Chapter

Information Technology Value Engineering (ITVE)

Lukman Abdurrahman

Abstract

Information Technology (IT) has been the main infrastructures in conducting businesses nowadays. IT had firstly emerged to automate business operations, in turn, IT has been able to make business operations more effective due to the nature of IT as a business enabler. Consequently, resource-based business efficiency is also the cornerstone of utilizing IT. Most recently, IT has become OTT (Over the Top), where IT is only the basic layer for conducting online business. In essence, the aforementioned estimations all still rely on qualitative estimates and are not yet based on quantitative estimates. This chapter wants to try to offer an IT value model whose value estimation can be done quantitatively using the Partial Adjustment Valuation (PAV) approach.

Keywords: information technology, business enabler, value, engineering, model, optimization, partial adjustment valuation

1. Introduction

Information Technology (IT) has already transformed into a business enabler and an intentional reason [1] in firms to date. However, the IT presence should get improved administration to cause more values [2] such as effective and efficient business processes, and profit growth [3]. Consequently, IT should replace from a business enabler to a business transformer as per IT ecosystem to convey the approach of IT services [4], in which IT does not only behave a driving instrument but also lets businesses innovate and disrupt customs to revitalize its presence inside the firm. In sequence, this revival will allow the firm to sustain its competitive advantage remains efficient [5].

Additionally, this chapter intends to verify the IT presence in terms of a business transformer in the firm operation [6–8] improving its performance. To do so, it needs a method to engineer the IT position in transforming the business. Also, the method is to show up the IT capitals bringing up more values. In other words, the method should involve a systems engineering viewpoint, which discloses prime thoughts of the systems approach such as holism, synthesis, interrelationships, along with the engineering-project-based estimates of system life cycle and requirements [9]. Likewise, the systems engineering utilizes an engineering design containing problem-solving, alternative solutions, solution selection, detailed model, model guard, and validated model [10].

Also, validating the chapter, the studies on the strength of resources on performance [11–13] turns into an essential theory to analyze IT systems as components of business completeness [14] because the studies emphasize on the resources an organization owns to promote its performance. This is in line with the intent of this chapter that also emphasizes that the business performance runs over IT resources owned [15–17]. Likewise, this chapter applies the Partial Adjustment Valuation (PAV) theory approach in congregating valuation methods among system components as promoted by [18–20]. Equally for the use of PAV in this chapter is the ability to relate between IT resources and the organizational performance mathematically. Thus, it is easier to trace the relationship of each component or subsystem for further synthesis.

Additionally, this chapter has continued the earlier studies addressing the IT value model from the ontological approach towards IT value engineering [21], the IT value model using a variance-based structural equation modeling (SEM) towards IT value engineering [22], engineering IT value in IT-based industries using PAV and RBV (Resource-Based View) approach [23], valuation methodology of IT value in the IT-based business [24], IT value engineering model and its optimum performance [25, 26], and hybrid configuration in IT value models [27]. The investigation leads IT to be valuable resources of the firm to revitalize the IT's role through the IT value engineering model. Formerly, those studies had associated with a number of studies discussing the relationship between IT resources to business performance, such as [11–13, 17–20, 28, 29]. Meanwhile, the IT value defined in this chapter is the added value in the form of a currency, which can also be expressed as the index ratio, generated due to the IT spending presence.

2. Information technology value model study

This chapter problem relates to past studies, which most of them had talked over the relationship between IT and the organization performance. Researchers identified the types of conclusion [8] about the relationship, where numerous conclusions show that the relationship might be positive [12, 13, 30], negative [3], and even neutral [11, 31], see **Figure 1**. Additionally, the positive relationship means that IT has a positive correlation to the organization to increase its business value and at that moment the negative is otherwise. The negative relationship shows in early empirical studies explaining the association between IT investment and organizational performance; they set off the controversy of the IT productivity paradox as Brynjolfsson's (1993) conclusion [32].

In addition, the neutral relationship explicates that IT and business performance have no relationship in between as Strassman (1997) argued that there was no clear relationship between IT investment and a few measures of firm profitability, including return on asset, return on equity, and economic value added [11]. This chapter, further, addresses the positive relationship, although there are unfortunate situations where IT may have a negative impact as well [33].

The earlier studies, especially about the positive conclusion, have not yet talked about how to engineer the value of IT to deliver more benefits to the organization. On one hand, this issue is a complement study to the previous one because the chapter topic is a continual study of the past studies. On the other hand, also, this chapter may strengthen to close the past study, especially in terms of positive relationships between IT and the business performance, therefore, this chapter is to enrich and develop this domain further.

Additionally, the past studies seem like passive research, meaning that the work performed in the IT-equipped organization before. Consequently, the study has been simply conducted in conventional organizations and it has been less hard if it has maneuvered in a planned system. Therefore, the IT value engineering model chapter tries to offer a new approach to studying the role of IT within an

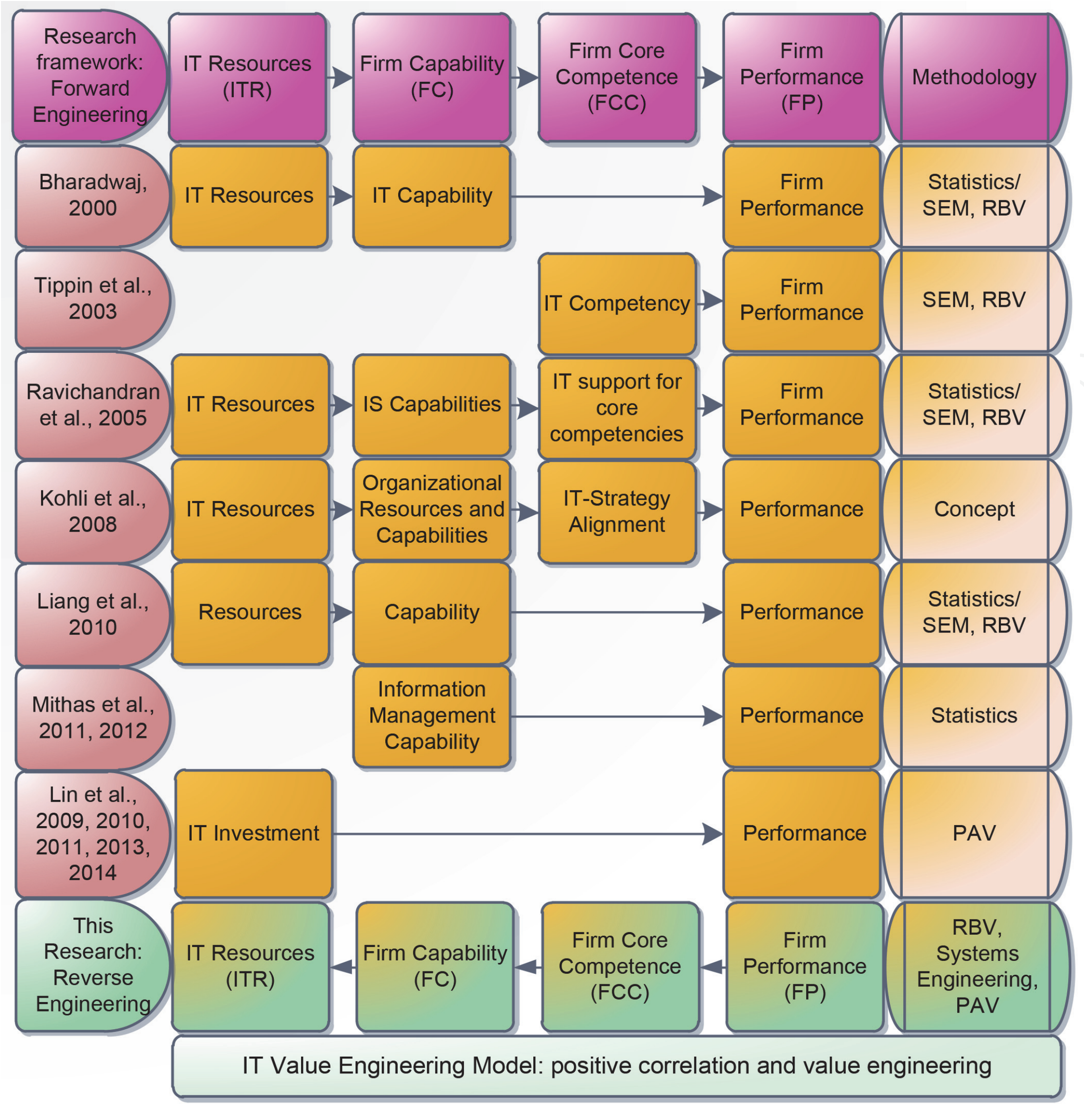

Figure 1.
The state of the art of ITVE.

organization. The approach initiates from RBV theory mentioning that the firm performance should root on the resources the firm owns, as the most famous fundamental theory in studying IT and organizational performance [13]. Then it explores sources of values of IT such that it can carry out a relationship formulation between IT value and the organization.

Figure 1 confirms to place this chapter among the others, which grounded on the earlier ones, nevertheless, with a different approach. For instance, from the subsystems point of views, this chapter solely resembles the Ravichandran's model, which also took in four subsystems, namely IT resources, IS capabilities, IT support for core competencies, and firm performance [12]. Likewise, [34] exhausted four subsystems, although their nomenclature is different from Ravichandran's. As for the other studies such as [11, 13] used three subsystems, namely IT resources, IT capability, and firm performance. However, [35] directly studied to link up between IT competency to firm performance, also [30, 36] simply studied between the data management capability to the performance as well as [18–20, 37, 38] researched the relationship between IT investment and public presentation. This chapter applies four subsystems based on RBV theory with their nomenclature as follows firm performance (FP), firm competence (FCC), firm capability (FC), and IT resource (ITR).

Furthermore, from an engineering point of views, the earlier studies generally exploited forward engineering, which begins from resources towards firm performance, while this chapter proposes reverse engineering for a serial configuration (see **Figure 1**), which begins from the required firm performance, afterwards, estimate the firm core competencies and firm capabilities to get IT resources composition. Also, from a methodological point of views, the earlier studies generally benefitted statistical approach or structural equation modeling (SEM) and RBV approach, excluding [18–20, 37, 38] who used PAV. This chapter appears with a different approach, whereas combining the earlier approaches such as RBV, PAV, and systems engineering at once. In other words, this chapter also carries the different final goal from the earlier ones, in which this chapter is to engineer IT resource about the required firm performance to let it performs at the lower cost.

Additionally, the chapter on the IT value was also conducted by the researchers such as [33] directing that the IT is an integrally part of a system of interrelated organizational factors, [39], who concentrated on the potential and realized IT values estimated by DEA (data envelopment analysis). Similarly, [6] estimated the IT business value by Cobb–Douglass function. Furthermore, [28, 40, 41] generally addressed the IT business value.

