DYNAMIC AND FRACTAL APPROACHES TO MEASURE BUSINESS PROCESS PERFORMANCE

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

DYNAMIC AND FRACTAL APPROACHES TO MEASURE BUSINESS PROCESS PERFORMANCE

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August 2018

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Process modelling is one of the foundational characteristics of business process management and became key activities in understanding business processes and in formulating competitive business process management practices. Many process modeling are available, however, some of them are too costly to construct due to lack of enough knowledge or the application does not really need such models complexity.

In view of the existing gap in the business process performance measurement literature, this research attempts to fill in the gap and propose some new approaches to the design and construction of business process performance measurement framework. This research consists of closely related chapters covering the issues and design of new business process performance measurement frameworks. The first involves a static model developed by defining the decision variables (revenue, cost) and the objective function(net profit). Static system representation is capable to provide the majority of information needed for dynamic system model construction, it does not possess the mechanisms needed to enact the process behavior constraints defined in its representation. The second model is constructed by design from the static approach into its corresponding dynamic framework by entering time-related data. Dynamic process modelling by construction is designed for communicating end-to-end business processes. It enables the changed process outcome to be evaluated in advanced to its implementation into the physical environment.

As business processes contain organized patterns of business activities, therefore, processes relations can generate fractal pattern. Thus, for the third approach, fractal can be used to measure business process performance in particular to address the extent of business complexity and dynamic environment of business companies. It can help organizations to describe the complexity and irregularity of business processes

such as financial processes. Final part of the research aims to define and formulate an evolving and dynamic fractal model for measuring business process performance. Irregular sets provide a much better representation of many natural phenomena than the figures of classical geometry do. The box-counting method is used to estimate fractal dimension of the business process. This fractal dimension value is the same as the Sierpinski Gasket, which indicates that the net profit business process displays a fractal pattern. Therefore, a fractal index can be constituted to measure the net profit process and discriminate its similarity and dissimilarity. Consequently, interpretative indices are developed; for both dynamic modeling and for fractal modeling, Use and application of both indices respectively for the dynamic and fractal models are illustrated using real data gathered from five companies in Bursa Malaysia. In general, the results indicate that the fractal index reveals fractal behavior of the datasets of the five companies and reveals the real changes in revenue and cost of each company. The range of fractal index is greater than dynamic index range showing more capability in measuring the disorder and stochastic changes which provides more opportunity to measure any irregular behavior of profit and assists predict in the long term. Fractal model recommended to implement a forecasting model to improve the financial management and decision-making abilities of any business, particularly if the forecasts are updated on a future developing component is added during each time.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENDEKATAN DINAMIK DAN FRAKTAL UNTUK MENGUKUR PRESTASI PROSES PERNIAGAAN

Oleh

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Proses pemodelan merupakan salah satu ciri asas pengurusan proses perniagaan dan menjadi aktiviti utama dalam memahami proses perniagaan dan membentuk amalan pengurusan proses perniagaan yang berdaya saing. Banyak proses pemodelan yang telah ada, bagaimanapun, sebahagian daripada mereka terlalu mahal untuk dibina kerana kurangnya pengetahuan yang cukup atau aplikasi itu tidak memerlukan satu model yang rumit.

Berdasarkan jurang yang sedia ada dalam literatur ukuran prestasi proses perniagaan, kajian ini cuba untuk mengisi jurang dan mencadangkan beberapa pendekatan baru untuk reka bentuk dan pembinaan rangka kerja pengukuran prestasi proses perniagaan. Penyelidikan ini mengandungi bab yang berkait rapat merangkumi isu-isu dan reka bentuk rangka kerja pengukuran prestasi perniagaan baru. Yang pertama melibatkan model statik yang dibangunkan dengan menentukan pemboleh ubah keputusan (pendapatan, kos) dan fungsi objektif (keuntungan bersih). Sistem model statik mampu memberikan sebagian besar informasi yang diperlukan untuk pembinaan model sistem dinamik, kerana ia tidak memiliki mekanisme yang diperlukan kerana kekangan perilaku proses yang ditentukan dalam perwakilannya. Model kedua dibina oleh reka bentuk dari pendekatan statik ke dalam rangka kerja dinamiknya yang sesuai dengan memasukkan data yang berkaitan dengan masa. Proses pemodelan dinamik dengan pembinaan direka untuk menyampaikan proses perniagaan hingga ke akhirnya selesai. Ia membolehkan hasil proses yang berubah untuk dinilai secara lanjutan untuk pelaksanaannya ke dalam persekitaran fizikal.

