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# UNDERSTANDING THE DYNAMICS OF BVIT PROCESS: A COMPLEX ADAPTIVE SYSTEMS APPROACH

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# UNDERSTANDING THE DYNAMICS OF BVIT PROCESS: A COMPLEX ADAPTIVE SYSTEMS APPROACH

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## Abstract

There has been a long-running discourse in the information systems literature around the business value of IT (BVIT). Researchers have adopted a myriad of conceptual, theoretical and analytical approaches to evaluating the tangible and intangible measures of BVIT. Little research however, has explored richer theoretical explanations of the dynamic nature of the BVIT processes in contemporary dynamic business environments. To address this gap, this research in progress seeks to explore how BVIT is created as a bottom-up emergent process. In pursuit of such understanding, this research embraces complex adaptive systems (CAS) theory to develop a bottom-up conceptual model of BVIT. The agent-based modelling (ABM) technique is introduced as an analytical tool for computationally representing and examining the CAS model of BVIT. Operationalization of the CAS model and ABM modelling will be demonstrated through a theory building exercise.

**Keywords**: Business Value of IT, Complex Adaptive Systems, Bottom-up Process, Emergence, Simulation.

# 1 Introduction

The business value of Information Technology (BVIT) has been one of the topmost concerns among practitioners and researchers for decades. There have been long-running debates and doubts in information systems literature about how to evaluate BVIT in organisations. Scholars have adopted a myriad of approaches to determine the impacts that IT has brought about. One stream of research emphasises the econometric measures of BVIT - capital market reactions, financial performance (ROA, ROI, etc.), market share, etc. Another stream draws intangible measures to assess BVIT. However, in recent years, more and more researchers have come to the realisation that, rather than focusing on the output-oriented and episodic view of BVIT, it is necessary to explore the antecedents and factors from which BVIT is created. Accordingly, IS scholars have expended much effort seeking the antecedents and the variety of factors that influence BVIT like management practices and organisational structure, as well as competitive and macro environment (Brynjolfsson & Hitt, 2000; Dewan & Kraemer, 2000; Melville, Kraemer, & Gurbaxani, 2004).

A substantial progress has been made toward understanding the various aspects of the BVIT construct. Many of those efforts have been valuable. However, traditional IS research has rarely highlighted the dynamic relationships among factors, whereby a lower level factor (e.g. resource level factors or antecedents) collaboratively influences BVIT at the organisational level. In addition, IS research still lacks robust empirical findings regarding the properties and underlying mechanisms of BVIT creation processes (Schryen, 2012). An examination of BVIT studies indicates that the variance based models tend to reflect a snapshot of variables at a point in time. Qualitative and quantitative research into BVIT processes rarely provides proper theoretical explanations on the dynamic and non-linear nature of BVIT processes. Frequent changes in organisational goals, heterogeneity in resources and capabilities (Helfat & Peteraf, 2003), usage of new technologies (e.g. Koellinger, 2008), and competitive business environment (Melville, et al., 2004) make the BVIT creation processes nonlinear and dynamic in nature. We argue that the BVIT processes can be conceptualized as bottom-up in nature to explore the dynamic properties.

This research-in-progress attempts to contribute to BVIT research by proposing a framework especially suited to the examination of bottom-up emergence of BVIT processes. More precisely, this study seeks to extend the analytical elements of complex adaptive systems (CAS) theory (Casti, 1994; Holland, 1995) in the context of the BVIT. By mapping the elements of CAS in the BVIT context, this study facilitates to encode the bottom-up emergence of BVIT process and enables a consistent and precise analytical method for studying it. Consequently, the objectives of this study are to explore the dynamic aspects of BVIT and seek to uncover underlying mechanisms of bottom-up emergence of BVIT process in organisations.

The structure of this document is as follows: First, a brief literature review of BVIT is presented. Then, a critical examination of the literature is shown and a list of research questions are presented afterwards. After that, a detailed research design is described, where the CAS model of BVIT is represented. Finally, conclusions and future research works are drawn.

