A Study on the System Dynamics Modeling of Business Technology Management Decision Support System

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ABSTRACT

This paper is a research on the integration of system dynamics, protfolio and scenarios. The prototyping is used in developing the system dynamics model which is focused on the activities of business technology management . At here, we will discuss about the implementation and some simulation results of the BTMDSS model.

Introduction

We majorly adopt three steps in the research. First, develop a system dynamics model which supports the technology management activities . Second, combine the model with the portfoio analysis where the portfolios play a decision making role in the model. Third, make a scenario analysis for the model and conduct a decison making analysis.

First, the system dynamics model will be built by considering the environmental factors of market. The major consideration of business's environment are strategic analysis, operational analysis and resources analysis. And the industrial analysis, competitor's analysis , customer's analysis and products' analysis will be considered in the environment of market .

Second, discontinuous decision loops will be built by applicaton of the portfolio analysis and consideration of the technological environment. By completion of the combination, a base-run simulation will be held by simulaton of the technoloy management decision support system dynamics model. The simulation will show us the behaviors of this model.

Third, a simulation of the scenarios will be held for providing more informations in various conditions. And then, we will discuss how to make decisions of technology management activites by the assistance of the model. The research process is as show in figure 1.

Implementation of the Business Technology Management Decision Support System (TMDSS) Model

The system model is constituted by four parts : decision , technology , market and business's resources. The decision model is constructed by discontinuous feedback loops and the others continuous feedback loops. Figure 2 shows us the construction of the TMDSS model.

Based on those different feedback loops , we could conceptually divide the model system into three subsystems : strategic, information and environmental. The strategic subsystem contains the decision making and decision analysis. The information subsystem contains the technology and business's resources. The environment analytic subsystem contains the part of market. Figure 3 shows the relationships of them.

Construction of the Strategic Subsystem

Portfolio and scenarios are being applied as decision analysis tools in the strategic subsystem. Portfolio (ie. Gorwth-Share matrix) which is proposed by the Boston Consulting Group (BCG) is generally used in handling of the resources distribution. In the system, it will determine two other strategies : marketing and R&D. The conceptual structure of portfolio is as in figure 4. The analysis of

scenarios will assist the model in detecting the possible changes of environment especially when in complex. The conceptual structure of scenarios is as in figure 5.

Depending on the previous two decision analysis structure, we could construct the decision making feedback loops. The R&D policy which contains two strategies - R&D people and R&D. The R&D people strategy is majorly in determining the on-job education and average objective R&D people. The feedback loop of R&D people is in the upper of figure 6 and the lower is the strategy of R&D.

Second, the marketing policy which is constituted by pricing and marketing strategy. The strategy of pricing is majorly in determining the product's price and marketing is in determining the marketing budget. The feedback loop of marketing policy is as in figure 7.

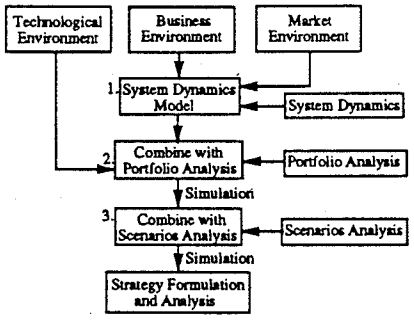

Figure 1 System Dynamics Modeling Research Structure of Business Technology Management Decision