Meanwhile, to complete the chapter, the PAV [20] applies to correlate the subsystem input to its output. Additionally, the PAV usually operates with a static speed of adjustment or with a dynamic speed of adjustment in a researched object, on the contrary, in this chapter both the static and the dynamic speed of adjustment work together at a time in the PAV experiment. Likewise, thus far the PAV has applied in the country level study such as [18–20], however, this chapter tries to use the PAV at the firm level as the other study of the IT investment correlation to the firm productivity [8]. As for the chapter analysis, system engineering is to find this chapter because the IT value engineering essentially consists of subsystems such as electrical, computer, and value engineering. Likewise, the system engineering approach analyzes the chapter from both system engineering life cycle and model point of views.

In turn, the chapter result may turn away to become a framework to design an IT-based governing body by looking at several factors either internal or outside factors, including business environment ones. In other words, this chapter is an active chapter using its result, it can plan an organization as well as develop an established organization. Consequently, this chapter encompasses a broader domain of IT-based organization: established and planned systems.

3. IT value engineering paradigm

3.1 Value concept

Discussing a value means that it is addressing usefulness, worth, benefit. Furthermore, the value may disclose if there is an interaction between two or added systems or subsystems, in which one system works with the other one and vice versa, or the system works due to the other systems. Why would the systems mutually function? There is an energy that urges them to work, which is latterly called the value, usefulness, worth, benefit, competitive advantage, or other terms. In other words, this construction can facilitate accomplishing the stage of value creation by benefiting system processes.

There are various types of values such as normative value, realist value, and perceived value. Consecutively, the normative value relates to the required value as planned previously, the realist value pertains to the resulted value that comes from an accomplishment, and the perceived value is what consumer relatively perceives [16]. Additionally, if comprehended from cost management perspectives, the other types of values are the use value, meaning the value of the required function associated with the cost. Afterwards, the cost value, namely all cost values, dedicated to result in the item; the esteem value, means that the value of surplus cost to pay the additional items; the exchange value, namely the value of an item to exchange something else [42, 43].

Moreover, as a fundamental nature of the value definition of this research, the equation definition below bases further studies. This equation technically articulates a value (V) as an index resulted from a function (F) division by cost (C) as proposed by [44] as follows:

$$V = \frac{F}{C} \tag{1}$$

According to the formula, several efforts to bring the value gaining are:

- For a similar function (F), diminish the cost (C) or
- The cost (C) is stable, improve the function (F) or
- The function (F) slightly reduced, the cost (C) significantly decreased or
- The cost (C) a slight increase, the function (F) has increased significantly or
- The function (F) increases while the cost (C) decreases.

It appears that by adjusting function and or cost, the system can control the value to ascend or descend consistent with what the purpose is, although, in practice, there are several considerations to essentially prepare in implementations [44].

3.2 IT value creation

As mentioned, the IT value may come from an estimate of the real worth, utility, or the IT system's significance. This definition does not limit from what the worth, the utility, or the significance come from, thus, it does not prevent the multiple perspectives possibility. There is the stakeholder expectation such this, in turn, it influences the IT value achievement. In substance, value stems from the IT system to support the stakeholder aims attainment. For example, a debit card system that removes the requisite for cashiers to manually count cash may present cashiers with value since it lessens tension on their hands [45].

In addition, to explore the value of IT needs to investigate some scales reflecting these values. Accordingly, the metrics development is a necessity to measure IT values, however, there are certain criteria for the metric development as proposed by [45]. These criteria depart from selected questions that might be considered as follows:

- What is the evidence to evaluate?
- Where must valuation occur?
- When must valuation occur?
- How must valuations be interpreted?

It has been completely recognized that the IT value systems can manifest as a complex system consisting of various subsystems, components, subcomponents, and parts. Furthermore, as measuring the IT value, it is valuable to think about measurements that concentrate on. Definitely, the building of the metrics as a means to evaluate values results in a variety of problems, which necessitates doing so with care [45].

On the other point of view, the IT value study has to involve two sections: (i) IT variable, IT management variable or manifestation, and (ii) endogenous variable with IT economic impact [46]. Doing IT valuation involves complex issues, including social accomplishment so it requires over a period of time. Thus, this study should perform in an inclusive fashion such that the IT value research corresponds to an imperative flow of work that leads to business value. Likewise, there are economic associates of IT and its manifestations, and by itself, the scope of the research should restrict to examine the IT value to engineering it at the organizational level.

In the meantime, the IT resources that are subsequently delivering their capabilities can not create value for themselves within the organization. They need interaction with a business environment such that each will complement one another. As a result, IT infrastructures and organizational factors appear to work in a synergistic way, where these factors are part of the IT-based system consisting of IT human resources and IT management skills, rules, and policies. This is as the organizational system that comprises non-IT human resources and management skills, business procedures, information benefits, affiliation benefits, way of life, organization, and rules. In reality, IT is production machines, therefore, it generates value in the output configuration resulting in benefits due to business processing. In other forms, the value is apparent by itself in the form of process improvements such as saving time, process effectiveness, profitability, such as a higher return on assets, on investment, and consumer surplus such as higher customer satisfaction.

Furthermore, [34] stated that there are numerous factors in terms of the IT value creation chain that is essential and required conditions. Included in these conditions are the IS-strategy configuration, organizational restructuring, business process accomplishment, knowledge sharing, and IT management among others. Accordingly, those are critical in terms of the encouraging of the transformation process and renovation of the effectiveness of IT advantages. Additionally, there are four foremost subjects to demonstrate how IT value is shifting to describe, quantify and show it. The four subjects are (1) value IT-based co-creation, (2) IT embeddedness, (3) information approach, and (4) value extension.

The following stage of the IT value creation should concentrate on the co-creation of value by means of IT instead of IT value itself, further, it is called IT-based co-creation of value. While, the co-creation stands for the thought that (a) IT value cannot manifest in an isolated environment, it is progressively more being formed and accomplished due to actions of numerous parties, (b) value comes from strong joint associations among organizations, and (c) configurations and encouragements for the parties to contribute in and equitably assign emergent values are essential to keeping up co-creation. Moreover, IT embeddedness relates to the condition in which the IT is a central part of the process such that it turns into identical to the product. For example, the IT in a bank's industry of instant credit check is intensely embedded in the loan endorsement process and hard to separate out. In other words, IT embeddedness is a fundamental model that attached to value co-creation, information mindset, and value expansion. Thus, it is plausible that preferred business capabilities drive IT embeddedness. Therefore, the effective convergence of preferred business capabilities and IT capabilities is a precondition "to realizing capabilities among organizations (co-creation), creating information value (information mindset), and ultimately realizing a wide repertoire of value (value expansion)" [34].

3.3 IT value engineering concept

Tohidi (2011) stated that the idea of value engineering is to employ the projects, strengthen accomplishment and diminish costs in all life cycles of the projects. In this case, the lifetime value of the engineering project with the productivity increment can result in the value of the project, namely the output to the input ratio. Hence, the value engineering application is boiling down to performance improvement of inputs and outputs, by applying a theoretical approach of value engineering processes together with project management, project analysis, value analysis, and value management. Additionally, he mentioned that value engineering is constantly dealing with the growth of technology, reducing the unnecessary costs that do not relate to improving the products or services quality. Reducing costs in conventional point of views do not associate with creativity, it only refers to familiarities, feelings, and practices. On the contrary, in value engineering, the usage of knowledge, the problem recognition, the method of problem-solving, the development of the creative solutions could combine to develop comprehensive approaches [47].

Additionally, value engineering is a structured method to investigate the systems function and its completeness in dealing with a systems fundamental function accomplishment at the lowest cost. However, the functions of systems consistently keep up a better performance, trustworthiness, quality, and security [48]. Consequently, the value engineering process arrives at success if it is to discover opportunities to diminish needless costs and at the same time it is able to keep up and raise quality, consistency, accomplishment, and other customer needs on products or services. In terms of IT value, the IT generally boils down on the effectiveness and efficiency of processes, including achieving the best organizational performance. In other words, IT should disseminate value-added advantages through strategic alignment with the organizations.

Essentially, the IT presence within an organization is the norm for the era that is so, there is no one business organization that does not exploit the IT, where the simple difference is the amount of IT capacity. Empirically, such circumstances are something that is unquestionable, but the problem now is how to place the IT position within the business organization with the aim of its presence increasingly contribute enormous weights to the organization performance. Thus far, the IT inclusion in organizations is due to the demands of the times as technology-driven instead of market-driven, it is more emphasis on administrative rather than business development activities. Therefore, this chapter attempts to reposition IT as a means to improve competitive advantages of firms as indicated in **Figure 2**, which appears that IT should set it on the layer where is as the engineering processes culmination that preceded by electrical, computer, software, systems, and a complex system engineering to lead generating an IT value engineering.

Intrinsically, IT value engineering positions the IT at the more well-organized since it can go through an engineering process to create additional significant values as a continuation value generated on the preceding layers (see **Figure 2**). In other words, IT value engineering is the added value due to the engineering of the systems consisting of value, software, computer, electrical engineering. Meanwhile, the organizational environment is a circumstance where a firm should perform its business here, which are competitive forces including risks due to the business activities. The organizational environment should controllable to continue firm's existence in business turbulence to sustain its competitive advantages, which are consisting of six categories, namely cost, differentiation, focus, execution,

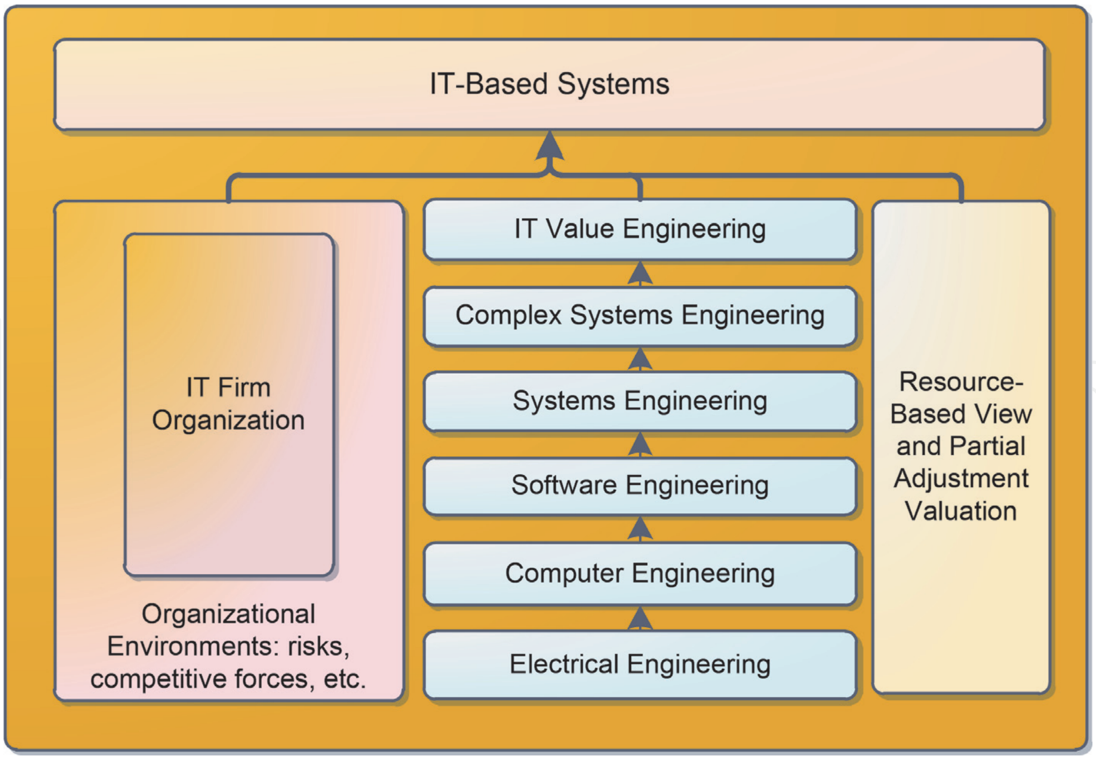

Figure 2.
IT value engineering position in an organizational environment.

knowledge, and maneuverability advantages [5]. In this study, the competitive advantage that becomes a highlight is a cost-competitive advantage, which can result from the IT value engineering through a system optimization effort.

