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A Scenario of Applying Cusp Catastrophe Model in Determining State of Organization

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Abstract: The management has been facing ambiguous result in monitoring the state of its organization due to of dynamic changes occurring within its system. This study focuses on the application of cusp catastrophe theory that is able to explain discontinuous behavior of the organization status and presents improvement of several stages in cusp catastrophe to prevision business instability. The study also introduces questionnaires to identify the significant control factors, both internal strength as well as external risk, potentially disturbing stability of an organization. Finally, the application of cusp catastrophe theory in an organization allows constructing a model of organization behavior as a matrix of scenarios indicating the state of organization: stable, semi-stable, or unstable.

Key words: Catastrophe, complex system, cusp catastrophe, organization management, organization situation

INTRODUCTION

In a complex organization system, latent errors may come up as discontinuous changing in management behavior; therefore they cannot be recognized easily. Contained in a systemic control and range widely from organization weaknesses to strengths, those latent errors can accumulate and possibly lead to unstable state of organization (Thom, 1975). However, at some critical points, success may be gained in the future if the organization succeeds to reverse its condition to stable state.

In case of bifurcation, a successful organization surely has its own method to manage problems happening in its branches. The problems commonly faced in bifurcation are, for example, changing of or distraction in business objective, or problem in insulating organization concealment (Zeeman, 1977). It is important to raise the organization awareness of latent errors so that the management can take the necessary action to prevent the disturbances in very early stage and does not have to wait until those latent errors creating instability of organization. The basic action is usually turning back to the fundamental objectives and position of organization.

Catastrophe theory which is indicated by abrupt change is also applicable in social science (Thompson and Strickland, 1992) where both quantitative and qualitative variables exist, even some variables that are not easily quantified. Catastrophe theory describes a qualitative system by representing the topological structure of the system where the dynamic conditions of organization's behavior are presented by the mathematical complexity of the topological surface.

CONSIDERATION REGARDING MATHEMATICAL THEORY IN MANAGEMENT

Complexity theory mentions that all things belong to the complexity have the characteristic of Catastrophes (Gilmore, 1993), that is internal part sudden changes within the system. Catastrophe theory is a term described in the application of Thom's abstract mathematical theory of structural stability system, which evaluating a model using an approach whether certain qualitative occurred in the system under consideration. One of catastrophes characteristic is as the interference between different levels relating to the normal changes.

Catastrophe theory was popularized in the 1970's and is still used in various researches. Despite well established and applied in the physical sciences, the theory is a tool to construct models in various fields, such as physics, psychology, science, economics and biology. Catastrophe theory is a method of modeling things which change suddenly, by fits and starts (Cobb and Watson, 1980). It helps to model discontinuous, abrupt changes in a behavior variable as the result of small and continuous changes in one or more other control variables. Each catastrophe has a potential function. Thom (1975) has proven that there are a maximum of 15 kinds of catastrophe forms when there are not more than five control variables (Cobb, 1978).

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THE CUSP CATASTROPHE THEORY

An organization also consists of a large complex management system where abrupt and discontinuous changes of behavior are likely happen. The discontinuous changes occur when latent errors accumulating within an organizational system and abruptly change the system behavior as the result of fundamental shift in management strategy, weaknesses and risk factors, etc.

The cusp catastrophe model has been applied most popular and frequently when the model has two control variables. This is the simplest of catastrophe models that exhibits discontinuous transitions in equilibrium states when the two control factors changing. The canonical form of the potential function for the catastrophe theory is illustrated in Eq. 1.