# 2 A Brief Literature Overview

There has been significant progress made in the area of BVIT research from the last decades. Scholars have embraced empirical, theoretical and analytical approaches to measure BVIT at different levels of an organisation (Melville, et al., 2004). The empirical studies include qualitative studies - case study and field study (e.g. Weill, 1992) - and quantitative studies that explicate BVIT at individual, firm and country levels of analysis (Dewan & Kraemer, 2000; Melville, et al., 2004; Mooney, Gurbaxani, & Kraemer, 1995). The conceptual and theoretical research adopts different theories and grounded observation to describe BVIT (Soh & Markus, 1995). In addition, studies that adopt variance theories explore variations in the magnitude of particular outcomes (Markus & Robey, 1988), whereas process theories provide causal explanations of how BVIT occurs in an organisation (Soh & Markus, 1995). Finally, analytical studies of BVIT use different modelling techniques and derive solutions to improve organisational performance by changing operational or management processes in the competitive business environment (Belleflamme, 2001; Devaraj & Kohli, 2000).

The substantial body of IS literature on BVIT shows that researchers developed different BVIT models based on different types of theories and methodologies. Some of the prominent BVIT models are- process oriented model (Soh & Markus, 1995), production-oriented model (Dedrick, Gurbaxani, & Kraemer, 2003), multi-path BVIT model (Dehning & Richardson, 2002) and resource based model (Melville, et al., 2004).

Much of the contributions to understand BVIT process are important, though the substantial body of literature on BVIT rarely provide a holistic view of dynamic nature of BVIT processes. To understand this complex and dynamic aspect, we argue to conceptualize BVIT as a bottom-up process and focuses on how BVIT emerges at organisational level from the relationships of resource level antecedents in contemporary dynamic environments.

# 3 Research Questions

The objective of this research is to investigate *how BVIT is created in dynamic contemporary business environments*. This is a bigger problem. In order to understand the dynamic aspects of BVIT, this study seeks to answer the following research questions-

- ***How can we understand BVIT as a bottom-up process?***

  We conceptualize BVIT as a bottom-up process, where BVIT emerges at higher level from the non-linear interactions among different antecedents at lower level. How BVIT emerges as a bottom-up manner is still elusive in IS domain.

- ***How can CAS model of BVIT be conceptualised for the theory building exercise?***

  We propose to expand the key elements of CAS theory to the concept of BVIT, as CAS allows to map its' basic elements to a real life process and helps to observe macro level emergent behaviours from micro level dynamics. The model will be simulated for theory building exercise.

- ***How can we validate the CAS model of BVIT?***

  The CAS model of BVIT needs to be validated to ensure that it mirrors the same theoretical logics as real data. We propose to compare real-life data from empirical studies with the simulated outcomes to ensure the model's validity.

# 4 Theoretical Grounding

This research is based on the theoretical concepts of Nevo and Wade (2010) study on IT enabled resources. Drawing the concepts of emergent properties from systems theory (Ackoff, 1971), the authors proposed that IT assets can be placed in a relationship with organisational resources, thereby creating synergistic IT enabled resources, the emergent properties (capabilites) of which facilitate an organisation to achieve profitability. Nevo and Wade (2010) proposed two important enablers to consider for evaluating realised synergy. First, IT assets and organisational resources must be *compatible* to be combined as IT enabled resources. It actually represents the appropriateness of the relationships between IT assets and organisational resources. Second, to become a consolidated system, the components of IT-enabled resources must be *integrated*. It refers to the activities taken by the management persons of an organisation to assist the implementation of IT assets within organisational resources.