Furthermore, the IT value engineering has presented in an IT-based firm (see **Figure 2**), which is a firm that its core business has two wide-ranging groups of products and services, namely lifespan application development and support services and production processes [5] or industrial products and services that catch, transmit and display data and information by electronic means [49]. In the meantime, using RBV theory, this chapter departs from firm performance towards IT resources instead of the regular RBV, which originates from the resources to the firm performance in terms of the serial configuration.

This chapter proposes to structure the four subsystems of the RBV-based result, namely firm performance (FP), firm competence (FCC), firm capability (FC), and IT resource (ITR) to accomplish the rigorous IT value engineering concept by considering the nature of VRIN (valuable, rare, inimitable, non-substitutable) IT resources. In this case, each subsystem needs to identify its measures, which facilitate to determine the characteristics of the subsystem to build relationships with other subsystems or between the subsystem input and output [50]. Therefore, the FP typically addresses financial and efficiency performance, which manifests in, such as time-to-market and mass customization [51], profitability containing return on investment, return on asset, return on equity [16, 52]. While the FCC emphasizes to a firm's core competence as the learning process ability to manage various resources and technology within the firm [53], consisting of three components: IT knowledge, IT operations, and IT objects. IT knowledge is the extent to which a firm possesses a body of technical knowledge about objects such as computer-based systems, while IT operations are the extent to which a firm utilizes IT to manage market and customer information. IT objects represent computer-based hardware, software, and support personnel [35].

Moreover, FC focuses on the assembling and installing IT-based resource capabilities to work together with the other resources in the firm [11] controlled by IT infrastructures, managed IT skills, and collaboration between IT and business [54]. The three measures combination can result in the firm capability, hence, it can create the VRIN IT resources, which also consist of IT infrastructure as tangible resources, human IT resources representing technical and managerial IT skills, and intangible IT-enabled resources such as knowledge assets, customer orientation, and synergy [11].

Preferably, to construct an IT spending model system, each measure or component of the subsystems relates one to another is not only qualitatively rational, but also quantitatively plausible as issued by [8]. However, to quantitatively plausible, the subsystems should also have complete measures that can manifest in a mathematical model. As proposed above, the mathematical formula to construct the relationship in this research is the partial adjustment valuation theory [20], which involves Cobb–Douglas production transformation as the input function.

4. Partial adjustment valuation (PAV) theory

Dedrick et al. (2003) stated that the failure of the subject area of the relationship between IT spending and the output performance at the firm level occurred due to the difficulty of quantifying measurement between these quantities [8]. Therefore, the chapter tries to do so by PAV. In this case, Nerlove (1958) was a developer of the origin of PAV theory and further developed by the researchers as it is today. The theory tells that the change in real output of a production process generally does not precisely fit the desired output alteration. The alteration measurement is in the present (t), compared with the previous period (t-1) for the real alteration and the desired alteration, which it is clear that there must be a coefficient bridging the relationship between the two alterations called a constant speed of adjustment [19, 20]. Therefore, if written in a mathematical formula, the theory manifests as follows:

$$y_t - y_{t-1} = \mu\left(y_t^* - y_{t-1}\right), \qquad (t = 1, 2, \dots, s) \tag{2}$$

It seems that y_t is the real output of a production process unit, for example, a firm, in time t, as for y_{t-1} is the real output of the equal production process unit at time t – 1. While y_t^* is the desired output of the production process unit at time t, and μ is the coefficient depicting a constant speed of adjustment [20]. In an estimation process, an old-fashioned random error symbolized by ϵ_t needs to consider completing the formula. Consequently, Eq. (2) manifests as follows:

$$y_t = \mu y_t^* + (1 - \mu)y_{t-1} + \in_t \qquad (t = 1, 2, \dots, s) \tag{3}$$

Whereas ϵ_t = conventional error. It appears that the real output is equal to the weighted average of the current desired output – with the weights μ – and the real output at a past time, with weights 1-μ. Furthermore, Lin and Kao (2014) suggested that μ in Eq. (2) and (3) can vary and be dynamic, therefore, μ may convert to μ_t where t represents fluctuations in time for the dynamic and μ for the constant or static. This scheme aims to provide more meaning of μ, for instance, the dynamic μ represents the speed of adjustment behavior in connecting the real output alteration with alterations in the desired one. In other words, these two alterations in output comprehend the dynamic nature of μ. Later, the scheme also exhibits the other signification of the state for further exploration [20].

At that time, the writing the equation above can turn to the subsequent Eqs. (4) and (5) [19, 20]:

$$y_t = \mu_t f(X_t;\beta) + (1-\mu_t)y_{t-1} + \in_t \qquad (t = 1, 2, \dots, s) \tag{4}$$

$$\mu_t = g(S_t;\gamma), \quad 0 \le \mu_t \le 1, \qquad (t = 1, 2, \dots, s) \tag{5}$$

Here $f(X_t,\beta)$ is the alternate function of the desired output (y_t^*), which manifests in the form of a production function [8, 18, 19, 37, 38]. Accordingly, X_t could consist of a vector of production such as the regular capital (K_t), the regular labor expense (L_t), and the technology spending, in this study related to IT spending (I_t). For the benefit of variable estimation of the production function, it may consist of two compositions. The first is K, L, and I combination to accommodate the factors of capital, labor, and IT spending immediately, and the second is K and L combination that accommodates the factors of capital and labor. Thus, there are two models: $X_t = (K_t, L_t, I_t)$ and $X_t = (K_t, L_t)$ while β is the unknown parameters [19, 20].

Meanwhile, the function $\mu_t = g(S_t;\gamma)$ represents a dynamic speed of adjustment that accommodates variables, which fluctuate along with the different fluctuations of the required output such as return on equity (ROE). The magnitude of μ_t or μ is in the range of 0 and 1 [20], where the value of 0 means that the real output at time t is precisely equal to the real output of the previous period, t-1. While if 1 indicates that the real output is equivalent to the desired output. Conversely, μ_t is a S_t function, a vector of the variable, affecting the speed of adjustment of a firm, and γ is the unknown parameters. Therefore, to return to the original PAV theory, Eq. (4) is as follows:

$$y_t - y_{t-1} = \mu_t f(X_t;\beta) - \mu_t y_{t-1} + \in_t \qquad (t = 1, 2, \dots, s) \tag{6}$$

Essentially the production function of the Eq. (4), namely $f(X_t,\beta)$, can originate from various production functions such as the Cobb–Douglas (CD), the Box–Cox, the Box–Tidwell, the translog, and the constant elasticity of substitution functions [18–20, 37, 38]. The work may select all or a number of them as a test target. For that reason, this study just exploits the CD production function to substitute $f(X_t,\beta)$ in Eq. (4). While, the CD equation is equally in the Eq. (7) below [18]:

$$f(X_t;\beta) = \alpha K_t^{\beta_1} L_t^{\beta_2} I_t^{\beta_3} e^{v_t - u_t} \qquad (t = 1, 2, \dots, s) \tag{7}$$

The Eq. (7) presents the CD function with X_t consisting of production factors K_t, L_t, and I_t. K_t is the regular capital, L_t is the regular labor expense, and I_t is IT capital over time. In other words, Eq. (7) takes into account the IT capital inclusion. Meanwhile α, β_1, β_2, and β_3 are the unknown parameters and $v_t \sim N(0, \sigma_v^2)$, and $u_t \sim |N(0, \sigma_v^2)|$. In addition, to estimate these parameters performs in an estimation process. Equally for the CD function without I_t presence is as follows in Eq. (8):

$$f(X_t;\beta) = \alpha K_t^{\beta_1} L_t^{\beta_2} e^{v_t - u_t} \qquad (t = 1, 2, \dots, s) \tag{8}$$

Justification of the Eq. (8) is equivalent to the Eq. (7), apart just the I_t absence. While the Eq. (5), the speed of adjustment, can display as in Eq. (9) [20]:

$$\mu_t = \gamma_1 + \gamma_2 S_t \qquad with \;\; 0 \le \mu_t \le 1 \tag{9}$$

Here μ_t is the dynamic speed of adjustment, and S_t is the dynamic factor that can manipulate the dynamics of μ_t suitable to the time-varying. Likewise, it may show as variances between the actual and the estimable variables of the firm. Furthermore, researchers provide a number of measures to fill these factors with various variables S_t, for example, return on equity, interest rate, firm size, growth option, economic value-added, and Tobin q [19, 20]. While γ_1 and γ_2 are the unknown parameters.