Oleh kerana proses perniagaan mengandungi corak aktiviti perniagaan yang teratur, maka, proses hubungan dapat menjana pola fraktal. Oleh itu, untuk pendekatan ketiga, kaedah fraktal boleh digunakan untuk mengukur prestasi proses perniagaan khususnya

untuk menangani sejauh mana kerumitan perniagaan dan persekitaran dinamik syarikat perniagaan. Ia dapat membantu organisasi untuk menerangkan kerumitan dan ketidakteraturan proses perniagaan seperti proses kewangan. Bahagian akhir penyelidikan ini bertujuan untuk menentukan dan merumuskan model fraktal yang berkembang dan dinamik untuk mengukur prestasi proses perniagaan. Set tidak tetap memberikan perwakilan yang lebih baik daripada banyak fenomena semulajadi daripada angka geometri klasik. Kaedah pengiraan kotak digunakan untuk menganggarkan dimensi fraktal proses perniagaan. Nilai dimensi fraktal adalah sama dengan Gasket Sierpinski, yang menunjukkan bahawa proses keuntungan bersih perniagaan memaparkan corak fraktal. Oleh itu, indeks fraktal boleh dibuat untuk mengukur proses keuntungan bersih dan membezakan persamaan dan ketidaksetaraannya. Indeks tafsiran dibangunkan untuk pemodelan dinamik dan pemodelan fraktal, Penggunaan kedua-dua indeks tersebut untuk model dinamik dan fraktal digambarkan secara menggunakan data sebenar yang dikumpulkan dari lima syarikat di Bursa Malaysia. Secara umum, keputusan menunjukkan bahawa indeks fraktal mendedahkan tingkah laku fraktal untuk lima set data syarikat dan menunjukkan perubahan sebenar pendapatan dan kos setiap syarikat. Julat indeks fraktal lebih besar daripada rentang indeks dinamik yang menunjukkan lebih banyak keupayaan dalam mengukur perubahan gangguan dan stokastik yang memberikan lebih banyak peluang untuk mengukur sebarang kelakuan yang tidak teratur keuntungan tersebut dan membantu meramalkan dalam jangka panjang. Model fraktal disarankan untuk melaksanakan model ramalan bagi meningkatkan kebolehan pengurusan kewangan dan membuat keputusan untuk mana-mana perniagaan, terutamanya jika ramalan ini dikemaskinikan menggunakan komponen pembangunan masa depan yang bertambah pada setiap masa.

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Without such a team behind me, I doubt that I would be in this place today.

I certify that a Thesis Examination Committee has met on 13 August 2018 to conduct the final examination of Keivan Moghtaderizadeh on his thesis entitled "Dynamic and Fractal Approaches to Measure Business Process Performance" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P. U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This is to confirm that:

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LIST OF ABBREVIATIONS

BPM	Business Process Modelling
BPMS	Business Process Management Systems
C	Cost
FD	Fractal Dimension
NP	Net Profit
NPI	Net Profit Index
OP	Operational Profit
R	Revenue
TO	Total Operation
TOB	Total Operation Box

CHAPTER 1

INTRODUCTION

This chapter represent the background and overview of business process modelling and accounting business process, problem statement, research questions, research objectives, significant of the study, research scope and contributions.

1.1 Background of Study

In the last decades business organizations has faced an increasing doubt and unmatched external environment. Increased competition pushed many organizations to rethink and redesign their business processes (Kim and Kim, 1997). Organizations that conduct business process in their regular activities are more effective than those do not do. Organizations should regularly endeavour to enhance their functioning to optimize customer value to remain competitive. Furthermore, organizations that apply information technologies to processes, without managing the process, are generally experience money waste (Brocke and Rosemann, 2010).

Traditional business processes have become outdated and ineffective. Development in information and communication technology led to automate many of these processes, which causes often to the deformation of the original structure of the processes in addition to increasing their complexity. Therefore, it becomes an urgent need to streamline and improve business processes in most organization (Patel and Hlupic, 2001). Moreover, rapid business and organizational changes and information technology have intensified organizational needs to realize the business systems behaviour and its impact on information systems development that improves their operation. Achieving a level of understanding and identifying business processes is a challenge, which needs modeling of business process (Heidari et al., 2013).