Through the lens of CAS theory (Casti, 1994; Holland, 1995), the interaction pattern between IT assets and organizational resources can be conceptualized as bottom-up emergent process, whereby properties appear at organizational level (macro) from the relationships of IT assets and organisational resources at resource (micro) level. The literature also proves that the basic components of CAS can collaborately create observations at the macroscopic level, which appear from the interactions of microscopic components (Nan, 2011).

# 5 Preliminary Conceptual Model

The study by Nan (2011) on the IT usage process is selected as a guideline for designing our preliminary conceptual model, as well as for conceptual mapping of BVIT (see Table 1). Nan (2011) conceptualizes IT usage as multilevel and dynamic in nature, whereby individual-level IT use behaviours collaboratively create collective-level IT use patterns and outcomes i.e. bottom-up IT use processes. This research has proposed the similar concept in a BVIT context and developed a preliminary conceptual model of BVIT.

The preliminary model (see Figure 1) is consistent with the conceptualisation of Nevo and Wade (2010) on IT enabled resources. We propose that IT assets (IA) derive their business value from the impact they make on the organisational resources (OR) with which they interact; the bi-directional arrows in Fig. 1 represent the interactions between these two entities which actually refers to the IT enabled resources. Thus, the intrinsic capabilities of the IA should not be used in isolation to infer

their business value; instead, the emergent capabilities arising from their relationships with OR should be examined and evaluated. In fact, we believe that emergent capabilities that are beneficial or positive have the potential to help IT-enabled resources to achieve organisational goals (Nevo & Wade, 2011; Nevo & Wade, 2010). The upside arrow represents the emergence of capabilities in a bottom-up fashion from the relationships of IA and OR. For example- one capability of customer service department (CSD, capability x) is to provide answers to the customer inquiries. Assume that CSD can process the inquiries in *high rate* and *slow rate*. Let's further assume that, CSD is able to answer the inquiries in a *slow rate*. But with the use of an online inquiry handling system (IHS, capability y), resulting a new relationships (IHS enabled CSD, capability z), CSD can answer the inquiries in a *high rate* and thus the new relationships can positively affect overall organisational capabilities and thus enhance organisational performance implicitly. We refer to this instance as emergent capabilities that rise from the interactions among entities and positively influence the overall BVIT in a bottom-up manner.

CAS consists of three basic elements- agents, interactions and environment (Dooley, 1996). The objective of the CAS model here is to encode the elements of BVIT process in terms of agents, the interactions among agents and the relationships with agents and environment for examining the process whereby lower level components IA and OR collaboratively interact to give rise IT enabled resources and subsequently influence BVIT in higher level. We represent an exemplary conceptual mapping using secondary data from Nevo and Wade (2011) (see Table 1). We are expecting to simulate the model in a virtual environment using agent based modeling to better understand the underlying complexities of BVIT process. The CAS mapping represents how the elements of IT enabled resources from the real world can be outlined as the functioning elements of CAS.

| CAS Elements | CAS model BVIT | Examples |
|---|---|---|
| **Agents** | IT assets | Software platform |
| | Organisational resource | Customer Service Department (CSD) |
| **Agents attributes** | Technology characteristics e.g. Processing power | Ability to perform a task quickly |
| | Resource characteristics e.g. fast response to customer complaints | How quickly CSD Provide service to the customer |
| **Behavioural rules for agents** | IT functionalities | The set of functions or capabilities delivered by IT assets |
| | CSD efficiency | Range of capabilities owned by CSD |
| **Interactions** | User-system interactions | Direct usage of software platform to solve problem |
| **Connection** | It assets and organisational resources link e.g. CSD people and software platform | Use of software platform |
| **Flow** | Intangible resources movement | Distribution of knowledge |
| **Environment** | Organisation | Contextual structure of organisation1 |
| **Environment attributes** | Organisation size | Size of the organisation |
| **Behavioural rules for Environment** | IT enable resource synergy | To fulfil organisational task. |

