel with the manual system for a trial period. Additionally, as soon as a capability was established, it was put onto the CRT. From early 1977, planners were using the CRT for a largely manual system, but establishing the first interface was seen as critical. From there, Genplan somewhat grew underneath them.

Attempts were made to make Genplan very user friendly. As each planner signed on he was greeted by the computer with his nickname. Additionally, a "trouble desk" was established so that planners could go somewhere with questions or problems without having to go to their supervisors and be concerned that they were being seen as incompetent.

One indicator of the degree of acceptance of this new technology is suggested by a story regarding open house. As many firms do, Geloc sponsored a social and open house for the families of employees on a weekend. Prior to the day, the planners themselves requested that the computer be up so that they could give demonstrations to their families, taking pride in a new skill of working with the computer. There has been some resistance by some slow to adapt but overall acceptance is seen as good.

An area where Compu-Plan met surprising little resistance was with the process planners themselves. The new technology was adopted enthusiastically and process planners even showed off the new system to their families. Part of the design of Compu-Plan includes a "user-friendly" interface, a "trouble desk" where planners can at any time bring problems to the team and other support services, such as education and downstream.

Compu-Plan is currently very successful. From 1978 to 1982 the company estimates saving millions in labor efficiencies, increased productivity, material savings, etc. The system has been extended to other processes and to other plants and subsidiaries. Currently the process is also being marketed externally for sale to other manufacturers. Also, it has dramatically decreased the time it takes to train a parts planner, from 7-8 years, to 1-3 years.

II. Analysis of Case: An Integrating Perspective

Our analysis of the key management choices in implementing Compu-Plan focus around an integrative model of innovation we have been developing (Drazin and Kazanjian, 1984). The key components of the model are shown in the figure. Our approach here is similar to the more general approaches described by others, but accounts for the specific issues related to creating and implementing process innovations.

The model consists of three major components: 1) the nature of the process innovation, that is, how related the process innovation is to existing manufacturing knowledge; 2) the choices of organization design taken to implement the innovation -- structure, staffing, reward systems, and management processes; 3) the outcomes associated with the innovation effort. Our analysis of the success of the Compu-Plan innovation will revolve around these factors

Insert Figure 1 Here

The Nature of Process Innovation

Manufacturing process innovation differs substantially from most product innovations. Product innovation is typically less constrained in the development of a new product we can virtually design from scratch, if necessary, new distribution channels, new manufacturing sites and new underlying technologies. The organization design problem for product innovation is to create a large degree of separation of the innovative task from ongoing resistive corporate cultures. Creativity is the major problem and eventual integration with the current system a secondary issue.

However, in process innovation we must attend much more closely to the existing manufacturing organization. Typically, the product does not change, most people do not change, and issues of implementation, relative to creativity, become more critical. The failure of many process innovations comes from treating them as if they were product innovations and designing them as though they were free of the constraints and concerns of the current system (see Galbraith, 1981).

The Compu-Plan innovation had the characteristic of being closely related to the existing knowledge base of the organization. All the manufacturing logic for parts and process planning resided with the existing technical staff of parts-planners. While the innovation itself is computerization, it relies heavily on the current organization to inform the system of its detailed data and decision-making approach. Often, implementing information processing innovations requires the transfer of knowledge from professional, or semi-professional groups to the computer. We would expect such groups to be naturally resistive to such changes, and the loss of power and control they apply. Without the cooperation of parts process planners, the Compu-Plan system could not have proceeded as well as it did.

Thus, the driving issue governing management choices in developing process innovations are their relatedness to the existing system. Management must structure, staff, reward and handle process issues to deal with this relatedness.

Structurally Supporting The Innovation Process

Organizational processes, especially those associated with innovation, change, and strategy formulation are impacted by the structural and political context in which they occur (Benson, 1977; Fredrickson, 1983; Normann, 1971). Support for the diversification process occurs primarily through the provision of an appropriate organizational context that will allow for both the development of new business ideas and for their subsequent integration into the system.