$$-V(z;x,y) = xz + \frac{1}{2}yz^2 - \frac{1}{4}z^4 \qquad (1)$$

where, z represent the system's state variable while x and y represent control parameters. The cusp catastrophe in Eq. 1 shapes a two dimensional surface living in three dimensional space where the floor is the two dimensional (x,y) control parameters. The cusp equilibrium surface is conceived as response surface where the height is a dependent variable (z) forecasted from the given value of independent variables (control factors x and y). The two dimensional control factors x and y are canonical factors which depend on the actual measured independent variables, $X_1, X_2, X_3, \ldots, X_m$, as an initial approximation. Suppose that the control factors are linearly independent variables are the Eq. 2, 3 and illustrate on Fig. 1.
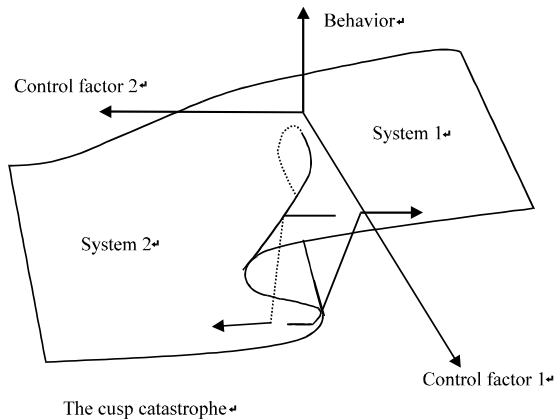
$$x = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \ldots + a_vX_v \qquad (2)$$

The cusp catastrophe

Fig. 1: The cusp catastrophe

$$y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_vX_v \qquad (3)$$

Then the system is in equilibrium if system state *y* is at a point where:

$$\frac{dV(z;c)}{dX} = 0$$

As a function of the control parameters, x and y are the solutions of the Eq. 4.

$$0 = x + yz - z^2 \qquad (4)$$

APPLICATION OF CATASTROPHE THEORY IN DETERMINING BUSINESS STATE

Business state analysis: Many factors affect organization in running business including the dynamic change of control factors and latent conditions present at the time that share to a temporal and unstable condition (Mary, 2005). To know what is going to happen and take necessary action in advance, such as improve management strategy, is significant to prevent crisis and to bring organization to the safer condition (Exiang and Xingsan, 2007).

This study suggests the important questions to check the health status of organization by determining how well or poorly of the organization is being performed. A questionnaire has been developed to observe two major factors affecting performance of organization: internal strength and external risk. Internal strength audit questions show the organization's capabilities in determining strengths and weaknesses of internal organization system that commonly consists of six main organizational functions: production, marketing, research and development, financial-accounting, management and information systems. External risk audit questionnaires mostly provide question for determining the threats of organization and external factors potentially impact the achievement of organization objectives. External risk can be categorized in five items: risk in current rivalry, risk in potential entrants, risk in buyer, risk in suppliers and risk in substitute products.

The final objective of the questionnaire is to determine the present status of organization, whether running in a stable and sustain situation, semi-stable, or unstable, identified from internal strength and external risk score given by manager-opinion polling. The full questionnaire is presented in Table 1.

Cusp catastrophe in organization behavior state: Let, y_i as internal strength and x_i as external risk factor. A

