A PORTFOLIO APPROACH TO MANAGING TECHNOLOGICAL INNOVATIONS: LINKING SYSTEM DYMAMICS TO ORGANIZATIONAL LEARNING AND GROUP DECISION MAKING

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ABSTRACT

Innovation is a topic that has received much attention in the literature in recent years. For the most part, these articles have not solved an important problem facing the managers in today's large organizations -- how to manage a portfolio of interactive product- and process- innovations , addressing the interrelated forces, including monetary constraints, manpower planning & technology capability, to a dynamic environment. By systems thinking of these problems, the author first set up a generic S.D. model as a Microcosm for portfolio analysis of technological innovations. Based on this Microcosm, an experiment aimed at pattern selection of product- & process- innovations was conducted, drawing the conclusions different from the famous Abernathy/Utterback's. Finally, the mechanism of group decision on project selection of innovation portfolio using the Microcosm was explained, and the group decision support system was constructed.

INTRODUCTION

Due to the important role of technological innovations in determining the long-term success of a company by modifying, replacing, or complementing the company's existing set of core competencies, innovation project management has been a long standing problem in management science, and a considerable literature has been developed. Till now, hundreds of models had been developed and work has continued into the 1990s'. According to Schmidt & Freeland (1992), the literature of which can be divided into two majority approaches : traditional 'decision-event' models (pre-1980) and recent 'decision-process' or 'system' models (after-1980).

Classical 'decision-event' models focus on a decision that is made at a particular organizational level at a particular point in time. They assume fixed criteria and alternatives and have no mechanism for altering the problem whinin the planning cycle. These models are only adequate for routine decisions with a high analytical content (Baker

1974) , and have been virtually ingored by industry on innovation management.

The new system-oriented philosophy rests on the fact that corportate innovation is a system and can be viewed as a set of interrelated subunits that are organized to a goal. It is still in the early stage of development. Several system models have been developed, but there is no one on strategic analysis & decision at the corporate level. No one can priortize decision making around the following goals which can be characterized as, 'What decisions can I make today about a broad range of innovations that will maximize profitability and potential for growth over time?' :

- balancing the long and short term objectives of the firm.

- balancing the source of technology (product vs. process, make vs. buy).

- maintain the balance of the interrelated forces: manpower planning, technology capability and monetary constraints.

- creating an environment that can assimilate changes in the external environment.

- creating an effective indigious innovatiom environment

By systems thinking the above goals, this paper first introduced a generic S.D. model as a Microscosm on strategic analysis of innovation portfolio. Based on this Microcosm, an experiment aimed at pattern selection of innovation will be described. The patterns drawing from our experiment is different from the famous Utterback/Abernathy's (1976), and will play an important role in strategic planning of innovation at the corporate level. Finally, using the Microcosm as a nucleus, the authors give the mechanism & model of group decision making on project-selection of innovations.

MICROCOSM FOR INNOVATION PORTFOLIO ANALYSIS

Microcosm is a S.D. model aided organzational learning due to P. Senge (1990) and J. Morecroft (1988). P. Senge has successfuly developed a Microcosm named CLL on the runaway cost facing an American insurance Co. (Senge 1990), and Morecroft constructed one called BIL for developing strategic analysis of an Bio Industrial Products Co. (Morecroft, 1988). Their research shows that Mocrocosm is an effective tool for analysing large complicated system. Compared with CLL & BIL, Microcosm developed here is different in two ways:

- Modeling the Microcosm in an organizational learning process. Model-building is more important than the model itself. Till now, modelers often construct a prototype first by individuals and then modify it if it is not effective in using or can not be accepted by the users. Model-building cycle is often too long, and the cost is often too high. The Microcosm built here is in an organizational learning process, including the following five steps:

    - individual cognitive maps of beliefs about cause-effect relationships among elements.

    - individual interpretations of environmential response which result in individual learning and updating of the individual maps.

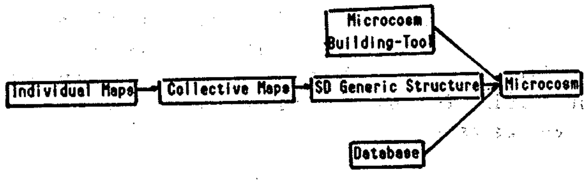
    - sharing of individual maps to form a collective organization.

    - stimulation & test the model.

    - more information sharing and updateing of the collective cause-effect map.

- Modeling the Microcosm using generic structure. Using generic structure to construct the Microcosm for special purpose will largely shorten the developing time (Senge 1990, Paich 1990). In our model, there exists two levels of generic structure. In the functional level, cause-effect of different kinds of innovation (competency replacing innovation, competency altering innovation, competency implementing innovation) and different kinds of manpower planning (product R&D personal, process R&D personal, technicial personal planning) are similiar. And in the corperate level, different corperation has the similar cause-effect of innovation portfolio analysis. The only difference among the submodels having the similiar cause-effect is on the relative coefficient among the varibles. So we first build different level generic structure for innovation portfolio analysis. Based on the generic structure and the database of the corperation, we set up the the Microcosm for special corporation using our Microcosm-building Tool in C language.