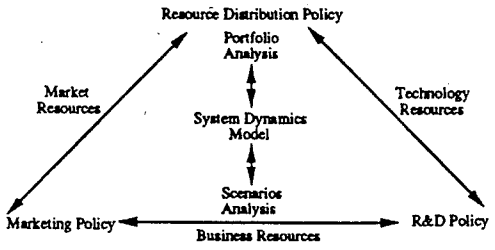

Figure 3 Conceptual Structure of Decision Analysis System

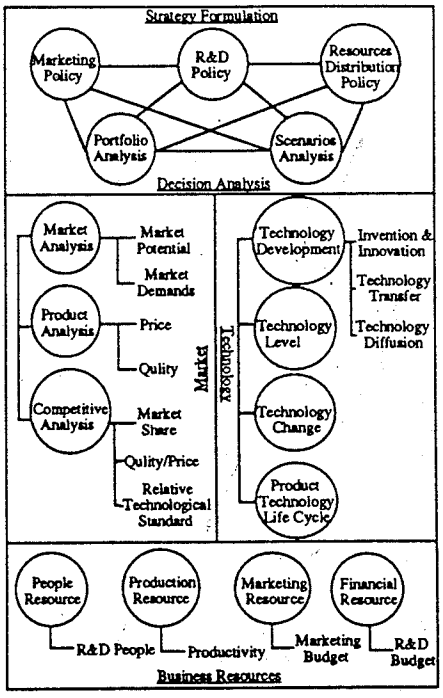

Figure 2 Construction of the TMDSS model

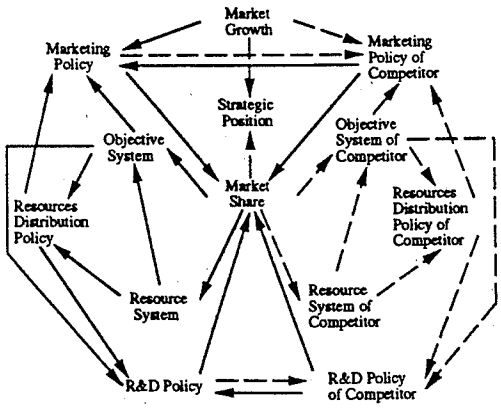

Figure 4 Conceptual Structure of Portfolio

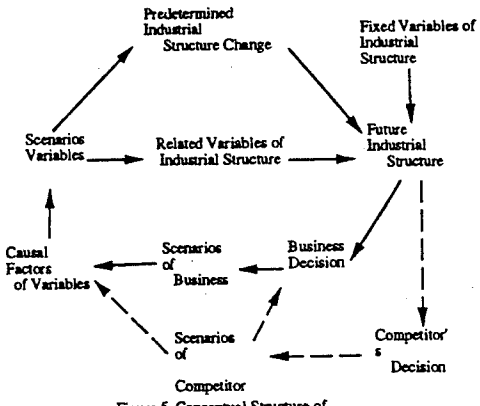

Figure 5 Conceptual Structure of Scenarios

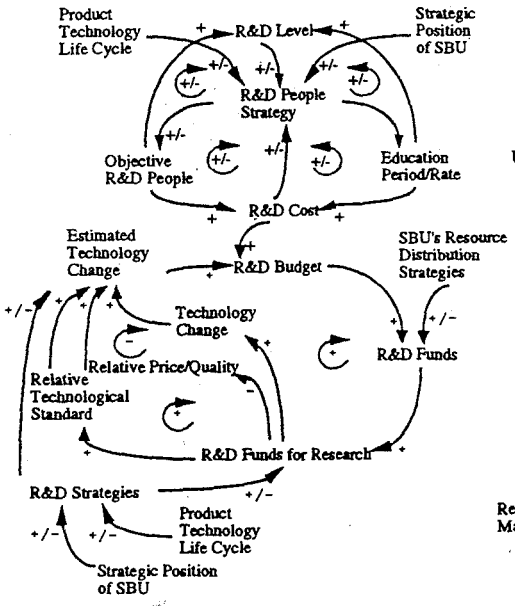

Figure 6. Causal Diagram of R&D Policy

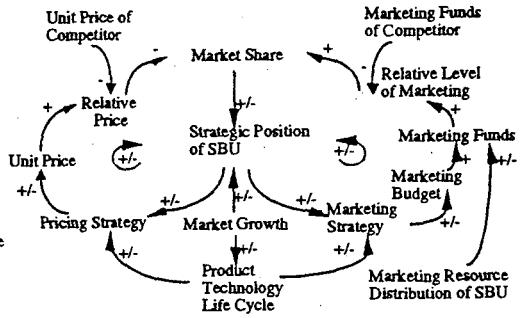

Figure 7. Causal Diagram of Marketing Policy

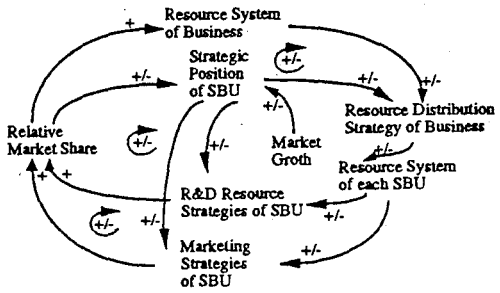

Figure 8. Causal Diagram of Resources Distributed Policy

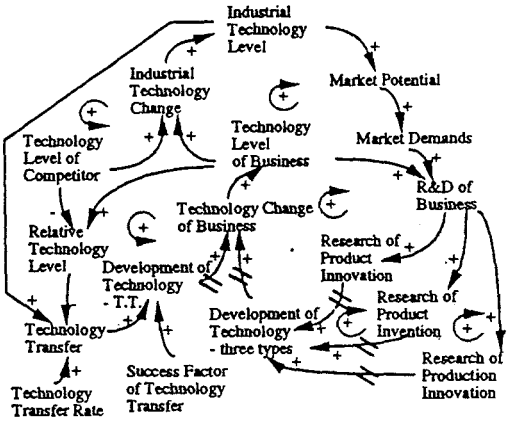

Figure 9. Causal Diagram of Technology Development

Third , the resources distribution policy is majorly in determining how to distribute the business's resources effectively. The resources of each SBU will be determined by the business's resources distribution strategy and each marketing will determines their resources distributed to R&D and marketing activities. The feedback loop is as figure 8.

Construction of the Information Analytic Subsystem

There are two parts in the information subsystem - technology and business's resources. The technology level of business is determined by four - product innovation, invention, production innovation and technology transfer. The technology level will determine the strengthes of business's R&D activities. And the technology transfer will be determined by the technology level in relative to competitors and the industrial global technology level. The causal feedback loop is as in figure 9.

There are four kinds of business resources- people, production, marketing and finance.Technology development and the policy of objective R&D people will determine the estimation demand of R&D people which will influence the actually involved people. Besides, the actually involved people will be determined by people martket's supply and the departure rate of R&D people. Technology development is determined by the successful rate of R&D which is influenced by the level of R&D. And the level of R&D is influenced by the actually involved R&D people.

At here, two kinds of productivity are discussed- capital and labor. They will influence the amount of production. And the amount of production will influence the unit cost of product and then influence the amount of sales. The amount of sales will influence the R&D investment which determines the technology level of production .As to marketing and financial resources, they are discussed in the section of resource distrbution policy.

Construction of the Environmental Analytic Subsystem