Table 1: Organizational performance questionnaire

Internal strength audit question(Yi)	External risk audit question(Xj)
Strength in procurement-operation	**Risk in current rivalry**
The organization have reliable and reasonably priced suppliers	The numerous of competitors
The good working condition of facilities, offices, machinery and equipment	The equal balanced competitors such as many strong competitors
The facilities strategically located close to resource and market	Industry sales growth decrease
The effective inventory control policies and procedures of organization	High fixed or inventory storage costs
The effective procedures of organization utilize quality control procedure	No differentiation or no switching costs
The appropriate amount capacity of organization	Significant differentiation or significant switching costs
The smoothly of process work	Large capacity increments required
The production-operations goals have been established and are work activities aimed at achieving these goals	Diverse competitors
The production-operations employees use appropriate operations planning and controlling tools and techniques	High strategic stakes
The organization developed any particular competencies in the areas of production-operations	High exit barriers
Strength in marketing department	**Potential entrants**
The organization segment markets effectively	High economies of scale
The organization position itself well against its competitors and conduct the effective market research	Cost disadvantages from other aspects
The organization have and effective sales force and priced its products and service appropriate	More other potential cost disadvantage
The effective of customer service	Weak of product differentiation
The effective of the advertising strategy promotion and publicity strategy	Huge capital requirements
The effective of marketing planning, budgeting and distribution channels	Government policy barrier
The development in any particular competencies in market area	**Risk in buyer factor**
Research and development	Buyer purchases small volumes
The adequate of R and D facilities	Product purchased are rarely significant part of buyer's costs
The qualified of R and D employee such as use appropriate tools and technique	Product purchased are standard or undifferentiated
The organizational culture encourage creativity and innovation	Buyer faces significant switching costs
The competitive of organization 's product technology	Buyer have ability to mannfacture product
The development time from concept to actual product is appropriate	Industry 's products aren't important to quality of buyer's product
The level of organization commit compare with their competitor	Buyer have full information
The organization has developed any particular competencies in the R and D area	Supplying industry has few companies and is more concentrated
The strongly of Organization financially according to the financial ratio analyses	Supplying industry has many companies and is fragmented
The ability of organization to raise short and long term capital	There aren't substitute products for supplier's products
The effective of organization's capital budgeting procedures	
Research and development	
The appropriate of financial goals and dividend payout policies reasonable	
The match between organization's sources and use of funds	
The financial-accounting employees use appropriate financial-accounting tools and techniques	
The organization developed any particular competencies in the financial-accounting area	
Strength in Management strategy and running	**Risk in supplying factor**
The strategically manage organization employees	Industry being supplied is an important customer
The organizational goals clear and measurable	Supplier 's product is an important input to industry
The development of organization's vision	Supplier 's product are differentiated
The organization attract appropriate job applicants	There are minimal switching costs in supplier 's products
The effective of employee selection procedure	Supplier has ability to do what buying industry does
The organization provide employee with appropriate training	**Risk in Substitute products**
Job description and job specification clear	There are few good substitutes
Organization compensation and reward program appropriately	There are several not-so-good substitutes
Organization employee discipline and control mechanisms appropriate	
The good relationship does the organization have with employee group	
The organization is effective team work	
The organization develop any competencies in its human resource management activities	
The organization developed any competencies in the management area	
Strength in Information System-Information technology	
The organization does gather and disseminate information	
The information system used by employees in making decisions	
Information is updated regularly	
Information is distributed effectively and efficiently	
Employee have access to contribute input to the information system	
Organization made an investment in information technology better than competitor	** strength audit question level 1-5 (1= weakness, 5 = strengthest)
Information technology use effectively and efficiently in all areas of the organization	Risk audit question level 1-5 (1= bad, 5 = good)

Table 1: Continued

Internal strength audit question(Yi)	External risk audit question(Xj)
The security of organization 's system	when
The friendly of organization 's information system user	Yi= Internal strength score
The organization developed any competencies in the information system-information technology area	Xj= External risk score
Strength in Management strategy and running	**Risk in supplying factor**
The strategically manage organization employees	Industry being supplied is an important customer
The organizational goals clear and measurable	Supplier 's product is an important input to industry
The development of organization's vision	Supplier 's product are differentiated
The organization attract appropriate job applicants	There are minimal switching costs in supplier 's products
The effective of employee selection procedure	Supplier has ability to do what buying industry does
The organization provide employee with appropriate training	**Risk in Substitute products**
Job description and job specification clear	There are few good substitutes
Organization compensation and reward program appropriately	There are several not-so-good substitutes
Organization employee discipline and control mechanisms appropriate	

manager indicates their opinion on the level of internal strength (y_i) quality by giving score on a 3-point scale (3 = strength, 1 = weakness). Next step is calculating the coefficients of the vector $w_k = (w_{,1}w_{,2}...w)_k$ where coefficient factor is budget in each department (as a percentage from total budget). The level of external risk (x_i) is then indicated on 3-point scale (3 = lowest risk, 1 = highest risk). Again, a correction to the coefficients of the vector $v_h = (v_1, v_2,....v_h)$ where coefficients factor is strategic priority ratio in each risk sector. Therefore, for observation independent variables opinion score Y_1, Y_2, Y_3,....,Y_n and independent variables X_1, X_2, X_3,....,X_m, where, m and n are number of strength and risk questions factors respectively, then total score distribution can apply in the form of catastrophe Eq. 2 and 3 as illustrated in Eq. 5 and 6.