Moreover, if the Eqs. (7) and (9) substitute components of the Eq. (6), it produces an Eq. (10) as follows:

$$\begin{aligned} y_t - y_{t-1} &= \left(\gamma_1 \alpha K_t^{\beta_1} L_t^{\beta_2} I_t^{\beta_3} e^{v_t - u_t}\right) + \left(\gamma_2 S_t \alpha K_t^{\beta_1} L_t^{\beta_2} I_t^{\beta_3} e^{v_t - u_t}\right) \\ &\quad -\left(\gamma_1 y_{t-1}\right) - \left(\gamma_2 S_t y_{t-1}\right) + \in_t \qquad (t = 1, 2, \ldots, s) \end{aligned} \tag{10}$$

The Eq. (10) is for the three-factor production function, namely K_t, L_t, and I_t. It looks that the equation above is analogous to the Eq. (6), except that the production function, namely f (X_t, β), has converted to the Cobb–Douglas function [see Eq. (7)] and the speed of adjustment μ_t replaced by the Eq. (9). The variables and parameters justification of the equation is equivalent to the preceding equations, which substitute it. Meanwhile, for the two-factor function [Eqs. (7) and (8) substituted into the Eq. (6)], the equation becomes Eq. (11) as follows:

$$\begin{aligned} y_t - y_{t-1} &= \left(\gamma_1 \alpha K_t^{\beta_1} L_t^{\beta_2} e^{v_t - u_t}\right) + \left(\gamma_2 S_t \alpha K_t^{\beta_1} L_t^{\beta_2} e^{v_t - u_t}\right) \\ &\quad -\left(\gamma_1 y_{t-1}\right) - \left(\gamma_2 S_t y_{t-1}\right) + \in_t \qquad (t = 1, 2, \ldots, s) \end{aligned} \tag{11}$$

The equation justification is also analogous to the Eq. (10), except just the I_t absence. Furthermore, the Eqs. (10) and (11) are non-linear equations, their solution must also exploit a non-linear least square (NLS) application [20].

5. ITVE methodology

5.1 Meta-analysis

The first method of the ITVE is the meta-analysis approach, where the study concerns with the previous results in the analogous context, namely the relationship between IT resources and business performance. The method enriches the study since various validated hypotheses provide the researcher with strengthening the topic justification, therefore, the study can lead to conclude towards the objective of the chapter qualitatively [13]. In addition, this technique authorizes authors to study several papers addressing the IT value to the business performance relationship from the RBV point of view. Consequently, based on a number of the previous papers, particular topics such as IT resources, firm capabilities, firm core competencies and firm performance are categorically recognizable, where each group has to have relationship one to another for what this relationship leads to a means to link one category to another to construct a model of the IT value. Essentially, the resulting model is not only based on the meta-analysis approach, but also based on the RBV theory.

5.2 Partial adjustment valuation experiment

This method addresses PAV theory, which is linked components of each subsystem to investigate the correlation between IT resources and business performance. This section first reviews the PAV utilization in this chapter through the theory experimentally of the real facts to measure several IT-based firms using the PAV approach to examine the level of the IT value within each firm.

5.2.1 Structure of conceptual models of IT value engineering

According to the meta-analysis, to create conceptual models, which involves logical and mathematical relationships, this method facilitates to develop two types of the model. The first model of IT value or the three-factor model is through substituting the Eq. (6) by the Eq. (7) and (9). Hence, the first model changes to the Eq. (10) above, which is the partial adjustment with Cobb–Douglas (CD) production function is inside and implying K_t (regular capital), L_t (labor expense), and I_t (IT spending) factors.

Meanwhile, through substituting the Eq. (6) by the Eq. (8) and (9) can create the second model of IT value (K_t and L_t) or the two-factor model as comprehended in the Eq. (11) above. Once again, both the Eqs. (10) and (11) are non-linear equations, thus, to estimate them must also use a non-linear least square (NLS) [20].

5.2.2 Determination of the dynamic and static speed of adjustment and the production function

This study selects the return on equity (ROE) [20] as a component of the dynamic factor of the speed of adjustment since the ROE has an adjacent relationship to the regular capital (K), which is the firm equity, thus, the ROE can seem more representative as a dynamic factor (S_t) in this study than the others. Also, in order for the fluctuation rhythm of the K to compensate by the ROE fluctuation. While the ROE is a gain for the year of the parent firm divided by total equity of the parent firm at year-end December. Thus, the ROE becomes a dynamic factor (S_t, t is a period of time) of μ_t (the speed of adjustment) function to signify the dynamics of the speed of adjustment as comprehended in the Eq. (5) or (9). As for the static speed of adjustment, the Eq. (5) or (9) is equal to a constant, which is estimable in the non-linear least squares (NLS) estimation process. Moreover, the production function of the Eq. (4) devotes to the Cobb–Douglas (CD) function as explicated in the Eq. (7) and (8) above due to its simplicity and familiarity in production function transformations [18, 55].

5.2.3 Chapter and estimation models

For the purpose of assessment to separate the presence (with I_{it}) and the absence (without I_{it}) of the IT capital in the PAV approach, the estimate works on both $X_{it} = (K_{it}, L_{it}, I_{it})$ and $X_{it} = (K_{it}, L_{it})$. Here i = 1, ..., r = 8, for example, for the number of testing firms, and t = 1,..., s = 11, for example, for the period of testing data, such as from 2004 to 2014. It is a time-varying, hence, the system is dynamic, therefore, for that reason, the study models can apply both Eqs. (10) and (11), however, caused the equations to overparameterize due to nonlinear, the estimate also needs the nonlinear least squares (NLS) application [20].

5.2.4 Estimation of the dynamic and static factor of the speed of adjustment

The Eqs. (10) and (11) estimation results in the unknown parameters, including γ_1 and γ_2 of the Eq. (9) for the dynamic speed of adjustment, while the static speed of adjustment is constant for all periods t. Therefore, the dynamic speed of adjustment as in the Eq. (9) is estimable to assess the dynamics of the μ_{it}. In addition, due to covering a period of time, the μ_{it} has the average speed of adjustment (ASA) as well. Assume γ_i estimate as $\hat{\gamma}_i$, the average dynamic speed of adjustment (ASA_i) appears as in the Eq. (12) [20].

$$ASA_i = \sum_t^s \frac{g\left(S_{i(t)}; \hat{\gamma}_i\right)}{s} \qquad (i = 1, \dots, r \quad and \quad t = 1, \dots, s) \tag{12}$$

At this point, $g(S_{it}; \hat{\gamma}_i)$ is the S_{it} function, a vector of the variable, affecting the speed of adjustment. In that case, i and t address firm category and period of time. This method allows the study to comprehend the dynamics of the speed of adjustment and the value disparity between the three-factor (K_{it}, L_{it}, I_{it}) and the two-factor (K_{it}, L_{it}) models, which the meaning of the I_{it} factor appears to contribute to the business performance. Meanwhile, the static factor of the speed of adjustment is constant for all periods t, its average is equivalent to its addition, within the periods divided by the amount of the periods.

5.2.5 Valuation of performance measures of the PAV experiment

In order to evaluate the change of the firm performance due to IT spending, Lin and Kao (2014) proposed the performance measures (PM) of the dynamic (μ_{it}) and static (μ_i) speeds of partial adjustment evaluate the performance change of the processing unit tested. This measurement manifests in Eq. (13) below [19, 20]:

$$PM_t = \mu_t f(X_t; \beta) = g(S_t; \gamma) f(X_t; \beta) \tag{13}$$

To estimate the parameter γ and β, both parameters further designated to become $\hat{\gamma}$ and $\hat{\beta}$, thus the Eq. (13) converts to:

$$PV_{it} = \widehat{PM}_{it} = \hat{\mu}_{i(t)} f\left(X_{it}; \hat{\beta}_i\right) = \; g\left(S_{i(t)}; \hat{\gamma}_i\right) f\left(X_{it}; \hat{\beta}_i\right) \tag{14}$$

In this case, PV_{it} is performance values of the processing unit or the firm. If averaged, the Eq. (14) results in:

$$APVi = \sum_t \frac{PV_{it}}{s} \quad (i = 1, \ldots, r \; and \; t = 1, \ldots, s) \tag{15}$$

Both the Eqs. (14) and (15) result in the currency value, however, that is further common, it would be superior if presented in the form of an index ratio. Consequently, PV_{it} should be divided by the real output (y_{it}), instead of a "devisor" (y_{it}^{Δ}) as suggested by [19] to become an index of performance ratio (PR). Therefore, the equation seems as the Eq. (6), and if averaged, the equation becomes the Eq. (7), which it can measure to what extent value the role of IT spending in the business organization, compared with no the investment.

$$PR_{it} = \frac{PV_{it}}{y_{it}} \quad (i = 1, \ldots, r \; and \; t = 1, \ldots, s) \tag{16}$$

The average value (APR) of Eq. (16) appears as using the subsequent formula:

$$APR_i = \sum_t \frac{PR_{it}}{s} \quad (i = 1, \ldots, r \; and \; t = 1, \ldots, s) \tag{17}$$

Using this method, it is plausible to consider the amount of value between the IT capital presence and its absence within a capital expenditure of the firm. In other words, the IT value model using the PAV guides the study to comprehend the value of IT.

In order to evaluate the change in the firm performance due to IT spending, Lin and Kao (2014) proposed the performance measures (PM) of the dynamic (μ_{it}) and static (μ_i) speeds of partial adjustment to evaluate the performance change of the processing unit tested. This measurement manifests in Eq. (18) below [19, 20]:

$$PM_t = \mu_t f(X_t;\beta) = g(S_t;\gamma) f(X_t;\beta) \tag{18}$$

To estimate the parameter γ and β, both parameters further designated to be $\hat{\gamma}$ and $\hat{\beta}$, thus the Eq. (18) converts to:

$$PV_{it} = \widehat{PM}_{it} = \hat{\mu}_{i(t)} f\left(X_{it};\hat{\beta}_i\right) = \; g\left(S_{i(t)};\hat{\gamma}_i\right) f\left(X_{it};\hat{\beta}_i\right) \tag{19}$$

In this case, PV_{it} is the performance values of the processing unit or the firm. If averaged, the Eq. (19) results in:

$$APVi = \sum_t \frac{PV_{it}}{s} \quad (i = 1, \dots, r \text{ and } t = 1, \dots, s) \tag{20}$$

Both the Eqs. (19) and (20) result in the currency value, however, that is further common, it would be superior if presented in the form of an index ratio. Consequently, PV_{it} should be divided by the real output (y_{it}), instead of a "devisor" (y^{Δ}_{it}) as suggested by [19] to be an index of performance ratio (PR). Therefore, the equation seems as the Eq. (21), and if averaged, the equation becomes the Eq. (22), which it can measure to what extent value the role of IT spending in the business organization, compared with no the investment.

$$PR_{it} = \frac{PV_{it}}{y_{it}} \quad (i = 1, \dots, r \text{ and } t = 1, \dots, s) \tag{21}$$

The average value (APR) of Eq. (21) is calculated using the subsequent formula:

$$APR_i = \sum_t \frac{PR_{it}}{s} \quad (i = 1, \dots, r \text{ and } t = 1, \dots, s) \tag{22}$$

Using this method, it is plausible to consider the amount of value between the IT capital presence and the absence of it within a capital expenditure of the firm. In other words, the IT value model using the PAV guides the study to comprehend the value of IT.

5.3 The PAV approach validation

In essence, the applied method in this chapter is identical to the abovementioned method, namely starting from the structure of the conceptual model of IT value consisting of two types of models: three and two-factor models up until valuation of performance measures. However, the difference is simply on the goal, namely the earlier method aims to examine the PAV theory using the real facts to make sure that the IT inclusion in the business organization is material and valuable, while, this subchapter is to validate the resulted experiment data in several IT-based firms to certify that the PAV theory encounters the criteria of system measurements from a statistical point of views [8] to identify the level of the IT value of each firm. The validation is through model data examinations.

