

A Stochastic Cusp Catastrophe Studied of Organizational Growth

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Abstract—Firm growth is a development of the management's system. That is an essential to its life cycle in identifying critical problems which have to be overcome during its stage in order to continue its growth. This paper perspective is to show a correlation with the key indices of Balance scorecard and the firm growth by simulation the linear and non-linear models. After, we used statistical testing methods to fit model in R software. The simulation showed that the application of non-linear model did better than other models in constructing the firm growth model with 77% from the nine firm case studies.

Index Terms—balance scorecard, catastrophe, firm growth, key index, life cycle

I. INTRODUCTION

Firm using several tools propose to fit the environment dynamic changing that is an essential for its life cycle to be growth. It must be effective and conscious that the manager should produce the results for which its exist, both also achieve it results efficiently and ability to adaptation to withstand its external environmental change then increasing stability of firm [1].

The Catastrophe theory has been attracted in explaining the dynamic and is widely accepted as a guide for understanding changes in various fields and more popular for its application to complex environments [3], catastrophe theory has been used to address several management issues [1]. It offers a guide which allows study of the changing of nature in the organization structure. It also used as an organizing framework to assess evolutionary as well as revolutionary processes in firms [6].

Robert Kaplan and David Norton (1993) developed the theory of performance measurement frameworks named the Balance Score Card (BSC). Having added strategic non-financial performance measures, BSC can give manager a more balance view of organizational performance [7]. It is an extensive performance evaluation tool to adequately plan and control an organization to achieve its goals [4]. It also assists the organization in developing a better performance system both use to translating strategy into action that turns the organization's strategy vision into clears and understandable [9].

The well development into a life cycle of organization growth has been a goal of researcher for organized this research article. First of all, six models of organization life cycles were reviewed to determine the behavior of the firm and major criteria of effectiveness exist in prime stage of development. Furthermore, a balance scorecard was constructed to consider the evaluation indexes of prime stage when summarized the key performance indexes from the literature relating to firms performance. Finally, the firm growth models were calculated by Cusp package of R software to simulation the models and compare all of the nine firm case studies using statistical analysis.

II. THE FIRM LIFE CYCLE AND ALANCED SCORECARD

A. The Firm Growth Life Cycle

The firm growth is a development to overcome at each stage of development first manifests themselves that arise from the growth and face to as many problems from internal and external changing until success of their life cycle. The development and growth manipulated in a random environment provoked by dynamic systems is a huge and complicated system. Besides, there could be many equilibrium points in each stage. The firm does not continue to growth indefinitely but including upper asymptotic limit can be imposed by a number of limit factors [8]. Generally, to succeed in growing, organization should understand the opportunities of the growth as well as identify critical problems to overcome during the stage of the firm growth [5].

The firm growth perspective is like life cycle of an organism. A number of literatures have been to define firm growth is from the perspective of their position on a growth curve. The life cycle models are from the organization development literature that summarized the studies into aggregate model containing the birth, growth, and maturity, but none include death [2]. That is a classic of S-curve typifies these life cycle models [11]. Several organization growth models have been proposed by researchers, from three stages to ten stages that are distinguished by variable perspective: motivation of growth, critical managerial concerns, or internal social control and structural of work. The popular of organization life cycle consists of a ten-stage model not associated to organizational activities [1]: courtship, infancy, go-go, adolescence, prime, stable, aristocracy,

recrimination, bureaucracy, and death. Fig. 1 illustrates organization life cycle in a ten-stage model.

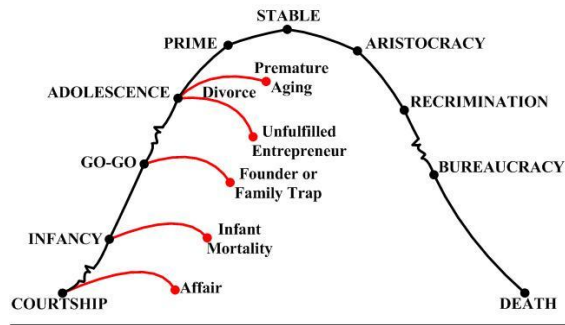


Figure 1. Organization life cycle [1]

Based on Adizes' organization life cycle, this article focuses on prime stage, i.e. continuous rising stage below the stable stage. Every organization attempts to reach prime stage but not touching the stable stage because it is the starting point to decline to death stage. This article focuses on prime stage; the organization has achieved a balance between control and flexibility. Its long time experience in the market often brings them high adaptability and keeps stability of organization in unpredictable environment. Since there are inert behaviors in the market, some organizations wait to decline but some others seek more profitability through focusing on opportunity to grow.