We argue that the Idea Generation phase of the innovation process can best be supported by structurally separating those individuals and units responsible for knowledge development apart from the activities of the current domain. We further argue that once separated, coordination and integration mechanisms must be established to facilitate appropriate funding and review decisions. The degree and form of differentiation and coordination is dependent on the level of knowledge development implied by the Strategic Context.

The prescriptive literature in the innovation area has persisted in developing a bi-polar perspective on production oriented versus innovative types of organizing (Galbraith, 1982; Burns and Stalker, 1961), without addressing the inconsistent demands that result from the simultaneous pursuit of two domains. While exceptions have appeared in the literature on managing technological innovation (Fusfeld, 1978; Tushman and Moore, 1982; Burgelman, 1983), the majority of thinking in this area has addressed the design of single business enterprises only and not the firm attempting to innovate within a larger bureaucratic context.

Recently, certain arguments have emerged that advocate structural differentiation as an organizational strategy for innovation and diversification. Ansoff and Brandenburg (1971), Van de Ven and Delbecq (1974) and Hirrigan (1983) have all recommended that strategic development be located apart from strategic expansion (current market innovation). The reasoning behind this is that maintaining the current business involves the incremental modification of existing products to promote segmentation and penetration, while diversification involves the conceptualization of entirely new products, markets, technologies or production methods. The task in the former is more certain and involves narrow search, limited to known consumption groups, with reasonably defined methods for understanding how expansion should occur (Tauber, 1977). In the latter case of diversification, a broader search is required, normally external to known consumer groups, with a great deal more uncertainty associated with how to gather and process information. Because known, definable activities usually take precedence over unknown, difficult activities (Fast, 1978; March and Simon, 1958) then the co-location of modification and diversification activities will result in the latter not being attended to, or done so inadequately.

We argue that, relative to the current business group, increasing levels of structural differentiation provide for greater capacity to generate non-routine knowledge (Duncan, 1976). The type of knowledge generating structure adopted should reflect the differences in capacity demanded by the targeted innovation and its implied degree of unrelatedness. Organizations that do not sufficiently differentiate structurally are likely to develop uncreative proposals, or proposals that do not adequately meet the demands for unrelatedness. Organizations that over-differentiate and go beyond the level of unrelatedness contained in the diversification strategy, are likely to develop proposals that are seen as too radical, and which have a high probability of never being accepted (Argyris and Schon, 1978; Fast, 1978).

The structural choices generally available for innovation, and their relationship to the level of knowledge development required, are shown in Figure 2. Two separate hierarchies of choices are contained in this exhibit. The first represents a series of within-function structural differentiation options that correspond to the low and moderate levels of unrelatedness (lower portion of exhibit). These within-function choices apply to marketing, technology and production areas, and should be considered as building blocks for an inter-functional team. This inter-functional team is the first level in a more encompassing hierarchy of choices. Beyond task teams the next options consist of separate organizational units containing their own complements of knowledge generating functions. These options are appropriate for the higher levels of unrelatedness usually associated with radical new product development.

Insert Figure 2 about here

In the Compu-Plan project Bill Maxton consciously chose to adopt the within-function team structure. The entire project was conducted in a team/project setting operating physically and organizationally separate from the existing process planning function, yet within the auspices of manufacturing. The team, in a manner very similar to the computer development group described in Tracey Kidder's Soul of a New Machine, was physically housed in a second floor office, "off the beaten path", which eliminated outside interruptions and allowed the team to go into a "Manhattan Project" mode, as they described it.

However, had the team solely been separated in this manner, it probably would have failed. Bill Maxton recognized that without the support and information of the existing process planners, any ideas the group would have generated would have been rejected. To facilitate the acceptance of the new computerized model Bill carefully staffed the team to provide a bridge to the existing organization.

In particular, his choice to have both novice outsiders (the Co-op students) and existing process planners served to integrate well the creative and existing portions of the organizations. The process planners who comprised the team were picked because of the respect they commanded with the other planners, as well as their technical knowledge. As described by Maxton, it would be hard for the average process planner to criticize a system developed, in part, by the best from their group.