Here, the exploited data have been covering the period, for example, from 2004 to 2014, collected from the audited financial statements and the published annual reports. To compare between the presence (with I_t) and absence (without I_t) of the IT capital in the PAV approach [20], the estimation involves both $X_t = (K_t, L_t, I_t)$, and $X_t = (K_t, L_t)$ where t = 1..., 11 at the time of confirmed data from 2004 to 2014 for both static and dynamic speed of adjustment.

5.4 Development of IT value engineering model

In reality, the adopted chapter method respects with the exposure of systems engineering processes offered by [50, 56], which is afterwards packaged in the method sequences as depicted below [10].

5.4.1 Definition of the problem

As mentioned, the primary problem of this chapter is how to carry out the need of worthy performance of the IT-based business organization to sustain competitive advantages by optimal costs, especially IT costs. Since this problem involves a variety of factors such as functional subsystems of RBV point of views, financial systems, competitive forces, business performance, risk management, resource management, and so forth. Accordingly, to solve this problem needs a systems engineering approach integrating various components into a unity solving the needed values.

5.4.2 Invention, evaluation, and selection of alternative solutions

In order to solve the problem, various alternative solutions could be a means to undo. Examples of the alternatives are with increasing the firm performance while the IT capital is constant, improving the IT competency and capability of the organization, and cost optimization by encouraging innovation, restructuring, IT cost-saving/ efficiency, and effective IT procurement. Indeed, each alternative has advantages and disadvantages, therefore, the preferred solution is all alternatives combinations to compile in a systems engineering process.

In the meantime, the preferred solution selected based on the five criteria that Kosky et al. (2013) initiated, namely "minimize information content, maintain the independence of functional requirements, ease of manufacture, robustness, and design for adjustability" [10].

5.4.3 Detail of design

According to [56], the systems engineering life cycle phases and the systems engineering method merges, which denotes that for each engineering phase of a horizontal nature, is vertically explored using these engineering models. This step is for concept development and engineering development phases, including each block of the phases. Meanwhile, the post-development phase is beyond this study. Consequently, the analytical results separated into two tables.

5.4.4 Development and validation of the model

Furthermore, the information technology value engineering model exists to develop three types of models: parallel, serial, and hybrid ITVE. Likewise, their validation takes place to certify that the model is reasonable philosophically and technically.

5.4.4.1 Parallel approach model

The parallel model is in **Figure 3** [25, 26]. This figure explicates that the principal subsystems of the model consist of firm performance (FP), firm core competence (FCC), firm capability (FC), and IT resource (ITR), which each subsystem links one to another in a parallel fashion. In a mathematical relationship, the parallel connection manifests an add operation (see **Figure 3**). It implies that the input (y^*_t) is proportionally divided into four sub-inputs, i.e. y^*_{1t}, y^*_{2t}, y^*_{3t}, and y^*_{4t} or

$y_t^* = y_{1t}^* + y_{2t}^* + y_{3t}^* + y_{4t}^*$. Each subsystem has each speed of adjustment (μ_{it}, i = 1,2,3,4 and t = period), i.e. FP has μ_{1t}, FCC has μ_{2t}, FC has μ_{3t}, and ITR has μ_{4t}, whether static (constant) or dynamic [20]. Likewise, the output consists of four sub outputs, i.e. y_{1t}, y_{2t}, y_{3t}, and y_{4t}, which can appear as $y_t = y_{1t} + y_{2t} + y_{3t} + y_{4t}$.

Using the partial adjustment valuation approach [see the Eq. (3)], each subsystem could be mathematically revealed as follows [25, 26], see **Figure 3**:

Firm Performance (FP):

$$y_{1_t} - y_{1_{t-1}} = \mu_1 \left(y_{1_t}^* - y_{1_{t-1}} \right) \tag{23}$$

$$y_{1_t} = \mu_1 y_{1_t}^* + \ (1 - \mu_{1_t}) y_{1_{t-1}} \tag{24}$$

Firm Core Competence (FCC):

$$y_{2_t} - y_{2_{t-1}} = \mu_2 \left(y_{2_t}^* - y_{2_{t-1}} \right) \tag{25}$$

$$y_{2_t} = \mu_2 y_{2_t}^* + (1 - \mu_2) y_{2_{t-1}} \tag{26}$$

Firm Capability (FC):

$$y_{3_t} - y_{3_{t-1}} = \mu_3 \left(y_{3_t}^* - y_{3_{t-1}} \right) \tag{27}$$

$$y_{3_t} = \mu_3 y_{3_t}^* + \ (1 - \mu_3) y_{3_{t-1}} \tag{28}$$

Information Technology Resource (ITR):

$$y_{4_t} - y_{4_{t-1}} = \mu_4 \left(y_{4_t}^* - y_{4_{t-1}} \right) \tag{29}$$

$$y_{4_t} = \mu_4 y_{4_t}^* + (1 - \mu_4) y_{4_{t-1}} \tag{30}$$

If Eq. (24), Eq. (26), Eq. (28), and Eq. (30) are together added would result in Eq. (31) [25, 26]:

$$\begin{aligned} y_t = \mu_1 y_{1_t}^* + \ (1 - \mu_1) y_{1_{t-1}} + \ \mu_2 y_{2_t}^* + (1 - \mu_2) y_{2_{t-1}} + \\ \mu_3 y_{3_t}^* + \ (1 - \mu_3) y_{3_{t-1}} + \mu_4 y_{4_t}^* + (1 - \mu_4) y_{4_{t-1}} \end{aligned} \tag{31}$$

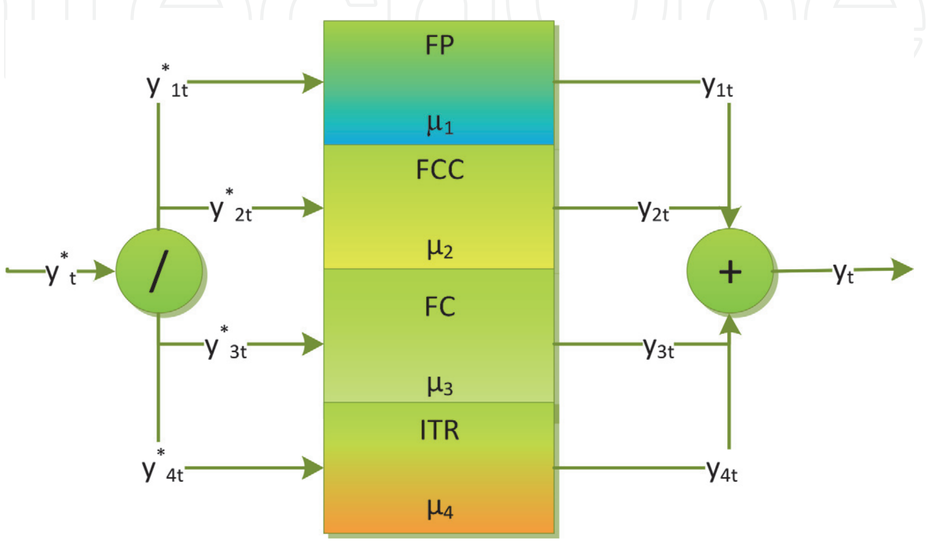

Figure 3.
IT value engineering model in a parallel relationship [25].

Where y_t = the real output of period t, y_{1t} = the real output of FP at period t, y^*_{1t} = the desired output (input) of FP, y_{1t-1} = the real output of the previous period (t-1), and μ_1 = the constant speed of adjustment of FP. Similarly, y_{2t} = the real output of FCC at period t, y^*_{2t} = the desired output (input) of FCC at period t, y_{2t-1} = the real output of the previous period (t-1), and μ_2 = the constant speed of adjustment of FCC. Afterwards, y_{3t} = the real output of FC at period t, y^*_{3t} = the desired output (input) of FC at period t, y_{3t-1} = the real output of the previous period (t-1), and μ_3 = the constant speed of adjustment of FC. Finally, y_{4t} = the real output of ITR at period t, y^*_{4t} = the desired output (input) of ITR period t, y_{4t-1} = the real output of the previous period (t-1), and μ_4 = the constant speed of adjustment of ITR.

5.4.4.2 Serial approach model

Instead of the parallel fashion, the serial ITVEM appears, in which to do so, suppose the Eq. (24), the Eq. (26), the Eq. (28), and the Eq. (30) exhibit in a serial relationship (see **Figure 4**), with an assumption that each output of a subsystem fully becomes an input of the subsequent ones, the end result is as Eq. (32) [25, 26].

$$\begin{aligned} y_t = &\left[\mu_1 y_t^* + (1-\mu_1)y_{1_{t-1}}\right] + \left[\mu_2\mu_1 y_t^* + \mu_2(1-\mu_1)y_{1_{t-1}} + (1-\mu_2)y_{2_{t-1}}\right] \\ &+\left[\mu_3\mu_2\mu_1 y_t^* + \mu_3\mu_2(1-\mu_1)y_{1_{t-1}} + \mu_3(1-\mu_2)y_{2_{t-1}} + (1-\mu_3)y_{3_{t-1}}\right] \\ &+\left[\mu_4\mu_3\mu_2\mu_1 y_t^* + \mu_4\mu_3\mu_2(1-\mu_1)y_{1_{t-1}} + \mu_4\mu_3(1-\mu_2)y_{2_{t-1}} + \mu_4(1-\mu_3)y_{3_{t-1}} + (1-\mu_4)y_{t-1}\right] \end{aligned} \tag{32}$$

As for the explanation of the symbols is equal to the parallel ITVE.

5.4.4.3 Hybrid approach model

The hybrid configuration [27] is an option for structuring each subsystem in the chapter. **Figure 5** explicates that the principal subsystems of the model consist of ITR, FC, FCC, and FP. It appears that the resources are the ITR consisting of the regular capital (K_t), the regular labor expense (L_t), and the technology spending, in this chapter related to IT spending (I_t). Furthermore, the resources become inputs of the FC subsystem as K_{cap}, L_{cap}, and I_{cap} to be processed in resulting the FC output, viz. w_{mt} (m = 1,2,3) or w_{1t}, w_{2t}, and w_{3t}, see **Figure 5**. Likewise, the resources also become inputs of the FCC subsystem as K_{com}, L_{com}, and I_{com} to be processed in resulting the FC output, viz. v_{jt} (j = 1,2,3) or v_{1t}, v_{2t}, and v_{3t}, see

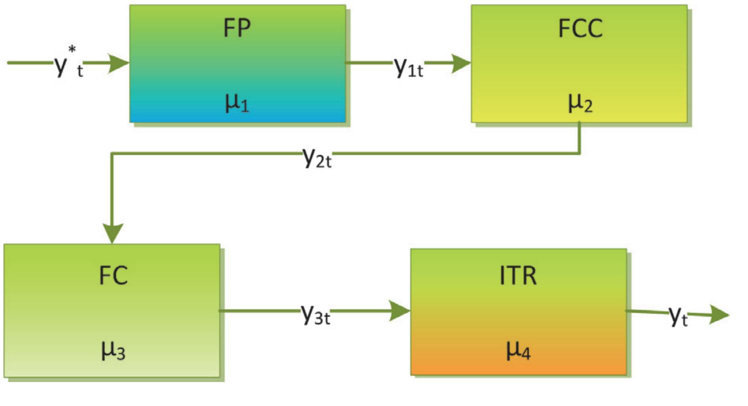

Figure 4.
IT value engineering model in a serial relationship [25].