*Table 1: CAS conceptual mapping of BVIT*

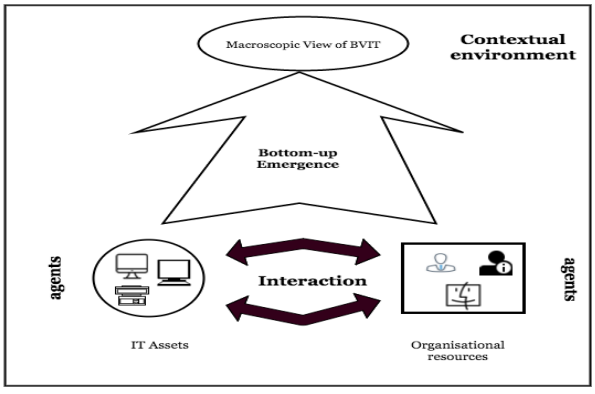


*Figure 1: Preliminary conceptual model of BVIT as CAS*

# 6 Research Design

The research design is based on the work of (Nan, 2011) on IT usage, but in BVIT context. It is also consistent with the roadmap for developing theory through simulation methods (Davis, Eisenhardt, & Bingham, 2007). Key phases of the research design are described below-

***Phase 1, Define the research problem:*** In this phase, we identified i) Research motivation(s), ii) Research problem & context, iii) Research question(s), and iv) Research Objectives. Topics reviewed were: i) existing BVIT studies, ii) prominent BVIT models, iii) usage of complex adaptive systems theory in the IS domain, iv) brief discussion on simulation research, and (v) related work on agent-based modelling.

***Phase 2, Propose the conceptual model of BVIT:*** Based on the theoretical concept of (Nevo & Wade, 2010), we have proposed our preliminary conceptual model of BVIT. By extending the key elements of CAS theory to the concept of BVIT, a conceptual view of BVIT processes is presented (see figure 1). This CAS model of BVIT is expected to serve as an ideal approach for encoding a bottom-up view of BVIT processes into a formal model. We have used secondary data from the (Nevo & Wade, 2011) study to develop the conceptual model.

***Phase 3, Develop the computational representation:*** The theoretical concepts of the conceptual model are necessary to be encoded into a computational representation (Davis, et al., 2007). This phase involves operationalisation of the theoretical constructs, and an algorithm defining the logical relationships of BVIT antecedents and specifying assumptions of different variables in a computational model. We have already proposed a conceptual mapping (see Table 1). The conceptual mapping will be translated into an algorithm and then a software code that captures step-by-step theoretical logic. The algorithm contains a series of steps to embody the construct values in accordance with the theoretical logic and assumptions (Davis, et al., 2007). Further, the algorithm will be translated into suitable programming languages- Logo Variant in NetLogo(Wilensky, 1999) to run the computational model. This step may need to be repeated multiple times for modeling feasibility.

***Phase 4, Verify and simulate the computational model:*** The verification process ensures the internal validity of the computational model. i.e. it accurately incorporates the theoretical logic of the conceptual model. It also ensures that the simulation results can be incorporated with confidence (Carley, 1996; Davis, et al., 2007). We will verify the computational representation is by comparing the simulation outcomes with the propositions of the conceptual model (Carley, 1996). If the simulation outcomes are consistent with the propositions of the conceptual model, then the theoretical logic and computational model are likely to be correct. We will also check the robustness of the computational model as a part of verification process.(Davis, et al., 2007). By changing the initial conditions and values of particular variables in the model, simulation results will be examined. A robust model is not sensitive to the changes of initial conditions and variable values.

***Phase 5, Validate with empirical data:*** This phase involves comparing empirical data from the real world with the simulated outcomes. If the results of the computer simulation match with the empirical evidence, the simulation is validated with that context (Davis, et al., 2007). Though scholars argue that, if the theory is based primarily on empirical evidence, then validation is less important, because the theory already has some external validity (Davis, et al., 2007). Different subtypes of validation like- face, parameter, process, and theoretical are checked during validation process (Carley, 1996). This research will use *grounding* and *calibrating* as recommended by (Carley, 1996) to validate face, parameter and process the ABM model. We are currently planning to use secondary empirical data from the (Nevo & Wade, 2011) study on BVIT to validate the computational model.