The price and quality of product, marketing, and others' competition are in the subsystem. In the loop , market share will influence the amount of sales and product's unit price(refer to the pricing decision in section 2.1). The amount of sales will influence the experience curve which is the basis of growth-share matrix portfolio analysis. The experience curve determines the learning effects and then influence the product's unit costs and the unit prices. And the prices competition is in correspondence.

In the model , we assume that the quality of product is determined by the technology level of business. So , the strength of R&D will influence the quality of products. And the products' quality is an important factor of customer's purchase willingness.

Formulation of the Strategic Subsystem Model

We built up two strategic tables where one is of portfolio and the other is PDLC. The portfolio analysis is divided into six identifications that called the strategic position. (figure 10) There are two portfolio strategic tables, one is the R&D policy (figure 11) and the other marketing policy. (figure 12)

R&D policy includes the Strategies of R&D and R&D people. R&D strategy is represented with the strengthes of R&D. And R&D people strategy is constructed by learning rate , learning period and objective R&D people.Marketing policy contains the pricing and marketing strategy. Pricing strategy will determine the prices of products and marketing strategy will determine the marketing strengthes of business.

Strategic table of PDLC (figure 13) is built in reference to the portfolio strategic tables except the strategy of R&D direction. A relationship is existed between the direction of R&D and the three stages of PDLC. Those tables represent the strategies of businesses in the model and the simulation will give us the different behaviors by the different strategies.

Simulation of the Business Technology Management Decision Support System Model

Base-run is majorly providing us the fundamental behaviors of the model. And scenario analysis provides the behaviors of the model when the environmental factors are changed. The simulations will tell us about the informations of the TMDSS model.

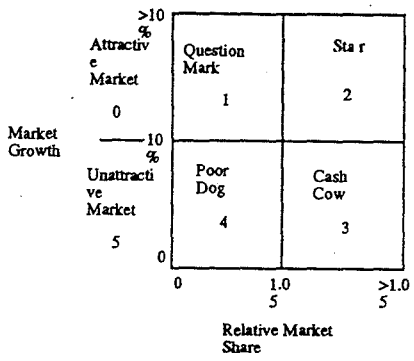

Figure 10. The Growthshare Protfolio Matrix of Diversfied

Strategic Position	Portfolio Strategy	R&D Policy	
		R&D Strategy	R&D People Strategy
Attractive Market 0	Build_up	Strength : high	Education Rate : high Education Period : short Objective People : 5
Question Mark 1	Offensive	Strength : middle	Education Rate : high Education Period : short Objective People : 5
Star 2	Investment	Strength : high	Education Rate : high Education Period : short Objective People : 5
Cash Cow 3	Defensive	Strength : low	Education Rate : high Education Period : short Objective People : 5
Poor Dogs 4	withdraw /Transfer	Strength : middle	Education Rate : high Education Period : short Objective People : 5
Unattractive Market 5	Transfer	Strength : middle	Education Rate : high Education Period : short Objective People : 5