This stage is design to the learner time. The decision making is more decentralized but allowing collaboration and teamwork to foster innovation and creativity, while improving strength connection between internal development and external stability. The organization is

still large and the need of customer is still significant. There is no need of defensive strategy in market in this stage. Instead, organization policy needs to be adjusted to be simple in both structure and procedures.

B. Case Studies

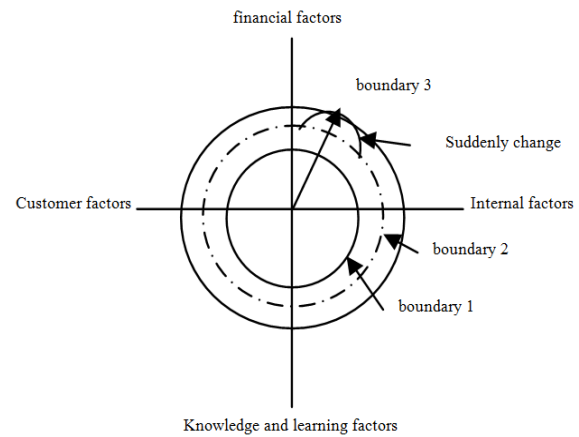


Figure 2. Firm adaptation and balance scorecard

Firm try to running business in stable state while it's a dynamic changing behavior. In normal state, firm operating business in boundary 1 until external factors impact system force the firm to adapt, Firm's good operating can jump to the next boundary(boundary 2) while the firm who failure to growth will reject to jump, still stay in boundary 1. Then the firm growth's life cycle is the adaptation for unpredictable situation and develop to the next boundary. As show in Fig. 2, illustrates firm adaptation and Balance scorecard.

TABLE I. OBJECTIVES AND MEASURE IN FOUR PERSPECTIVES

Perspective, weight (w_i)	Stage objective	Measure	Variables
Financial	high satisfy in stakeholder	total expense rate	X_1
	working more cost consciously	dividend yield	X_2
	higher positive cash flow		
	higher return		
Customer	delivery the solutions, products and service on time	missing rate	X_3
	retain good relationship of current customer	market share	X_4
	dominant share in the global market		
	Image of organization and products		
Internal	maintain the cutting edge production capabilities	capability utilization	X_5
	effectiveness in current asset	% outsource	X_6
	considerate appropriate outsource		
	Optimal reliability		
Development	Improve employee satisfaction degree		
	improve knowledge	training rate	X_7
	maintain a trained and knowledgeable workforce	turnover rate	X_8
	employee stabilities		
	active participation by everyone in improvement teams		
	Higher labor productivity		

Business operating generally in the dynamic characteristic and suddenly change. If the manager can select appropriate management tools for monitor and control, then they will growth and develop. Balance scorecard is one of the exactly tool to monitoring and control firm operation, it's an indices to perform firm performance. The manager must know the dynamic changing also selecting the best strategy that fit to this change, so the firm will success to growth.

Balance scorecard of an organization can be divided into four perspectives: financial, customers, internal processes, and knowledge and learning [7]. The perspective of finance shows present financial situation while customer's perspective shows the source of the success or failure in financial situation associated to organization position in the market and also customer satisfaction. Internal operation processes perspective measures effectiveness of the processes and the perspective of knowledge and learning shows the abilities to change and future development.

We collected the data of the nine firm case studies that have been running business more than 15 years. Where all of them are experienced through courtship stage, infancy, go-go, adolescence, until prime stage [1]. The behavior of this prime stage are running for with a little growth, running high safety factor in financial state, and indicating very high saturation of management. From the BSC perspectives, and base on review of the literature. The key indexes related to the firm growth in prime stage were summarized is show in Table I.

Firm in the prime stage appears to be characterized by the criteria associate with the learning and development. At this stage, firm has enough experience for viability in market. It has found enough customer support for its existence and enough revenue to continue its operations. It has also enough financial support to grow and then they take action on development and learning aspects, customer relationship, financial aspect, and internal process.

III. RESEARCH DESIGN

A. Set up Parameters

This paper focuses on the possibility of applying the Cusp catastrophe model to show the correlation of key performance indices of BSC with firm growth. The research interest is on prime stage period of firm life cycle with two years of dynamic data. The study case took nine companies that running business with gradual and stable growth indicated by their growth rate data.

The adjustment of the behavior states in a cusp model is a function of two sides, asymmetry and bifurcation. First of all, the 2-year data of the firm growth rate were collected as behavior variable (z). Also, significant factors of four perspectives of BSC were placed as control factors. The key factors that are divergent to the organization growth rate (X_1, X_3, X_6, X_8) were used as the bifurcation side, while key factors of BSC that are convergent with the organization growth rate

(X_2, X_4, X_5, X_7) were used as the asymmetry side (also called normal side) in Equation 2.