Modeling process of our Microcosm is as followes (Fig. 1):



Along with this process, we developed the generic structure for innovation portfolio analysis. Figure 2 presents an overview of the model. It consisted of four interactive subsystems: innovation portfolio, manpower planning, monetary constraints and technology capability. The current model contains 90 equations. Needless to say, the model will not be presented here on an equation by equation basis. Nonetheless, it is possible the essence of the model in the form of somewhat cause-effect diagrams. Figure 3 describes the model in more detail.

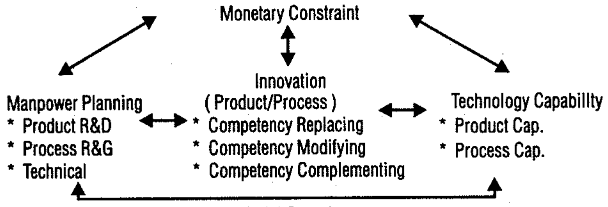


Fig. 2 Model Overviews

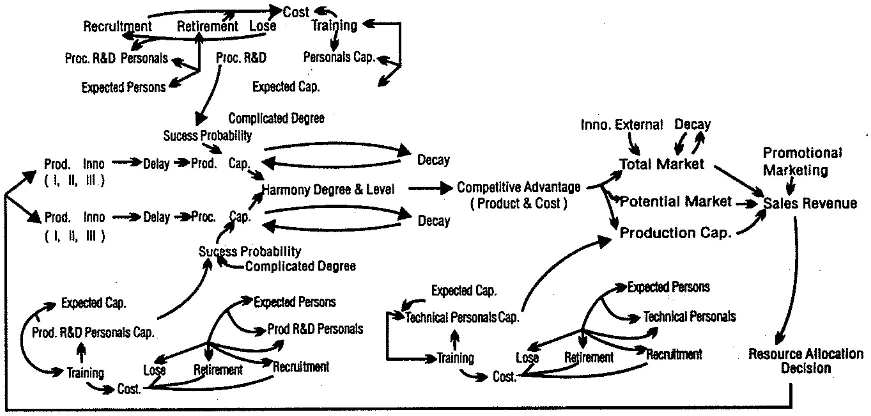


Fig. 3. Detail Structure of the Model

Innovation in this model is categorized into three types by its effect on a firm's core competencies: compentency replacing, compenctency modifying and competency complementing innovations belong to product or process, which make great contribution to its competitive advantage & technology capability. As offered by Louis Rajczi (1991), a competency replacing innovation (innovation I) is thought of as any innovation that changes the dominant design of a product or process (for example: transistor replacing the vacuum tube). It poses a tremendous opportunity for the firm, but with high cost, high uncertainty and needing high innovation capability. Competency modifying innovations (innovation II) are innovations in which an existing product or process is refined in such a way that the dominant design does not change, but one or more of the core competencies that embodies the innovation have been altered (for example: automatic transmission in cars replacing the manual transmission). These innovations are usually driven by a

motivation to better address a segment of the product's target market or an attempt to reduce the cost of the product. Each competency modifying innovation provide firm with some incremental benefit, with low uncertainty & short life cycle. Competency complementing innovation (III) is one in which two or more existing competencies are imbedded in an innovation, needing further development & refinement. It lead to perfect market opportunity, needing lower capability compared to competency replacing innovation.
We suggest that innovation not only generates new information to improve the firm's competitive advantage (product & cost advantage), but aslo enhances the firm's ability to assimiliate and exploit existing information, while its probability of success depends on its innovation characteristics, firm's technology capability accumulation and harmony degree of product & process capability. Resource allocation pattern on different innovations is decided by gaps among three variables: total market sales for all firms, potential market share of the research firm and production capability of the firms according to the firm's technology strategy.

Monetary constraint is more concerned by the researchers among the three ones. Decision of increasing or decreasing funding will have an impact on manpower & capability through innovation. So we take all three legs into account in the model in case to only accepting projects that are affordable in the near term.

Technology capability in this model is categorized into product capability and process capability. Capability improving will not only promote innovations within the firm, but may aslo make the threat of innovations generated outside the firm more apparent, in the meanwhile puting strain on manpower planning & monetary.

Manpower planning, including product R&D personal, process R&D personal & technical personal plannings, is to have enough qualified people to get the work done. Since creative, innovative people are often hard to attract in today's market, this subsystem is even more important. In the model, scale of manpower will be changed by the way of recruitment, retirement and lose , while their capablity is improved by training.