1.2 Business Process Modelling

Business process modeling is significant in presenting, analysing and enhancing business processes. It provides business processes realization and presentation in diverse abstraction levels from individual ideas like activity to concepts composition such as sub-processes and to the business process as a whole (Heidari et al., 2013).

Business Process Modelling (BPM) is a technique of efficiently bringing into line an organization with clients' needs. It is a complete management method that increases business efficiency and effectiveness while struggling for invention, flexibility and integration with technology. As organizations attempt to reach their objectives, business process modeling tries to constantly improve processes (Zwikamu and Alahmadi, 2015). Organizations increase the maturity of their process orientation

through business process management. Process modelling is one of the initial characteristics of business process management (Jonnavithula et al., 2015). Business process analysis and modelling became main activities in grasping business processes and in formulating management practices of competitive business process (Zwikamu and Alahmadi, 2015). Furthermore, business process modelling became a vital part of grasping and redesigning the activities that a distinctive organization utilizes to attain its business goals. From an organization modelling viewpoint, business process modelling is considered as complement to domain modelling as it permits capturing the dimension of organization in terms of workflows, actors, and activities. Moreover, business process model's quality will affect the information systems quality and on conceived business process developments (De Oca et al., 2015).

Business process modeling has been developed to help organizations to have common understanding and analysis of a business process and to enhance their business processes and achieve a competitive advantage (Aguilar-Saven, 2004; Nagm-Aldeen et al., 2015). Moreover, it helps to reduce the business process redesign risk, understand, represent, and, when necessary, redesign the fundamental business processes (Kim and Kim, 1997). Modelling is a method for problem solving where the use of models has a vital role (Koole, 2010). The modelling process is shown in Figure1.1.

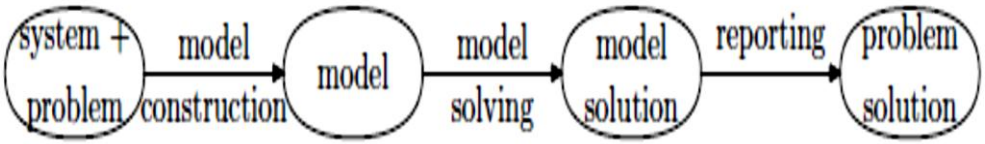

Figure 1.1 : Modelling Process (Koole, 2010)

Process modeling principally solves problems by using models. The process industries utilize models, generally for operations and plant design. Approximately, all process analysis areas depend on various types of process models. A generalized model is illustrated in Figure 1.2. It can be used for various essential aspects such as identification, simulation, design and evaluation (Jaako, 1998).

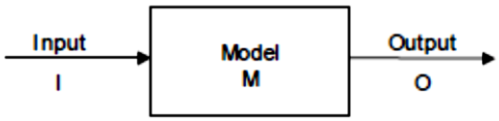

Figure 1.2 : A Generalized Model (Jaako, 1998)

General formula of a model can be represented by (Barnett, 2003):

$$y = f(x)$$

Where x is the input to a model (I), the model is symbolized by the function *f* (M), and y is the model output (O).

A business process model contains of an activity models set and implementation restrictions among them. Each model of business process performs as a design for a set of business process samples and each activity model acts as a design for a set of activity examples. Models of business process are the key objects for executing business processes (Zwikamu and Alahmadi, 2015).

Many model types are utilized to estimate specified process characteristics such as intuitive, causal, qualitative, quantitative, verbal, dynamic or static models. Mathematical models belong to the quantitative models. Partial differential equations (PDEs) or algebraic equations (AEs) define static system, where time is ignored. Dynamic systems are defined by the difference algebraic equations (DAEs), ordinary differential equations (ODEs) or PDEs (Jaako, 1998).

1.3 Accounting Business Process

Accounting provides information about an enterprise position and performance that is valuable to a broad range of probable users in making decisions (Leiwy, 2015). Accounting is a communication and measurement process utilized to declare the activities of profit business organizations. Accounting provides management with important financial data valuable for decision making (Hermanson et al., 2015). Traditionally, this information is financial, but accounting is gradually used to address economic, social, and environmental concerns. The initial role of accounting information was to record and measure financial transactions and to offer information for management objective. Financial accounting is part of organizations financial reporting, which issues their financial accounting information in financial statements form. Expenses (cost) and income (revenue) are reported in the income statement that exhibits business transactions history over some historical period. The income statement displays the business financial performance in the historical accounting period (typically one year), thus, the business profits can be calculated through the variance between cost and revenue, which is called profit (Leiwy, 2015).

$$\text{Net income (profit)} = \text{Revenues} - \text{Expenses (cost)}$$

Profitability is one of the main goals of every business, which demonstrates its ability to produce income. The business cannot continue and attain its other goals if it cannot produce reasonable revenue and pay its debts (Hermanson et al., 2015).