Figure 5. Moreover, the output of both FC and FCC turn into the input of the FP. In other words, (w_{1t}, w_{2t}, w_{3t}) and (v_{1t},v_{2t}, v_{3t}) appear as inputs of the FP.

Therefore, the PAV model of the hybrid configuration (see **Figure 5**) is as follows [27]:

Firm Capabilities "cap" (FC):

$$w_{m_t} - w_{m_{t-1}} = \mu_m \left(\alpha_m K^{\beta_{1m}}{}_{cap\,m} L^{\beta_{2m}}{}_{cap\,m} I^{\beta_{3m}}{}_{cap\,m} - w_{m_{t-1}}\right) \quad (m = 1, 2, 3; t = 1, \dots, 11) \tag{33}$$

or

$$w_{m_t} = \mu_m \alpha_m K^{\beta_{1m}}{}_{cap\,m} L^{\beta_{2m}}{}_{cap\,m} I^{\beta_{3m}}{}_{cap\,m} + (1 - \mu_m) w_{m_{t-1}} \tag{34}$$

Where w_{mt} = the real output of FC at period t, μ_m = the constant speed of adjustment of FC, α_m = a constant of Cobb–Douglas function; β_1, β_2, and β_3 are input elasticity of production factors regarding the regular capital (K), the labor expense (L), and the IT capital (I), and w_{mt-1} = the real output of the previous period (t-1). Hence, if the FC consists of three variables (m = 1, 2, and 3), viz. IT infrastructures, IT managerial skills, and Collaboration [54], thus each variable has output as follows [27].

IT infrastructures (w_{1t}):

$$w_{1_t} = \mu_1 \alpha_1 K^{\beta_{11}}{}_{cap\,1} L^{\beta_{21}}{}_{cap\,1} I^{\beta_{31}}{}_{cap\,1} + (1 - \mu_1) w_{1_{t-1}} \tag{35}$$

IT managerial skills (w_{2t}):

$$w_{2_t} = \mu_2 \alpha_2 K^{\beta_{12}}{}_{cap\,2} L^{\beta_{22}}{}_{cap\,2} I^{\beta_{32}}{}_{cap\,2} + (1 - \mu_2) w_{2_{t-1}} \tag{36}$$

Collaboration (w_{3t}):

$$w_{3_t} = \mu_3 \alpha_3 K^{\beta_{13}}{}_{cap\,3} L^{\beta_{23}}{}_{cap\,3} I^{\beta_{33}}{}_{cap\,3} + (1 - \mu_3) w_{3_{t-1}} \tag{37}$$

Firm Core Competence "com" (FCC):

$$v_{j_t} - v_{j_{t-1}} = \delta_j \left(\lambda_j K^{\sigma_{1j}}{}_{com\,j} L^{\sigma_{2j}}{}_{com\,j} I^{\sigma_{3j}}{}_{com\,j} - v_{j_{t-1}}\right) \quad (j = 1, 2, 3; t = 1, \dots, 11) \tag{38}$$

or

$$v_{j_t} = \delta_j \lambda_j K^{\sigma_{1j}}{}_{com\,j} L^{\sigma_{2j}}{}_{com\,j} I^{\sigma_{3j}}{}_{com\,j} + \left(1 - \delta_j\right) v_{j_{t-1}} \tag{39}$$

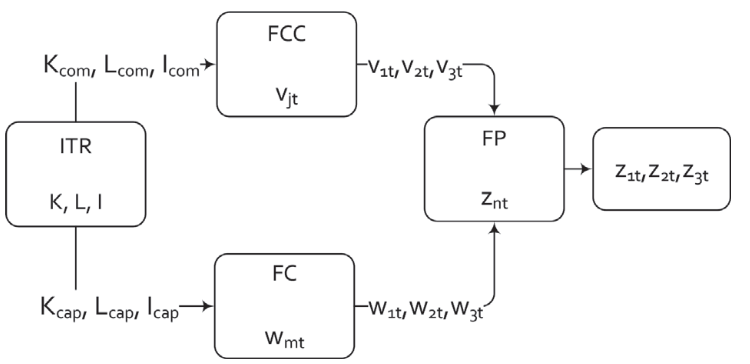

Figure 5.
IT value in the hybrid configuration [27].

Where v_{jt} = the real output of FCC at period t, λ_j = the constant speed of adjustment of FCC, λ_j = a constant of Cobb–Douglas function; σ_1,σ_2, and σ_3 are input elasticity of production factors regarding the regular capital (K), the labor expense (L), and the IT capital (I), and v_{jt-1} = the real output of the previous period (t-1). Hence, if the FCC consists of three variables (j = 1, 2, and 3), viz. IT knowledge, IT operations, and IT objects [35], thus each variable has output as follows [27].

IT knowledge (v_{1t}):

$$v_{1_t} = \delta_1 \lambda_1 K^{\sigma_{11}}{}_{com\,1} L^{\sigma_{21}}{}_{com\,1} I^{\sigma_{31}}{}_{com\ 1} + (1-\delta_1) v_{1_{t-1}} \tag{40}$$

IT managerial skills (v_{2t}):

$$v_{2_t} = \delta_2 \lambda_2 K^{\sigma_{12}}{}_{com\,2} L^{\sigma_{22}}{}_{com\,2} I^{\sigma_{32}}{}_{com\ 2} + (1-\delta_2) v_{2_{t-1}} \tag{41}$$

Collaboration (v_{3t}):

$$v_{3_t} = \ \delta_3 \lambda_3 K^{\sigma_{13}}{}_{com\,3} L^{\sigma_{23}}{}_{com\,3} I^{\sigma_{33}}{}_{com\ 3} + (1-\delta_3) v_{3_{t-1}} \tag{42}$$

Firm Performance “per” (FP):

$$\begin{gathered} z_{n_t} - z_{n_{t-1}} = \eta_n \left[\gamma_n (w_{1_t}, w_{2_t}, w_{3_t})^{\varphi_{1n}}{}_{per\,n} (v_{1_t}, v_{2_t}, v_{3_t})^{\varphi_{2n}}{}_{per\,n} - z_{n_{t-1}} \right] \\ (n = 1, 2, 3; t = 1, \dots, 11) \end{gathered} \tag{43}$$

or

$$z_{n_t} = \eta_n \gamma_n (w_{1_t}, w_{2_t}, w_{3_t})^{\varphi_{1n}}{}_{per\,n} (v_{1_t}, v_{2_t}, v_{3_t})^{\varphi_{2n}}{}_{per\,n} + (1-\eta_n) z_{n_{t-1}} \tag{44}$$

Where z_{nt} = the real output of FP at period t, η_n = the constant speed of adjustment of FC, γ_n = a constant of Cobb–Douglas function; ϕ_1 and ϕ_2 are input elasticity of production factors regarding the FC output (w_{1t},w_{2t},w_{3t}) and the FCC output (v_{1t},v_{2t},v_{3t}), and z_{nt-1} = the real output of the previous period (t-1). Hence, if the FP consists of three variables (n = 1, 2, and 3), viz. ROE, ROA, and Revenue [16], thus each variable has output as follows [27].

ROE (z_{1t}):

$$z_{1_t} = \eta_1 \gamma_1 (w_{1_t}, w_{2_t}, w_{3_t})^{\varphi_{11}}{}_{per\,1} (v_{1_t}, v_{2_t}, v_{3_t})^{\varphi_{21}}{}_{per\,1} + (1-\eta_1) z_{1_{t-1}} \tag{45}$$

ROA (z_{2t}):

$$z_{2_t} = \eta_2 \gamma_2 (w_{1_t}, w_{2_t}, w_{3_t})^{\varphi_{21}}{}_{per\,2} (v_{1_t}, v_{2_t}, v_{3_t})^{\varphi_{22}}{}_{per\,2} + (1-\eta_2) z_{2_{t-1}} \tag{46}$$

Revenue (z_{3t}):

$$z_{3_t} = \eta_3 \gamma_3 (w_{1_t}, w_{2_t}, w_{3_t})^{\varphi_{31}}{}_{per\,3} (v_{1_t}, v_{2_t}, v_{3_t})^{\varphi_{23}}{}_{per\,3} + (1-\eta_3) z_{3_{t-1}} \tag{47}$$

6. System optimization

The ITVE optimization involves the cost minimization in accordance with the major problem of this research to raise the firm performance at optimal cost [26]. To do so, it needs several assumptions [57] along with the optimization process. For example, the Cobb–Douglas production function [20] replaces each the desired output (the starred y^*_{it}, i = 1, 2, 3, 4 and t = 1, ..., 11, for example) of subsystems. The Cobb-Douglass function is as follows:

$$y_{it}^{*} = \alpha K_{it}^{\beta_1} L_{it}^{\beta_2} I_{it}^{\beta_3} \quad (i = 1, \dots, 4 \ \ and \ \ t = 1, 2, \dots, 11) \tag{48}$$

Whereas y_{it}^{*} = the desired output with i = subsystem and t = period, K_{it} = the regular capital, L_{it} = the labor expense, I_{it} = the IT capital, α = total factor productivity, and β_1, β_2, β_3 = the output elasticity of the regular capital, the labor expense, and the IT capital. Therefore, the partial adjustment for each subsystem is as follows (to simplify, i is disappearing):

$$y_t = \mu_t y_t^{*} + (1-\mu_t) y_{t-1} = \mu_t \alpha K_t^{\beta_1} L_t^{\beta_2} I_t^{\beta_3} + (1-\mu_t) y_{t-1} \tag{49}$$

Whereas μ_t is the static speed of adjustment and y_{t-1} is the revenue in the earlier period. Additionally, for cost minimization, the partial derivatives of the Eq. (48) should fulfill these conditions [58, 59]:

$$\frac{\partial y_t}{\partial K_t} = 0, \quad \frac{\partial y_t}{\partial L_t} = 0, \quad \frac{\partial y_t}{\partial I_t} = 0 \tag{50}$$