Other Staffing Issues

An additional element for discussion is an isolation of the key roles manifested by this innovation. Maxton ascribes to a listing of major roles developed by Ed Roberts (1978), in which the following roles are seen as necessary for innovation to occur:

1. idea generator - this is the person who serves as a spark plug - who sees a better way of doing things.
2. entrepreneur - this is the person who takes the idea and is the one who makes it happen.
3. gatekeeper - this is the person who knows the reality or domain of the innovation. In other words it is the person who knows and champions the old way of business.
4. program manager - this is the person who imposes some order of the entrepreneur chaos. He is the one who manages via the structure of schedules, budgets, deadlines and required inter-unit coordination.
5. sponsor - this is the godfather of the project, the one who nurtures ideas in development and fends off the idea killers. He is typically the provider of the budget.

Prior to discussing who fits which role, it is important to discuss the involvement of the VP of Manufacturing who ran manufacturing during the period of Compu-Plan's development. This VP was a firm believer in MBWA (Management by Walking Around) and as such would take period tours - unobstrusively - around the shop floor. On one such occasion, Maxton caught his attention and discussed some of his ideas about process planning. From then on, the VP made it a point to ask Bill how things were working and what problems were had. The view of several people was that the VP's blessing, and directives at times, ensued the resources that Maxton needed, who at the time was a rather lower level manager. There were times when Maxton was helped and didn't know it, for example, when requests for programming support to Data Processing were made and Data Processing would check with the VP of Manufacturing to determine if in fact Moxton's requests were authorized and were real priorities. Later, the VP became an avid spokesman, bringing top management down for demonstrations and creating visibility for the project. Overall, however, he was not a leader in the project. He saw something good happening and nurtured it without directing, manipulating Compu-Plan in other ways or forms.

In Maxton's view, according to Roberts' role scheme, the VP served as the sponsor. The process planners and technical people on the project served as gatekeepers. Maxton feels that he filled the roles of idea generator, entrepreneur and program manager. A case could also be made for identifying Christiansen as part entrepreneur and as having a considerable portion of the program manager role.

The individuals who filled these roles were rewarded in two ways. First, by the time the project was completed and installed all parties involved had been promoted. Bill Maxton, for example, was put in charge of all computerized manufacturing in the company. In addition, all members of the team received monetary bonuses for completing the project.

It is also worthwhile noting the non-monetary incentives that motivated the group. There were intense feelings of group loyalty, of creating a worthwhile product and of allegiance to Bill Maxton. It appears that these rewards, more than the financial benefits, were the big incentive.

Conclusions

The case of the successful Compu-Plan innovation supports the notion that successful implementation of process innovation occurs when issues of structure, staffing, leadership and rewards are addressed simultaneously. It appears that, from the data of the case, no single factor alone would have been capable of adequately supporting the innovation process in this company. If for example, the group had been organized too close to the existing structure it would have never been capable of being creative. Had, on the other hand, the team been too far removed, it is likely that the existing parts planners would not have accepted the recommended solution.

Staffing, too, appears to be a necessary consideration in managing process innovation. If the team had been built solely from insiders, or outsiders, the blend of skills, competencies and motivations seen in the case likely could not have occured.

But are these issues alone sufficient to bring about change? Other factors, not in our model need to be considered as well. Looking back over Compu-Plan's history, as relayed collecting the data, it appears that there are many other factors which contributed to the prospect of a successful project as well. These factors are in addition to the implementation strategy and other strengths listed above. One factor mentioned by several sources was that the initiation of the project came at the time when the work load was down suggesting that there were more slack resources available, but almost all of that resource was people time. On the other hand, the project ran very lean on other resources, which some cited as an advantage as it did not allow for outside consultants and other diversions. In point of fact, the core of the project was done by 4-5 people in about a year, with others from other parts of manufacturing brought in as needed.

Developing an expanded model of process innovation should incorporate these and other issues as well. In the meantime the guiding heuristic of nature of the innovation, structure, staffing, rewards and process, should remain a useful approach for practicing managers to embellish upon.