$$y = w_1y_1 + w_2y_2 + w_3y_3 + ... + w_ky_m \qquad (5)$$

$$x = v_1x_1 + v_2x_2 + v_3x_3 + ... + v_hx_n \qquad (6)$$

For example, a manager is polled to give score of internal strength and external risk. Polling result says that the coefficient value of control factors (x,y) in Eq. 5 and 6 is (2.5, 2.5). Wolfram mathematic program is then used in solving Eq. 2 and resulting behavior equation (z) as presented in Eq. 7-9.

$$z_1 = \frac{\left(\frac{2}{3}\right)^{\frac{1}{3}}y}{\left[-9x + \sqrt{3}\sqrt{27x^2 - 4y^3}\right]^{\frac{1}{3}}} - \frac{\left[-9x + \sqrt{3}\sqrt{27x^2 - 4y^3}\right]^{\frac{1}{3}}}{2^{\frac{1}{3}}3^{\frac{2}{3}}} \qquad (7)$$

$$z_2 = \frac{\left(1 + i\sqrt{3}\right)y}{2^{\frac{2}{3}}3^{\frac{1}{3}}\left[-9x + \sqrt{3}\sqrt{27x^2 - 4y^3}\right]^{\frac{1}{3}}} - \frac{\left(1 - i\sqrt{3}\right)\left[-9x + \sqrt{3}\sqrt{27x^2 - 4y^3}\right]^{\frac{1}{3}}}{2^{\frac{1}{3}}3^{\frac{2}{3}}2} \qquad (8)$$
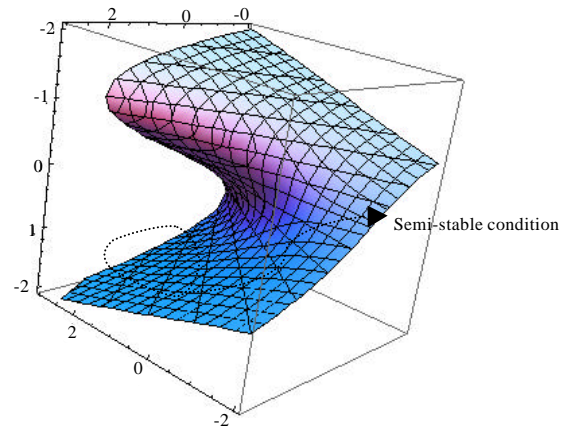
Fig. 2: Organization behavior scenario

$$z_3 = \frac{\left(1 - i\sqrt{3}\right)y}{2^{\frac{2}{3}}3^{\frac{1}{3}}\left[-9x + \sqrt{3}\sqrt{27x^2 - 4y^3}\right]^{\frac{1}{3}}} - \frac{\left(1 + i\sqrt{3}\right)\left[-9x + \sqrt{3}\sqrt{27x^2 - 4y^3}\right]^{\frac{1}{3}}}{2^{\frac{1}{3}}3^{\frac{2}{3}}2} \qquad (9)$$

Wolfram mathematic program is also applied to plot 3D surface scenario. The plotted surface is then compared to the Cusp Catastrophe surface presented in Fig. 1. It can be concluded that both surfaces are similar; therefore the Cusp Catastrophe theory is applied to the organization Moreover, the status of organization can be defined by examine the position control factors coefficient (2.5, 2.5). In Fig. 2, it can be seen that control factors coefficient (2.5, 2.5) is on the semi-stable condition area. Thus, it can be concluded that the coefficient (2.5, 2.5) leads the organization to semi-stable condition as illustrated on Fig. 2.

BUSINESS SITUATION ANALYSIS

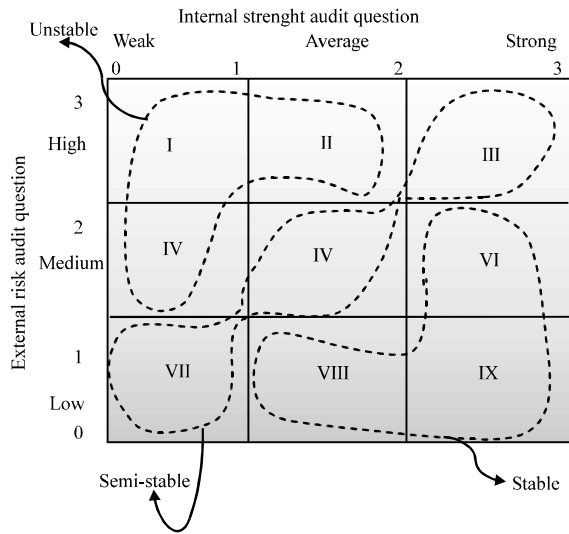The business status is described by constructing a scenario of the organization healthy matrix. It was created