***Phase 6, Analyse the simulation findings:*** By changing the parameters and assumptions in the computational model, we can get many valuable insights about the BVIT process. The findings of the simulation will be analysed for deeper understanding of the BVIT processes.

# 7 Expected Contributions

The use of CAS theory in this study will add a new perspective to understand BVIT by emphasising the bottom-up emergence of IT enabled capabilities and their effect on the overall BVIT process. Thus it also challenges the traditional strategic management theory, like RBV, which is limited in its capacity for explicitly representing the underlying dynamics and characteristics of BVIT mechanisms. Moreover, traditional approaches to understand the BVIT process dominantly concerned with the discrete changes in the system's state at discrete time intervals. To capture the unfolding emergent dynamics, we need theories that can capture the changing state in the continuous time space (Merali,

2004). The CAS approach helps to describe state cycles in the simulations and thus provide a better way of exploring dynamic interactions among the BVIT entities in virtual space.

Moreover, the traditional approaches of studying BVIT lack of predicting the state of the processes in a future point of time, as it does not keep information about the continuous time space (Merali, 2004). However, the use of CAS theory in the BVIT case will help to foresee the probable states of processes in a future point of time through virtual simulation. Thus, it will assist managers to plan future investment decisions or make strategic planning according to the predictions from the simulation outcomes.

The proposed model can also be used for testing new theoretical insights. For example, from the literature we know that resources do not remain static over time, rather they change and evolve by adding or changing components (Wade & Hulland, 2004), but we do not know how the resources co-evolve each other in the internet-enabled world (Merali, 2004), how resources self organise in the dancing, rugged landscape of product and services (Tanriverdi, Rai, & Venkatraman, 2010) in organisations. The use of simulation facilitates to study these issues.

Another important theoretical contribution is the development of an integrated model to study BVIT based on two studies Nevo and Wade (2010) and Nan (2011). The concept of the IT enabled resources (Nevo & Wade, 2010) is the kernel of this study and we use CAS concept, emergence to describe how IT enabled resources can influence BVIT. The study of Nan (2011) just guides us how the constructs of the model can be mapped using CAS thinking in BVIT context. Thus, we proposed our preliminary CAS model of BVIT.

# 8 Current Status and Outlook

We are currently looking through IS literature for further empirical studies for the basis of our conceptual model. In addition, we are also formulating an in-depth literature review paper on CAS studies in IS domain. The purpose of the review is to identify how CAS theory has been used in IS research and the relevance of it with ours one. Furthermore, we are also looking for empirical research to validate our model. Lastly, we are currently in the middle of specifying the mathematical model. Future research will follow the key research phases described in section 6.

# 9 Refernces

Ackoff, R. L. (1971). Towards A System of Systems Concepts. *Management Science, 17*(11), 661-671.

Belleflamme, P. (2001). Oligopolistic Competition, IT Use for Product Differentiation and The Productivity Paradox. *International Journal of Industrial Organization, 19*(1–2), 227-248.

Brynjolfsson, E., & Hitt, L. M. (2000). Beyond computation: Information technology, organizational transformation and business performance. *The Journal of Economic Perspectives, 14*(4), 23-48.

Carley, K. M. (1996). Validating computational models. *Paper Available at:* http://casos.cs.cmu.edu/publications/papers/howtoanalyze.pdf.

Casti, J. L. (1994). *Complexification Explaining a Paradoxical World Through the Science of Surprise*. New York: HarperCollins.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2007). Developing Theory Through Simulation Methods. *Academy of Management Review, 32*(2), 480-499. doi:10.5465/AMR.2007.24351453

Dedrick, J., Gurbaxani, V., & Kraemer, K. L. (2003). Information technology and economic performance: A critical review of the empirical evidence. *ACM Computing Surveys (CSUR), 35*(1), 1-28.