1.4 Problem Statement

Several organizations face critical problems through their business process redesign implementations. Business process redesign is regarded a high-risk mission from the perspective of organization (Kim and Kim, 1997). Achieving an understanding level and identifying business processes is a challenge, which requests business process modelling (Heidari et al., 2013). Models of business process may not be of high quality. Several studies revealed that many models include errors, such as syntactic mistakes. Obviously, it is required to provide guidelines to practitioners on how to create high quality models (De Oca et al., 2015). Organizations may still find it difficult to realize the challenges that emerge when trying to select appropriate languages, technologies, frameworks, and paradigms (Jonnavithula et al., 2015). It seems impractical to reach consensus on what standard modelling language should be, (Koster, 2009). Moreover, the practice of process modelling is developing considerably, with an increase in diversity, sophistication, and complexity (Jonnavithula et al., 2015).

Obviously, business process modeling is a complex process, and that diverse modeling methods have weaknesses and strengths in various aspects because of the diversity of their principal formalisms (Lu and Sadiq, 2007). Mathematical models can define process concepts rigorously and precisely, but it is difficult to describe mathematical model in a proper way responsive to analytical methods. However, they lack to support the processes design as business process basics and restrictions are typically of qualitative nature. Moreover, these models are too costly to construct due to lack of enough knowledge to construct such models or the application does not actually need such models complexity (Jaako, 1998). Languages Models (activity, UML, etc.) contain several concepts which are not well defined (Aguilar-Saven, 2004; Carnaghan, 2006). Diagrammatic Models (Flowchart, IDEF, etc.), which considered as static modeling methods, are valuable for representation of fast and informal process, but they are grounded on graphical representations only and lack the required semantics to support more complicated and identical structures (Sidnev et al., 2005). However, they do not capture the dynamic characteristics of business processes (Vidovic and Vuksic 2003). Furthermore, static modelling cannot describe the time-variant behaviour (Whitman and Presley, 1997). Dynamic modelling enables activities display and events flow within a process; however, they do not enable the changed process outcome to be anticipated (Patel and Hlupic, 2001). Also, they are more difficult to handle (Patel and Hlupic, 2001). Generally, none of the business process modelling techniques is normally accepted as a standard in the industry (Heidari et al., 2013). Table 1.1 summarized some of the drawbacks of the modelling techniques.

Table 1.1 : Drawbacks of Modeling Techniques

Mathematical Models	Diagrammatic Models	Languages Models
1. The model cannot support the processes design because elements of business process are qualitative nature and it's difficult to describe them in formal ways. (Jaako, 1998) 2. Actual processes representation utilizing mathematical models is complicated and impossible as these contain complex attributes like feedback loops, decision points (Boekhoudt et al., 2000)	1. Absence of required semantics to support more complicated and identical structures (Sidnev et al., 2005) 2. The study grounded on graphical representations only and lack the required semantics to support more complicated and identical structures (Vergidis et al., 2008a) 3. Lack of quantitative data that impedes any additional analysis and evolution of analysis tools and techniques (Vergidis et al., 2008a) 4. This model cannot define dynamic and practical process features (Aguilar-Saven, 2004)	1. The study offer a combination of symbols, which are slackly mapped to specific concepts such as decision points and activities (Aguilar-Saven, 2004; Carnaghan, 2006) 2. Many semantics concepts are not well set (Aguilar-Saven, 2004; Carnaghan, 2006).

Further to the above modeling techniques' drawbacks, Table 1.2 summarized drawbacks of common models of business process.