STIMULATION EXPERIMENT FOR PATTERN SELECTION

Using the Microcosm developed , we made an experiment aimed at pattern selection of product- & process- innovation. Two types of pattens are assumed to exist-- short term profit oriented and long term profit oriented. Innovations are selected according to the gaps among total market of all firms (q), potential market share of the hypothetical firm (m) and production capability (k). Selection rules in short term profit oriented pattern is as followes, where 'a<<b' stands for the gap between a & b is too large, and 'a=b' stands for the gap between a and b is too small:

rule 1 If select modifying or complementing,
then if |k-m|/max(k,m)>50%,
then select complementing innovation;
else select modifying innovation

rule 2 If select product and process innovation,
then 50% product innovation, 50% process innovation

rule 3 If k<m, then select process innovation (competency modifying or complementing innovation)

rule 4 If k=m<<q, then select product or process. (Competency complementing innovation).

rule 5 If k>m, then select product innovation (Competency modifying or complementing innovation).

rule 6 If k=m=q, then select product or process innovation (complementing replacing inno.)

while selection rules in long term profit oriented pattern includes rule 1 to rule 7:

rule 7 If select only one kind of innovation (a),
then should consider another kind of innovation.

Making the experiment, we get the results showing in Figure 4 and Figure 5, where the proxy variable of innovation is capability improvement.

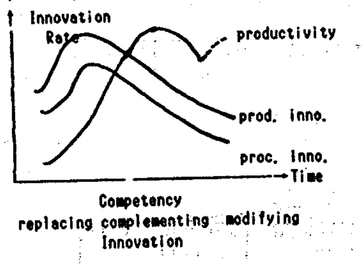


Fig. 4 "short-term" Pattern

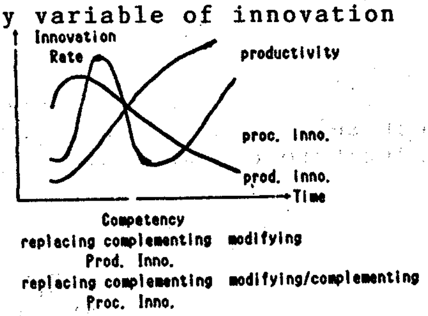


Fig. 5 "long-term" Pattern

Result of "short-term" pattern (Fig 4) is largely consistent with Abernathy and Utterback's arguments. Along with this pattern, productivity of the firm will fluctuate, and it is not so efficient as the "long-term" pattern. So the " short-term' pattern can only be used in SBU. The "long-term" pattern is more suitable at the corperate level. Results of such research would have important implications for the management of innovation.

GDSS FOR INNOVATION PROJECT SELECTION

Group decision has become such a common ways of innovation project selection that most organizations would not know how to proceed without them. In American corporations, middle management is estimated to spend about 35% of their work in meeting while top management may spend 50% to as much as 80% of their time in " an endless stream of committee meetings absorbing countless precious hours" (Lewis, 1987).

The components for general type of group decision making on project selection are as followes:

- A set of decision makers;
- Different set of projects, resulting from possible actions by different decision makers,
- Different set of criteria, for different decision makers
- Set of evaluations, for different decision makers & their criteria to different projects

And it is in fact a multiple participant- multiple criteria decision making process (MPMC).

As offerred by Hipple (1993), a MPMC process can be considered as being involved in the following processes:

- A Single participant-multiple criteria (SPMC) decision process with respect to his or her own set of criteria.
- A multiple participant- single criteria (MPMC) decision process with regards to the interactions with the others.

Along with this idea, we construct the GDSS for innovation project selection on PDP-II in C language. Figure 6 presents the structure of our GDSS:

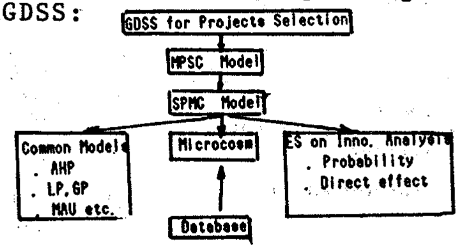


Fig. 6 Logical Structure of GDSS

Is this model, SPMC decision is made in the Microcosm by stimulation . and MPSC decision is made according to the graph model for conflicit resolution due to Fang (1993), while the contribution of the selected portfolio will aslo be shown in Microcosm.

SUMMARY AND DISCUSSION

Existing models of innovation management are largely belong to decision-event ones, which can not solve innovation management problem at the corporation level. By system thinking of the interaction among innovation, monetary, manpower and capability, this paper set up a microcosm for innovation portfolio analysis, with organization learning method and S.D. generic structure method. Result from the experiment conducted with this model shows that short-term profit oriented pattern of product and process innovation selection is consistent with Abernathy and Utterback's and only appropriate at the SBU level. At the corperation level, we should make strategy according to the long term profit oriented pattern of product- & process-innovation selection. This experiment is aslo gave the clue to strategy analysis of innovation portfolio, linking S.D. to organizational learning. Finally, it explained the way to link S.D. Microcosm to group decision support, and set up a GDSS for project selection.

Considerable additional research remains to be done. First , a more complicated environmental model must be linked to an iterative decision mechanism. Such a linkage would facilitate a study on innovation management in decentralized, hierarchical organizational setting.

Aslo, additional research is needed to refine th organizational learning process of Microcosm building . The effective model-buliding tool needs to be developed.

Finally, GDSS for portfolio analysis should be estibilished under the network environment so that it can used effeciently.

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