If the Eq. (49) is mathematically derived to K, L, and I, it respectively results in the following equations (whereas p_1, p_2, and p_3 are added to the equations as unit prices of the regular capital (K), the labor expense (L), and the IT capital (I):

$$\frac{\partial y_t}{\partial K} = \mu_t \alpha \beta_1 p_1 K^{\beta_1 - 1} p_2 L^{\beta_2} p_3 I^{\beta_3} \tag{51}$$

$$\frac{\partial y_t}{\partial L} = \mu_t \alpha \beta_2 p_1 K^{\beta_1} p_2 L^{\beta_2 - 1} p_3 I^{\beta_3} \tag{52}$$

$$\frac{\partial y_t}{\partial I} = \mu_t \alpha \beta_3 p_1 K^{\beta_1} p_2 L^{\beta_2} p_3 I^{\beta_3 - 1} \tag{53}$$

Using the Eq. (50) prerequisites, the Eq. (51) = the Eq. (52) = the Eq. (53), further equations arise as follows:

$$K = \frac{p_3}{p_1} \frac{\beta_1}{\beta_3} I; \quad L = \frac{p_1}{p_2} \frac{\beta_2}{\beta_1} K; \quad and \ I = \frac{p_2}{p_3} \frac{\beta_3}{\beta_2} L \tag{54}$$

If the Eq. (49) is substituted by the Eq. (54) such that the new equation appears in the regular capital (K) variable, the equation is as Eq. (55) and afterwards simplified to become Eq. (56).

$$y_t = \mu_t \alpha K^{\beta_1} \left[\frac{p_1}{p_2} \frac{\beta_2}{\beta_1} K \right]^{\beta_2} \left[\frac{p_1}{p_3} \frac{\beta_3}{\beta_1} K \right]^{\beta_3} + (1-\mu_t) y_{t-1} \tag{55}$$

$$y_t = \mu_t \alpha \beta_1^{-\beta_2 - \beta_3} \beta_2^{\beta_2} \beta_3^{\beta_3} p_1^{\beta_2 + \beta_3} p_2^{-\beta_2} p_3^{-\beta_3} K^{\beta_1 + \beta_2 + \beta_3} + (1-\mu_t) y_{t-1} \tag{56}$$

Furthermore, the Eq. (56) becomes K variable as in Eq. (57) and afterwards simplified as in Eq. (58) as follows:

$$K^{\beta_1+\beta_2+\beta_3} = \mu_t^{-1} \alpha^{-1} \beta_1^{\beta_2+\beta_3} \beta_2^{-\beta_2} \beta_3^{-\beta_3} p_1^{-\beta_2-\beta_3} p_2^{\beta_2} p_3^{\beta_3} \left[y_t - (1-\mu_t) y_{t-1} \right] \tag{57}$$

$$\begin{aligned} K = {} & \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \beta_1^{\frac{\beta_2+\beta_3}{(\beta_1+\beta_2+\beta_3)}} \beta_2^{\frac{-\beta_2}{(\beta_1+\beta_2+\beta_3)}} \beta_3^{\frac{-\beta_3}{(\beta_1+\beta_2+\beta_3)}} p_1^{\frac{-\beta_2-\beta_3}{(\beta_1+\beta_2+\beta_3)}} \\ & p_2^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} \left[y_t - (1-\mu_t) y_{t-1} \right]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \end{aligned} \tag{58}$$

Using the equivalent way, the variable L and I can become as follows:

$$L = \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \beta_1^{\frac{-\beta_1}{(\beta_1+\beta_2+\beta_3)}} \beta_2^{\frac{\beta_1+\beta_3}{(\beta_1+\beta_2+\beta_3)}} \beta_3^{\frac{-\beta_3}{(\beta_1+\beta_2+\beta_3)}} p_1^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} p_2^{\frac{-\beta_1-\beta_3}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} [y_t - (1-\mu_t)y_{t-1}]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{59}$$

$$I = \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \beta_1^{\frac{-\beta_1}{(\beta_1+\beta_2+\beta_3)}} \beta_2^{\frac{-\beta_2}{(\beta_1+\beta_2+\beta_3)}} \beta_3^{\frac{\beta_1+\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_1^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} p_2^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{-\beta_1-\beta_2}{(\beta_1+\beta_2+\beta_3)}} [y_t - (1-\mu_t)y_{t-1}]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{60}$$

If K, L, and I are multiplying p_1, p_2, and p_3 as unit prices respectively, then it appears as follows:

$$p_1K = \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \beta_1^{\frac{\beta_2+\beta_3}{(\beta_1+\beta_2+\beta_3)}} \beta_2^{\frac{-\beta_2}{(\beta_1+\beta_2+\beta_3)}} \beta_3^{\frac{-\beta_3}{(\beta_1+\beta_2+\beta_3)}} p_1^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} p_2^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} [y_t - (1-\mu_t)y_{t-1}]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{61}$$

$$p_2L = \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \beta_1^{\frac{-\beta_1}{(\beta_1+\beta_2+\beta_3)}} \beta_2^{\frac{\beta_1+\beta_3}{(\beta_1+\beta_2+\beta_3)}} \beta_3^{\frac{-\beta_3}{(\beta_1+\beta_2+\beta_3)}} p_1^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} p_2^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} [y_t - (1-\mu_t)y_{t-1}]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{62}$$

$$p_3I = \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \beta_1^{\frac{-\beta_1}{(\beta_1+\beta_2+\beta_3)}} \beta_2^{\frac{-\beta_2}{(\beta_1+\beta_2+\beta_3)}} \beta_3^{\frac{\beta_1+\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_1^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} p_2^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} [y_t - (1-\mu_t)y_{t-1}]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \tag{63}$$

Moreover, the Eqs. (61), (62), and (63) substituted into Eq. (64), the total cost of yielding y units in the low-cost technique manifest as the Eq. (64) and (65).

$$\begin{aligned} C(p_1, p_2, p_3, y_t) &= p_1K + p_2L + p_3I \\ &= B\, p_1^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} p_2^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} p_3^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} [y_t - (1-\mu_t)y_{t-1}]^{\frac{1}{(\beta_1+\beta_2+\beta_3)}} \end{aligned} \tag{64}$$

Where B:

$$B = \mu_t^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \alpha^{\frac{-1}{(\beta_1+\beta_2+\beta_3)}} \left[\left(\frac{\beta_1}{\beta_2}\right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} \left(\frac{\beta_1}{\beta_3}\right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} + \left(\frac{\beta_2}{\beta_1}\right)^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} \left(\frac{\beta_2}{\beta_3}\right)^{\frac{\beta_3}{(\beta_1+\beta_2+\beta_3)}} + \left(\frac{\beta_3}{\beta_1}\right)^{\frac{\beta_1}{(\beta_1+\beta_2+\beta_3)}} \left(\frac{\beta_3}{\beta_2}\right)^{\frac{\beta_2}{(\beta_1+\beta_2+\beta_3)}} \right] \tag{65}$$

Whereas p_1, p_2, and p_3 is unit prices of the regular capital (K_t), the labor expense (L_t), and the IT capital (I_t) respectively, y_t is the real output of period t, y_{t-1} is the real output of earlier period t-1, and C is the total cost [26].

7. Conclusion

The significant problem surrounding this study is to sustain superior firm performance as desired at optimal costs due to the IT presence, which has inevitably become a need for running the business world. Numerous studies on the relationship of the firm performance of the IT resource were more focused on a statistical method that links between components using survey data. In essence, this study undertakes an analogous study, but with a different approach, namely, the systems engineering approach combined with RBV theory, systems engineering, the theory of partial adjustment, including the CD production function, which, in turn, lead to creating the ITVE. Furthermore, to create the ITVE, the followed stages are to build the conceptual model of the IT value based on the RBV theory, model experiment using PAV, validate PAV, model the ITVE, confirm the ITVE and study managerial impacts of the model.

The conceptual model of IT value has logically exemplified the relationship between ITR, FC, FCC, and FP in terms of competitive advantages. The theory of partial adjustment links logically the model, which formulates it in two types of models. Explicitly, the first model addresses PAV with the IT capital presence (with I_t) inside of its production function, and the second model with the IT capital absence (without I_t). The applied production function is the CD function while the dynamic factor component of the speed of adjustment is the ROE. However, it may be replaced by other dynamic factors.

The principal problem of this chapter is how to achieve the optimal resources, for instance, IT resource costs, for required business performance. By benefiting the earlier studies, namely the systems engineering methodology, the conceptual model of IT value, the RBV theory, and the PAV theory can solve this problem so that the solution results in the IT value engineering. Furthermore, using the analysis results, a synthesis work leads to composing a block diagram, which depicts a model in terms of the systems engineering of IT value engineering framework, which ultimately results in serial, parallel, and hybrid configurations. Likewise, by benefiting CD production function involved within PAV, the optimal cost of the required firm performance occurs. For that reason, it should surely be an experiment as a simulation on work mechanisms of the model. Consequently, the ITVE technically appears as a framework to study IT value models. However, in practice, this model contributes to managerial implications, which should reinforce the match between techniques and practices.

Author details

Lukman Abdurrahman
Information Systems Program Study, School of Industrial Engineering, Telkom University, Bandung, Indonesia

*Address all correspondence to: abdural@telkomuniversity.ac.id

References

[1] Akkermans H. Intelligent e-business: from technology to value. IEEE INTELLIGENT SYSTEMS. 2001:8-10. DOI: 10.1109/5254.941352

[2] Hadaya, P., and Cassivi, L. Joint collaborative planning as a governance mechanism to strengthen the chain of IT value co-creation. The Journal of Strategic Information Systems. 21**.** 2012: 182–200.

[3] Kohli, R., Devaraj, S. and Ow, T.T. Does information technology investment influence a firm's market value? A case of non-publicly traded healthcare firms. MIS Quarterly. 36(4). 2012: 1145–1163. DOI:10.2307/41703502

[4] Iansiti, M. And Richards, G.L. The information technology ecosystem: structure, health, and performance. Antitrust Bulletin*.* 51(1). 2006: 77–110.

[5] Boar, B.H. The art of strategic planning for information technology. 2nd ed. John Wiley and Sons, Inc., New York, USA; 2001.

[6] DeMaagd, K.A. Identifying and measuring the value of information technology in developing economies. [Ph.D. dissertation]. Business Administration: The University of Michigan; 2006.

[7] Dehning, B., Richardson, V.J and Stratopoulos, T. Information technology investments and firm value. Information & Management. 429(7). 2008: 989–1008. DOI: 10.1016/j.im.2004.11.003.

[8] Dedrick, J., Gurbaxani, V. and Kraemer, K.L. Information technology and economic performance: a critical review of the empirical evidence. ACM Computing Surveys. 35(1). March, 2003: 1–28. DOI:10.1145/641865.641866.