Figure 11. R&D Policy Base on Investment Portfolio

Strategic Position	Portfolio Strategy	Marketing Policy	
		Pricing Strategy	Marketing Strategy
Attractive Market 0	Build_up	———	———
Question Mark 1	Offensive	Upper : competitor -5% Lower : 50% of total cost	Competitive Standard +20%
Star 2	Investment	Upper : competitor Lower : 75% of total cost	Competitive Standard +5%
Cash Cow 3	Defensive	Upper : competitor +5% Lower : +4% of total cost	Competitive Standard
Poor Dogs 4	withdraw /Transfer	Upper : competitor +10% Lower : +8% of total cost	Competitive Standard
Unattractive Market 5	Transfer	———	———

Figure12. Strategy Sets for Different Portfolio Situations

Stage of PDLC	R&D Strategies			R&D People Strategy		Marketing Strategy
	Strength	Direction 1	2 3	Education Rate	Education Period	Competitive Standard
Development	high	A	- -	middle	long	of the same
	middle	A	B C	high	short	of the same
Embryonic	middle	C	A C	middle	middle	+10%
	middle	C	A C	middle	middle	+10%
Growth	high	C	A B	high	long	+20%
	high	C	B B	high	long	+20%
Mature	high	C	C A	middle	middle	+10%
	low	B	C B	middle	middle	of the same
Aging	middle	A	C C	low	long	of the same
	middle	A	- -	low	long	of the same

1. invention ; 2. product innovation ; 3. production innovation
A: high ; B: middle ; C: low

Figure13. R&D and Market Policy Base on Life Cycle Analysis

Base-Run Simulation

The base-run is based on some assumptions, following are the important ones.

Basic business datas: (1) Business operation period : begins from time 0
(2) SBUs of business : 4
(3) SBU's competitor : 1

Decision related datas
(1) Strategies under portfolio
1. attractive market : build-up strategy, 2. question mark : offensive strategy, 3. star : investment strategy, 4.cash cow : defensive strategy, 5.poor dos : withdraw/transfer strategy , 6.unattractive market : transfer strategy
(2) R&D policy : figure 11
(3) Marketing Policy : figure 12
(4) Resource distribution Policy : fully supplied

Technology related datas
(1) Level of technology init =100
(2) Rate of successful = Level of R&D
(3) On-job education period/rate : by R&D policy
Market related datas
(1) Market situation

Year	1	2	3	4	5	6	7	8	9	10
Growth Rate	0	0	0.12	0.15	0.2	0.25	0.32	0.35	0.05	0.025

Stages | development : 1 - 2 embryonic : 3 - 4 growth : 5
| mature : 7 - 8 aging : 9 - 10

(2) Market Stage of each SBU (year)
SBU1 : 3 ; SBU2 : 5 ; SBU3 : 7 ; SBU4 : 9
(3) Demands of Market
SBU1 = 100000 ; SBU2 = 130000 ; SBU3 = 200000 ; SBU4 = 390000
(4) Price of product : by pricing policy
(5) Cost of product : by experience curve
(6) Quality of product : by standard of technology
Competitive related datas
(1) R&D policy : figure 13
(2) Level of technology init =100
(3) Cost of product : by competitor's experience curve
(4) Quality of product : by level of competitor's technology

Figure 14 shows the strategic positions of each SBU from time 0 to time 10 (year). Strategic position is a reflection of each market SBU's situation for market and competition. Besides the strategic positions of each SBU will determine the strategies which influence the model behaviors.

Figure 15 shows the technology changing rate for each SBU. Technology change is influenced by the strategies of R&D which is determined by strategic positions. So , we can find that the strategic position of question mark or star results a more higher changing speed. And the strategic positon of cash cow or poor dog results a lower changing speed. At last, the changing speed of unattractive or attractive market's position will be in the middle.