Table 1.2 : Drawbacks of Common Models of Business Process

Common Business Process Models	Drawbacks
Maturity models normally contain a series of levels which compose an expected or rational path from a primary state to maturity (Roglinger et al., 2012).	Maturity models need a flexible way to achieve all levels otherwise the organization will overlook its real goal to improve the processes. Moreover, these models cannot be utilized as a contingency method to recover from a hard situation (Atwal, 2008).
Data Flow Diagrams are diagrams that illustrate the information flow from place to place (Aguilar-Saven, 2004; Carnaghan, 2006).	This model does not illustrate the control flow (Aguilar-Saven, 2004; Carnaghan, 2006).
Flowcharts method utilizes flowcharts to describe processes (Aguilar-Saven, 2004; Carnaghan, 2006).	Model representation is very big, and there is no variance among core and sub activities that make it hard to read the chart (Aguilar-Saven, 2004; Carnaghan, 2006).
Extended Process Chain (EPC) diagrams utilized in integrated information system to define business processes, and to demonstrate the control view that connects data, functions, and organizations (Carnaghan, 2006).	Do not have an obvious construct for modeling controls. There is no depiction to the resources needed for an activity outside the organization unit that executes activities (Carnaghan, 2006).
Business Process Modeling Notation is the graphical representation provided within modeling of business process and is based on flowchart methods (Carnaghan, 2006).	This modeling can support only business processes automated analysis. It focuses mainly on activities portrayal; data inputs and outputs are elective but it is mandatory to show the activities sequence of a process (Carnaghan, 2006).
Petri net is a graphical language for systems design, simulation, verification, and specification (Morimoto, 2008).	The models often became too large, because it must directly represent all data operation in the structure of the net. Moreover, there are no hierarchy notions, and therefore it is not probable to construct a large model by a set of distinct sub models with clear interfaces (Morimoto, 2008).

To take all the above issues into consideration, this research aims to develop an evolving dynamic fractal model for measuring the net profit business process performance.

1.5 Research Questions

1. What are the current modeling approaches?
2. How to map mathematical modelling to net profit business process performance?
3. How to model net profit business process performance using fractal?

4. How to evaluate the developed dynamic and fractal models for business process performance.

1.6 Research Objectives

1. To investigate the current modeling in business process performance.
2. To map and measure business process performance by using static and dynamic mathematical modelling.
3. To develop fractal model of net profit for business process performance.
4. To evaluate the dynamic and fractal models using selected companies' financial information.

1.7 Significance of the study

Business process modeling helps organizations to understand and analyze a business process, which can assist to reduce the business process redesign risk, consequently improve business processes and achieve organization business goals. However, the increase of business process modelling techniques makes it difficult for organization to find the best model among many possible models because none of them can be regarded as a standard one. Moreover, current models cannot map real complex systems. Fractals can assist organizations leadership to enhance content and pattern, volatility flows toward the main mission of a department or an organization. This is due containing business problems organized patterns as a segment of larger business systems. Organizations will gradually use fractals as a promoter to identify/align market opportunities more quickly to regulate their business models opportunity cost.

1.8 Scope of the study

Financial performance is a main purpose of a business organization (Neely, 2007). This research focuses on financial uses of accounting in organizations whose aim is to make profit. The research aims to model the net profit business process, which is an accounting process as a function of revenue and cost. Profit is an appropriate performance measure and accounting profit is the organized formula that establishes the selection criteria in business. The research target is to model the net profit business process using traditional methods such as static and dynamic mathematical modelling. Then, the fractal approach is applied to define and formulate the target business process for assisting in measuring its performance comparing with other models. The fractal and dynamic mathematical models are verified and tested on real data collected from five firms in bursa Malaysian from various sectors.

1.9 Contribution of study

The research introduces a new modelling for business process using dynamic and fractal, it has two major contributions in business process performance, which believe is starting point for the future research in different areas.

- **Theoretical contribution:**
  a) The research introduces a new business process model for business process performance using static and dynamic.
  b) The research introduces a new business process model for business process performance using fractal approaches.
  c) The research enriches the literature by paving the way for the researchers to conduct more research for developing business process models.
- **Empirical contribution;**
  a) The new modeling assists to identify organizations market opportunities quickly to adjust their business models opportunity cost.
  b) Implementation of fractal model is to enhance and to forecast management decision making and improvement of process.

1.10 Thesis Organization

The thesis is organized into six chapters as follows: Chapter 1 introduces an overview on business process modelling and the limitations of the current models, problem statement and research objectives. It also explains research questions, purpose, significance and scope. Chapter 2 is devoted to review the literature on business process management, business process measurement, and business process modeling. Chapter 3 demonstrates the static mathematical modeling of a net profit business process performance. Chapter 4 illustrates the dynamic business process performance measurement. It also presents the evaluation of the dynamic model on real data of several companies. Chapter 5 introduces the applying of fractal approach to measure the performance of business process. Moreover, it introduces the evaluation of fractal model on several companies' real data. Chapter 6 is dedicated to summary and conclusions.

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