The control factors (X_1, X_3, X_6, X_8) respectively represent total expense rate, missing rate, % outsource, and employee turnover rate. This four divergence factors from the four perspectives of balance scorecard are the key performance index of the organization growth in prime stage of its life cycle. They should be internal factors which cause splitting of the system; therefore, their contributions to affect the bifurcation side of the model.

Similarly, the control factors (X_2, X_4, X_5, X_7) respectively correspond to dividend paid, market share, capability utilization, and training rate. These factors are convergent with the are considered to have effect to the behavior variable on normal side and counted as factors of the model in the asymmetry side.

B. Fitting the Cusp Model

The companies' data is used for running the models with assuming an unconstrained model. We applied Cusp fit package in R software to fit the cusp model to control variable (a , b) and state variable (z) using the Cusp Catastrophe equation. As show on Eq (1-3). we fit the data to linear regression, logistic, and also cusp catastrophe model. The hypothesis is that cusp catastrophe model fits to the data better than the linear and logistic model, indicated by higher R-square value and lower AIC/BIC value.

$$V(z; a, b) = bz - \frac{1}{2}az^2 + \frac{1}{4}z^4 \quad \text{Eq. (1)}$$

$$a = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \dots + a_vX_v \quad \text{Eq. (2)}$$

$$b = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_vX_v \quad \text{Eq. (3)}$$

First of all, the three models are compared by using the value of asymptotically *chi*-squared distributed with degrees of freedom. If the *chi*-square testing value is higher than the value from the *chi*-square table, we cusp catastrophe model is significantly different from the linear model. Meanwhile, R-square test is known as a measurement of the goodness of fit indicated by a value between 0.0 and 1.0. Generally, the higher R-square value, the more the model fits to the data.

In contrast, the comparison between the cusp model and logistic model is conducted by applying the Akaike and Bayesian information criteria (AIC/BIC). The AIC/BIC is a method that measures the fitness of a set of observations. In addition, AIC/BIC includes a penalty function, which is an increasing function by the number of estimated parameters. The hypothesis is accepted when the AIC/BIC of the cusp catastrophe model is be lower than the logistic model.

Table I shows the statistic results comparison among three models of nine firms. Chi-square values shown in Table II indicate that the eight of nine firms of cusp models are significantly different from the linear regression models. Although the pseudo R-square value

in the cusp catastrophe model is quite the same to that of logistic model, and the eight of nine firms of the AIC/BIC of cusp catastrophe models are lower than logistic

models. Therefore, the cusp catastrophe model is 87% better than the linear and logistic models of the firm growth.

TABLE II. COMPARISON OF CUSP FIT VALUE OF NINE PUBLIC COMPANINES

Firm	Linear	Logistic				Cusp				Chi-square test linear&Cusp	
	R ²	P-R ²	AIC	AICc	BIC	P-R ²	AIC	AICc	BIC	Chi-Square	p-value
1	0.45	0.72	143.16	156.25	151.13	0.77	21.17	39.17	30.13	132.50	≈0
2	0.76	0.82	76.88	89.97	84.85	0.79	19.58	37.58	28.55	60.16	5.55E-16
3	0.62	0.61	77.17	90.26	85.13	0.84	21.70	39.70	30.67	78.03	1.52E-12
4	0.25	0.64	44.04	62.04	53.00	0.78	9.74	22.83	17.71	15.44	2.99E-06
5	0.26	0.50	58.34	71.43	66.31	0.55	44.26	44.26	53.22	18.27	7.28E-07
6*	0.44	0.82	28.71	46.71	37.67	0.74	43.68	56.77	51.65	43.01	3.08E-12
7	0.54	0.67	139.02	148.02	47.15	0.80	6.66	32.37	14.16	91.10	≈0
8	0.54	0.67	139.02	148.02	148.77	0.72	30.67	42.67	41.64	111.70	≈0
9*	0.89	0.84	74.90	88.00	82.87	0.85	0.82	8.92	8.88	98.50	≈0

IV. CONCLUSION

In application of cusp catastrophe to show the organization growth status, organization growth rate is employed as a dependent variable and four perspectives of key performance index in BSC indices as independent variables. The independent variables are supposed to have direct relation to the adaptation of the companies' growth. The result is that seven out of eight key performance indices have significant impact to organization growth with R² more than 75% (at 0.1 significance level). The other two performance indices rejected the hypothesis in the cusp model.

This article also helps in understanding that organization system is a dynamic behavior, therefore, assists to confirm the current situation of organization, helps to monitor and predict what is seemly to occur, and then gives early warning of the critical state. Proper these control factors giving benefits to the organization keep stability and growth. It is expected that the framework can be a useful tool for empirical research or assist organization in documenting its growth, demonstrating its operation status, and giving early warning of coming latent error.

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