Dehning, B., & Richardson, V. J. (2002). Returns on Investments in Information Technology: A Research Synthesis. *Journal of Information Systems, 16*(1), 7-30.

Devaraj, S., & Kohli, R. (2000). Information technology payoff in the health-care industry: A longitudinal study. *Journal of Management Information Systems, 16*(4), 41-67.

Dewan, S., & Kraemer, K. L. (2000). Information technology and productivity: evidence from country-level data. *Management Science, 46*(4), 548-562.

Dooley, K. (1996). Complex Adaptive Systems: A Nominal Definition. *The Chaos Network, 8*(1), 2-3.

Helfat, C. E., & Peteraf, M. A. (2003). The dynamic resource‐based view: capability lifecycles. *Strategic management journal, 24*(10), 997-1010.

Holland, J. H. (1995). *Hidden Order: How Adaptation Builds Complexity*. Reading, MA: Addison-Wesley.

Koellinger, P. (2008). The relationship between technology, innovation, and firm performance—Empirical evidence from e-business in Europe. *Research Policy, 37*(8), 1317-1328.

Markus, M. L., & Robey, D. (1988). Information technology and organizational change: causal structure in theory and research. *Management science, 34*(5), 583-598.

Melville, N., Kraemer, K., & Gurbaxani, V. (2004). Review: Information Technology and Organizational Performance: An Integrative Model of IT Business Value. *MIS Quarterly, 28*(2), 283-322.

Merali, Y. (2004). Complexity and Information systems. In J. Mingers & L. Willcocks (Eds.), *Social Theory and Philosophy For Information Systems* (pp. 407-446). London: Wiley.

Mooney, J. G., Gurbaxani, V., & Kraemer, K. L. (1995). A Process Oriented Framework for Assessing The Business Value of Information Technology. In G. A. J. I. DeGross, C. Beath, R. Hoyer, and C. Kemerer (Ed.), *In proceedings of the 16th International Conference on Information Systems (ICIS)*.

Nan, N. (2011). Capturing Bottom-Up Information Technology Use Processes: a Complex Adaptive Systems Model. *Management Information Systems Quarterly, 35*(2), 505-532.

Nevo, S., & Wade, M. (2011). Firm-level benefits of IT-enabled resources: A conceptual extension and an empirical assessment. *The Journal of Strategic Information Systems, 20*(4), 403-418.

Nevo, S., & Wade, M. R. (2010). The Formation and Value of IT-Enabled Resources: Antecedents and Consequences. *Management Information Systems Quarterly, 34*(1), 163-183.

Schryen, G. (2012). Revisiting IS business value research: what we already know, what we still need to know, and how we can get there. *European Journal of Information Systems, 22*(2), 139-169.

Soh, C., & Markus, M. L. (1995). How IT creates business value: a process theory synthesis. In J. I., G. A. DeGross, C. Beath, R. Hoyer, and C. & Kemerer (Eds.), *In proceedings of 16th International Conference on Information Systems (ICIS)*.

Tanriverdi, H., Rai, A., & Venkatraman, N. (2010). Reframing the Dominant Quests of Information Systems Strategy Research for Complex Adaptive Business Systems. *Information Systems Research, 21*(4), 822-834.

Wade, M., & Hulland, J. (2004). Review: The resource-based view and information systems research: Review, extension, and suggestions for future research. *MIS quarterly, 28*(1), 107-142.

Weill, P. (1992). The Relationship Between Investment in Information Technology and Firm Performance: A Study of the Valve Manufacturing Sector. *Information Systems Research, 3*(4), 307-333.

Wilensky, U. (1999). *NetLogo [Computer Software]*. Evanston, IL: Northwestern University, Center for Connected Learning and Computer-Based Modeling.