Figure 1: Management Choices in Developing Process Innovations

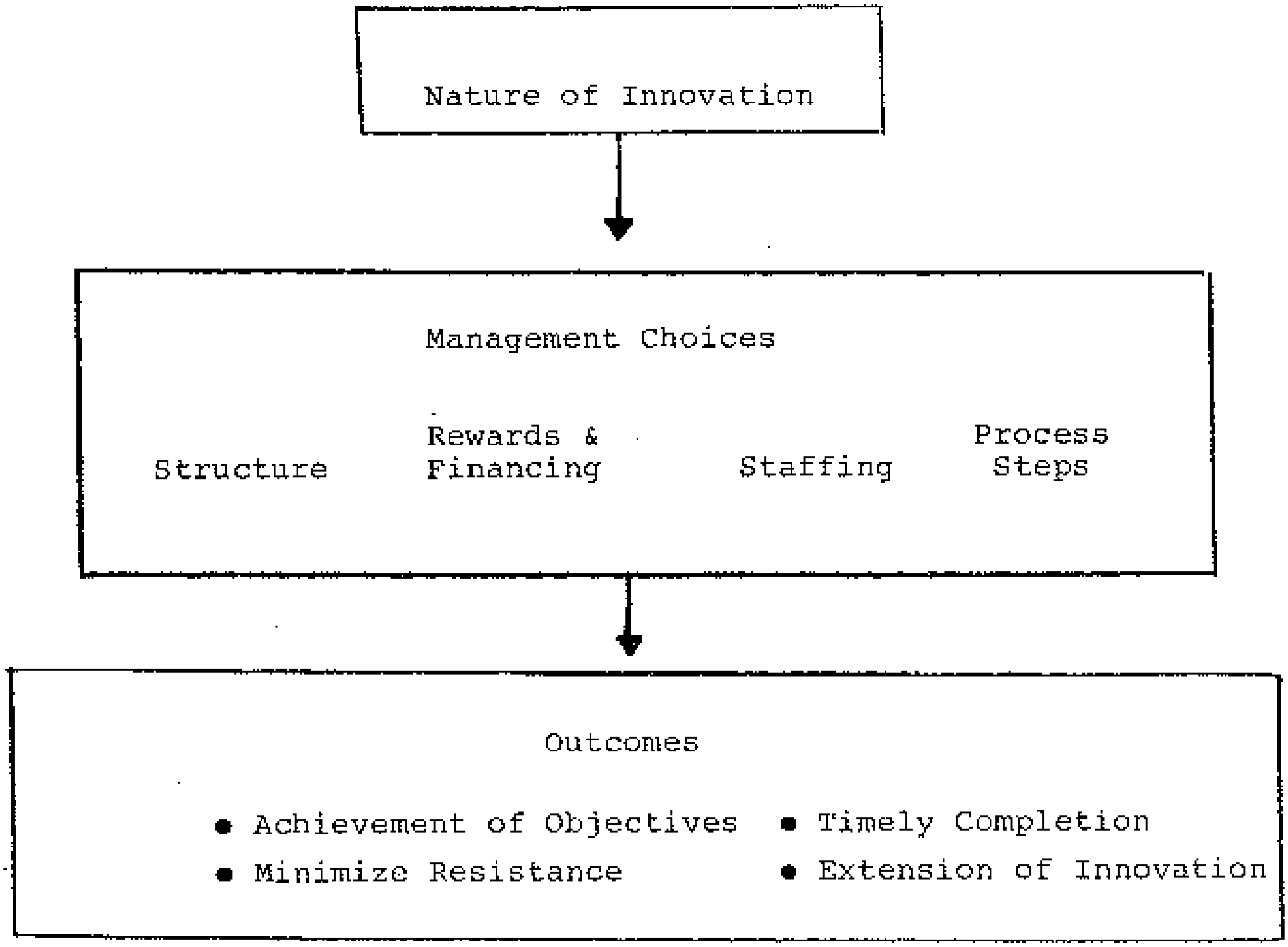
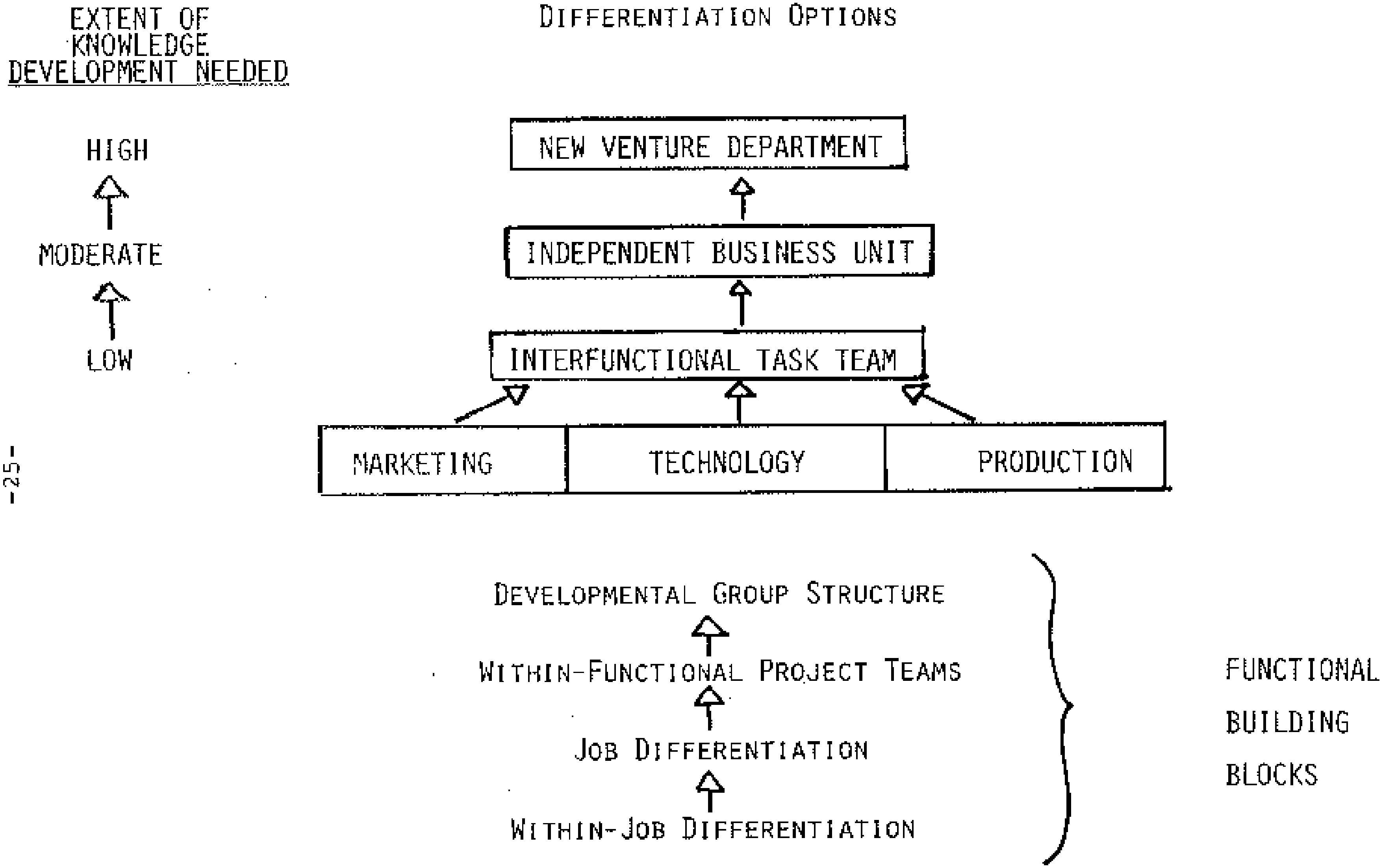


FIGURE 2:

HIERARCHY OF STRUCTURAL DIFFERENTIATION OPTIONS



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Robert Drazin
Graduate School of Business
Columbia University

And

Robert K. Kazajian
Graduate School of Business
University of Michigan

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