Fig. 3: Organization health matrix

to determine organization stability whether it is stable, semi-stable or unstable. The matrix is 3×3 matrix where the X axis is a measure of the internal strength level and the Y axis is a measure of the external risk level. Both X and Y is obtained from the audit questionnaire. The matrix can be divided into three state of stability: stable, semi-stable and unstable. The score of polling obtained from the audit questionnaire can directly be applied to this matrix to know the state of organization. On the above example, organization health score coordinate (2.5, 2.5) is plotted on cell III in the matrix (Fig. 3). It can be conclude that the organization is experiencing strongest level of internal strength and at the same time facing highest level of external risk; therefore, the semi-stable status is implied.

The dynamic situation function of organization, strength and risk latent can also be mapped onto the 3-D space of the Cusp Catastrophe model in order to illustrate the dynamic situation of organization performance. A represents the situation of the most positive situation with highest level of strength and lowest level of risk (stable situation). C represents the semi-stable situation and D represents an unstable situation.

The dynamic change is described as the movement along the axis from point to point. If the change moves from point A to point B and continues to point C, the state will change from stable to semi-stable. Catastrophic event is usually occurring in a semi-stable to unstable status when the change moves from point C to D where the lowest level of internal strength and highest level of external risk lie. On the other case, organization condition may go better when the
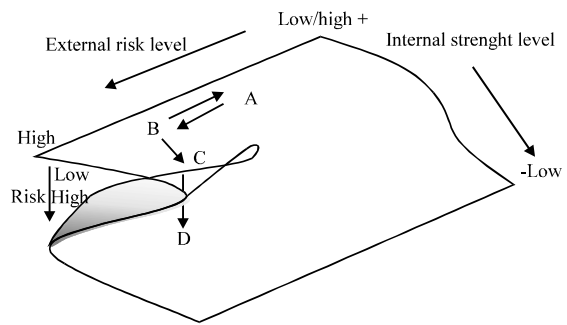

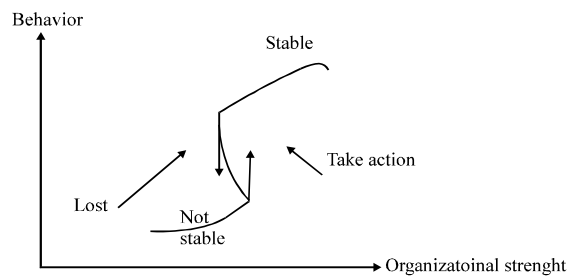Fig. 4: 3-D space of the Cusp model

Fig. 5: Cross section in behavior cusp model

organization performs better, indicated by the movement from point C to point A (Fig. 4).

According to the model, that is a cross section of 3-D space of the cusp catastrophe model, an organization can move across catastrophic event from unstable behavior to a stable behavior by taking necessary actions to increase internal strength of organization and decreasing external risks (Fig. 5). It should be noted that at some certain point on the behavior surface, a small weakness of organization can lead to an abrupt change in behavior, for example, a lack of appropriate strategy tends to disturb the organization stability.

CONCLUSIONS

Cusp catastrophe theory application in organizational management aims to help in understanding organization's condition by analysing the state of organization. This application is also helpful to monitor and predict what is seemly to be happen using two control variables influencing status of organization behavior internal strength and external risk factors. Proper treatment is significant to maintain from time to time those two factors giving benefits to the organization and keep its stability.

Even though the application of catastrophic model takes time especially if catastrophic change is the main interest, this model at initial stage can help the manager to improve and enrich control variables into the behavior

approaching the complexity of organizations. Therefore, inspite of lack understanding and experience, the organization members, manager and worker, should try to fill in the questionnaire and give the score in order to know the close-to-real behavior of the organization. Lastly, from examining the questionnaire, the management can also exercise the range condition of each control variable that needs to be focused and monitored.

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