[9] Ramos, A.L., Ferreira, J.V., & Barcel'o, J. Model-based systems engineering: an emerging approach for modern systems. IEEE Transaction on Systems, Man, and Cubernetics-Part C: Applications and Reviews. 42(1). 2012: 101–111. DOI: 10.1109/TSMCC.2011.2106495.

[10] Kosky, P., Balmer, R., Keat, W. and Wise, G. Exploring engineering: an introduction to engineering and design. 3rd ed. Elsevier, Waltham, MA, USA; 2013.

[11] Bharadwaj, A.S. A resource-based perspective on information technology capability and firm performance: an empirical investigation. *MIS Quarterl.* 24**.** 2000: 169–196. DOI: 10.2307/3250983

[12] Ravichandran, T. and Lertwongsatien, C. Effect of information systems resources and capabilities on firm performance: a resource-based perspective. Journal of Management Information Systems*.* 21**.** 2005: 237–276.

[13] Liang, T.P., You, J.J. and Liu, C.C. A resource-based perspective on information technology and firm performance: a meta-analysis. Industrial Management & Data Systems*.* 110(8). 2010: 1138–1158. DOI: 10.1108/02635571011077807.

[14] Muhanna, W.A. and Stoel, M.D. How do investors value IT? An empirical investigation of the value relevance of IT capability and IT spending across industries. Journal of Information Systems*.* 24(1). 2010: 43–66. DOI: 10.2308/jis.2010.24.1.43

[15] Byrd, T.A., Pitts, J.P., Adrian, A.M. and Davidson, N.W. Examination of a path model relating information technology infrastructure with firm performance. Journal of Business

Logistics. 29(2). 2008: 161–187. DOI: 10.1002/j.2158-1592.2008.tb00091.x

[16] Lin, B.W. Information technology capability and value creation: evidence from the US banking industry. Technology in Society. 29. 2007: 93–106. DOI: 10.1016/j.techsoc.2006.10.003

[17] Kohli, R. and Devaraj, S. Measuring information technology payoff: a meta-analysis of structural variables in firm-level empirical research. Information Systems Research. 14(2). 2003: 127–145. DOI: 10.1287/isre.14.2.127.16019.

[18] Lin, W.T. The business value of information technology as measured by technical efficiency: evidence from country-level data. Decision Support Systems. 46(4). 2009: 865–874. DOI: 10.1016/j.dss.2008.11.017

[19] Lin, W.T., Chuang, C.H. and Choi, J. H. A partial adjustment approach to evaluating and measuring the business value of information technology. Int. J. Production Economics. 127(1). 2010: 158–172. DOI: 10.1016/j.ijpe.2010.05.007.

[20] Lin, W.T. and Kao, T.W. The partial adjustment valuation approach with dynamic and variable speeds of adjustment to evaluating and measuring the business value information technology. European Journal of Operational Research. 238(1). 201: 208–220. DOI: 10.1016/j.ejor.2014.03.019.

[21] Abdurrahman, L., Langi, A.Z.R. and Suhardi. Development of methodologies for measuring IT capability in the information and communication industries. In: IEEE Proceeding of the International Conference on Information Technology Systems and Innovation (ICITSI); 24–27 November 2014, Bandung-Bali: IEEE; 2014. p. 189–194.

[22] Abdurrahman, L., Suhardi and Langi, A.Z.R. Information technology (IT) value model using variance-based structural equation modeling: towards IT value engineering. In: IEEE Proceeding of the Second International Conference on Information and Communication Technology; 28–30 May 2014, Bandung: IEEE; 2014. p. 499–504.

[23] Abdurrahman, L., Suhardi and Langi, A.Z.R. Engineering information technology value in IT-based industries using partial adjustment valuation and resource-based view approach. Int. J. Information and Communication Technology. 8 (4). 2016: 420–435. DOI: 10.1504/IJICT.2016.076824

[24] Abdurrahman, L., Suhardi, Langi, A.Z.R. Valuation methodology of information technology (IT) value in the IT-based business: A case study at a leading telecommunication company. International Journal on Electrical Engineering and Informatics. 8(4). 2016: 864–884. DOI: 10.15676/ijeei.2016.8.4.12.

[25] Abdurrahman, L., Langi, A.Z.R., Suhardi, and Simatupang, T.M. Information technology value engineering model and cost efficiency in IT-based firms. IEEE Systems Journal. 12(3). 2018: 2925–2936. DOI: 10.1109/JSYST.2017.2663418.

[26] Abdurrahman, L., Suhardi, Simatupang, T.M., and Langi, A.Z.R. Information technology value model and its optimal application in IT-based firms. Int. J. Mathematical Modelling and Numerical Optimisation. 8(4). 2018: 331–350. DOI: 10.1504/IJMMNO.2018.10015800.

[27] Abdurrahman, L. Hybrid Configuration in Information Technology Value Model. IEEE Systems Journal. 14(4). 2020: 4515–4522. DOI: 10.1109/JSYST.2020.2968415.

[28] Kohli, R. and Devaraj, S. Realizing the business value of information

technology investments: an organizational process. MIS Quarterly Executive. 3(1). 2004: 53–68.

[29] Gidumal, J.B. and González, M. Maximizing the positive influence of IT for improving organizational performance. Journal of Strategic Information Systems. 20. 2011: 461–478. DOI: 10.1016/j.jsis.2011.09.004.

[30] Mithas, S., Tafti, A., Bardhan, I. and Goh, J.M. Information technology and firm profitability: mechanisms and empirical evidence. MIS Quarterly. 36 (1). 2012: 205–224. DOI: 10.2307/41410414.

[31] Piatkowski, M. Does ICT investment matter for growth and labor productivity in transition economies [Internet]. 2005. Available from http://ssrn.com/abstract=510082.

[32] Kim, G., Shin, B., Kim, K.K, and Lee, H.G. IT capabilities, process-oriented dynamic capabilities, and firm financial performance. Journal of the Association for Information Systems. 12. 2011: 487–517. DOI: 10.17705/1jais.00270.

[33] Cao, G., Wiengarten, F., and Humphreys, P. Towards a contingency resource-based view of IT business value. Syst Pract Action Res. 2011: 85–106. DOI: 10.1007/s11213-010-9178-0.

[34] Kohli, R. and Grover,V. Business value of IT: an essay on expanding research directions to keep up with the times. Journal of the Association for Information Systems. 9 (1). 2008: 23–39. DOI: 10.17705/1jais.00147.

[35] Tippins, M.J., and Sohi, R.S. IT competency and firm performance: Is organizational learning a missing link? Strategic Management Journal. 24. 2003: 745–761. DOI: 10.1002/smj.337.

[36] Mithas, S., Ramasubbu, N. and Sambamurthi, V. How information management capability influences firm performance. MIS Quarterly. 35(1). 2011: 237–256. DOI: 10.2307/23043496.

[37] Lin, W.T. and Chiang, C.Y. The impacts of country characteristics upon the value of information technology as measured by productive efficiency. Int. J. Production Economics. 132(1). 2011: 13–33.

[38] Lin, W.T. and Chuang, C.H. Investigating and comparing the dynamic patterns of the business value of information technology over time. European Journal of Operational Research. 228(1). 2013: 249–261. DOI: 10.1016/j.ejor.2013.01.023.

[39] Goh, K.H. Process and outcome-related IT value: innovations in theory and methods for measurement. [Ph.D. dissertation]. Minneapolis: Faculty of The Graduate School, University of Minnesota; 2007.

[40] Rau S.E. and Bye, B.S. Are you getting value from your IT? Journal of Business Strategy. 2003: 16–20.

[41] Wagner, H.T. and Weitzel, T. Towards an IT production function: understanding routines as fundamental for IT value creation. Journal of Enterprise Information Management. 20(4). 2007: 380–395.

[42] Webb, A. Value engineering part 1. Engineering Management Journal. 1993: 171–175.

[43] Webb, A. Value engineering part 2. Engineering Management Journal. 1993: 231–235.

[44] Jin-wen, Z. and Xiao-ying, Z. The new tools of enterprise's innovation management: value engineering. In: Proceeding of International Conference on Information Management, Innovation Management and Industrial Engineering; 2009. p. 507–510.

[45] Tse, D.C. A conceptual model for assessing the value of information technology [Master thesis]. Ontario, Canada: Management Sciences, University of Waterloo; 2006.

[46] Pang, M.S. *Information technology and value creation in the public sector organizations* [Ph.D. dissertation]. USA: Business Administration, The University of Michigan; 2011.

[47] Tohidi, H. Review the benefits of using value engineering in information technology project management. Procedia Computer Science. 3. 2011: 917–924. DOI: 10.1016/j.procs.2010.12.150.

[48] Sharma A., and Belokar, R.M. Achieving success through value engineering: a case study. In: Proceedings of the World Congress on Engineering and Computer Science; 2012.

[49] International standard industrial classification of all economic activities. 2015. Availabble from http://unstats.un.org/unsd/statcom/doc02/isic.pdf. [Accessed: January 8, 2015].

[50] Lightfoot, R.S. Enhanced concurrent engineering: an approach for accelerating the systems engineering process while minimizing the risk. In: IEEE International Engineering Management Conference 2. IEEE; 2002. p . 779–782.

[51] Byrd, T.A. Information technology, core competencies, and sustained competitive advantage. Information Resources Management Journal. 2001: 27–36. DOI: 10.4018/irmj.2001040103.

[52] Cardeal, N. and António, N. Valuable, rare, inimitable resources and organization (VRIO) resources or valuable, rare, inimitable resources (VRI) capabilities: what leads to competitive advantage? African Journal of Business Management. 6(37). 2012: 10159–10170. DOI: 10.5897/AJBM12.295.

[53] Prahalad, C.K. and Hamel, G. The core competence of the corporation. Harvard Business Review. 1990: 79–90.

[54] Yin, G. and Yang, B. The construction of firm's IT capability and its impact on IT assimilation: an empirical investigation in China. In: Pasific Asia Conference on Information Systems; 9–12 July 2010; Taipei, Taiwan: 2010. p . 11–20.

[55] Hong, G.E., Yu-wei, GUO. and Ming-di, LI. Measurement of IT returns on firm with multiple production processes by simultaneous production functions. In: *Proceeding of the International Conference on Management Science & Engineering (20th)*, July 17–19; Harbin, China: 2013.

[56] Kossiakoff, A., Sweet, W.N, Seymour, S. J. and Biemer, S.M. Systems engineering: principles and practice. John Wiley and Sons, Inc., Hoboken, New Jersey; 2011.

[57] Townsend, J.T. Serial vs parallel processing: sometimes they look like tweedledum and tweedledee but they can (and should) be distinguish. Psychological Science. 1(1). 1990: 46–54.

[58] Hu, Z.H. Reliable optimal production control with cobb-douglas model. Reliable Computing. 4. 1998: 63–69.

[59] Fraser, I. The cobb-douglas production function: an antipodean defence? Economic Issues. 7(1). 2002.