Figure 16 shows the R&D directions of SBU1. The directions of R&D is determined by PDLC. According to the stages of PDLC , the major directions of R&D are sequentially the product invention , innovation and production innovation. As to technology transfer , it is determined by the relative level of technology. In figure 16, the stages of PDLC for SBU1 are embryonic , growth , mature , aging and then development. So that the major directions of R&D are product innovation , production innovation and then product invention.

Scenarios Analysis and Simulation

The analysis adapts four steps :

1. find the uncertain factors that could influence the model behavior
2. modify the model based on the uncertain factors
3. simulation
4. analyze the behaviors and make decisions

At first , we must find out the uncertain factors. The analysis of scenarios here will focus on two phases - external and internal of industry. External factors includes the emergency of new technoloy , the estimation of new technology and the changing of technology life cycle (TLC). Internal factors includes four :

1. industry - attractiveness of industry , critical success factor , magnitude of marketing and growth of industry
2. competition - current competitors and potential competitors
3. customer - market differentiation , purchase motivations and unsatisfied demands
4. product - the product life cycle (PDLC).

Depending on those, we select the important ones (called scenario variable) which could influence the model significantly. And then construct a scenario analysis table (figure 17) depending on the variables of scenarios.

By modification and simulation we could gain the behaviors under scenarios, it will help us analyze the influences of the scenario variables and assist the decision making activities.

Figure 18 shows the model behaviors under the emergency of new technology. In figure 18 , we assume that the emergency of new technology is at time 3 of SBU1 and time 5 of SBU2. The technology changing rate of SBU1 and SBU2 are different when compared with figure 15. From this ,we could observe the influences of new technology.

Figure 19 shows the R&D direction of SBU1 when the technology life cycles are changed. From this, we could find that the R&D directions in different kint of life cycles (refer to figure 16).

The major objective of the model is to provide us about the imformation for strategy making activities in various scenarios. In the model, the different scenarios are based on the combination of various variables. By construction of the different scenarios , we could change the variables of the model and run the model game and the simulation will give us more informations where the decision maker could make more informed decisions.

Conclusion

This prototype model integrates the system dynamics , portfolio and scenario analysis . The integration provides us not only a method for construction of decision support system models , but also provides a system model which could be applied of business in action.

By completion of the research , there are still some remaining topics that could be studied. First is the extension of the model range. Second, the application of the model to business's T.M. DSS in active use.

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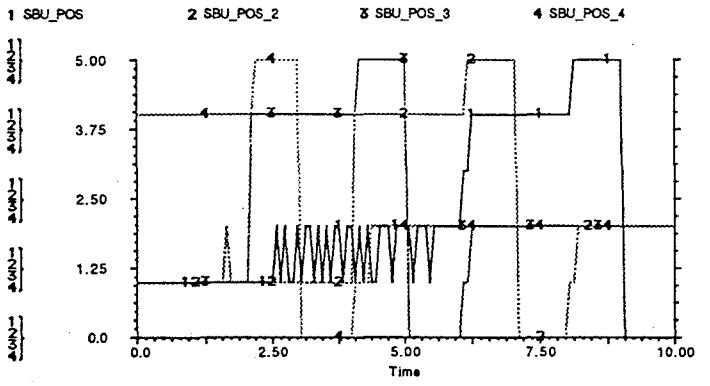

Figure 14 Unit : year

SBU_POS_i : strategic POSition of SBUi

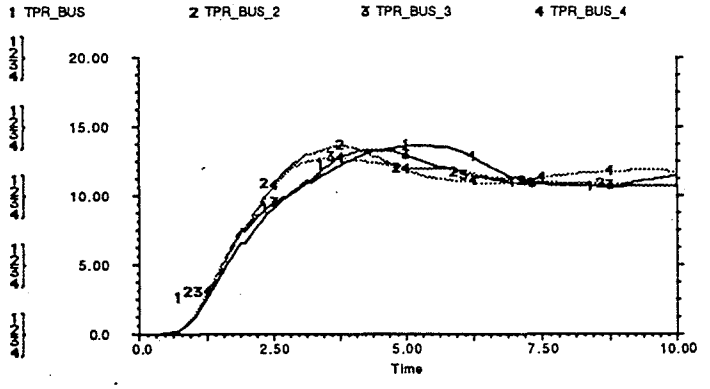

Figure15 Unit : year

TPR_BUS_i : Technology Progress Rate of BUSiness sbui ;

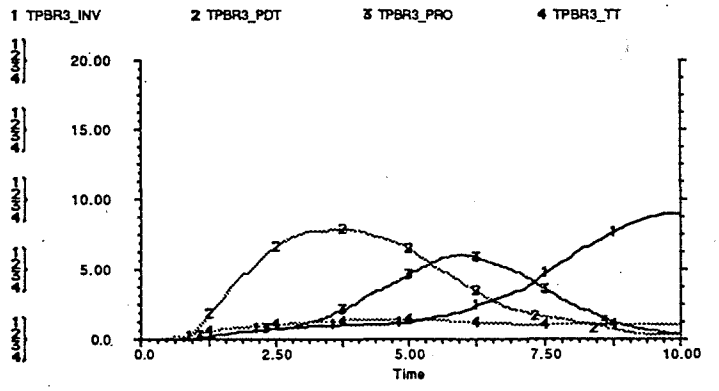

Figure 16 Unit : year

TPBR3_INV : Technology Progress of Business for INVention ;
TPBR3_PDT : Technology Progress of Business for ProDuct innovation ;
TPBR3_PRO : Technology Progress of Business for PROduction ;
TPBR3_TT : Technology Progress of Business for Technology Transfer ;

Scenario Varables	Scenaro Variation	Model Modification
Emergency of New Technology	Completely Replacement	Reduce the Technology Standard of Business to 100
	Partly Replacement	Reduce half of the Technology Standard of Business
Change of the Product Technoloy Life Cycle	Longer	Change the PDLC (long)
	Shorter	Change the PDLC (short)
Competitive Strenth of Current Competitor	Product Strenth	Increase the competitor's competitive strength
	Price Strength	Increase the competitor's price competitive strength
	Marketing Strength	Increase the competitor's marketing competitive strength
Competitive Strenth of Potential Competitor	Share with the business's current market	Reduce themarket share of business
Purchase Motivation of Competitor	Function 2 2 Price 1 3 Good-will 3 1	Change the weighting of the market share chaning function

Figure 17. Scenario Analysis

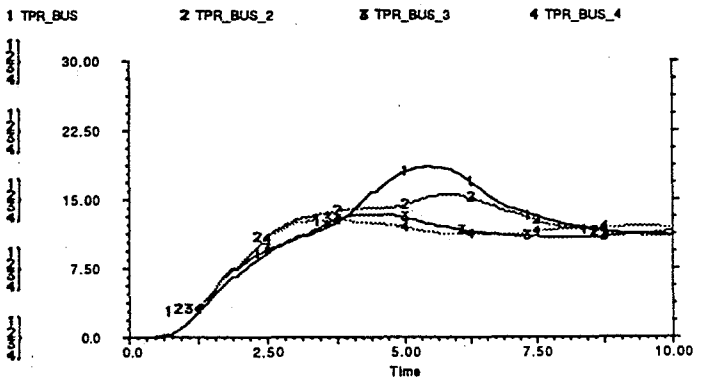

Figure 18 Unit : year

TPR_BUS_i : Technology Progress Rate of BUSiness sbui ;

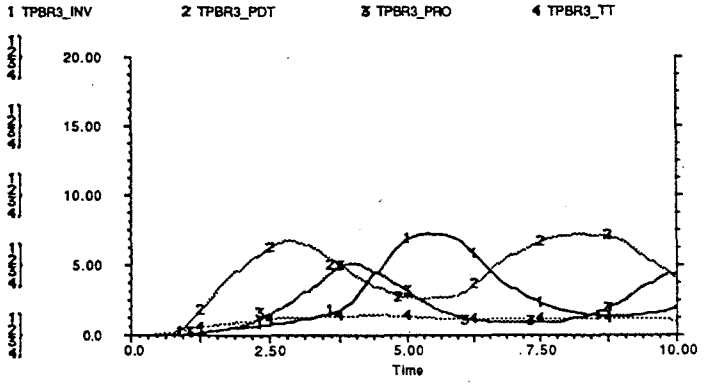

Figure 19 Unit : year

TPBR3_INV : Technology Progress of Business for INVention ;
TPBR3_PDT : Technology Progress of Business for ProDuct innovation ;
TPBR3_PRO : Technology Progress of Business for PROduction ;
TPBR3_TT : Technology Progress of Business for Technology Transfer ;