The Development of a Productivity Dynamic Model

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Abstract

The concept of productivity has received growing attention, both in the manufacturing and service industries. However, it is often neglected by those who influence production process as there is no standard tool for measuring productivity. This study develops a productivity dynamic model to be used as a tool to assess the current productivity maturity level of an organization and planning for productivity improvement. Five productivity factors, including ‘leadership’, ‘strategic quality planning’, ‘data and information’, ‘people’, and ‘process management’, are used for model development. The simulation results reveal that an organization with no productivity-concerned should primarily focus on enhancing the ‘leadership’ and ‘people’ constructs to successfully progress through to higher maturity levels in the future. The productivity index, developed through the dynamic model, is used together with the five levels of productivity maturity to indicate the current maturity level of the organization. An organization can perform the simulations, with different productivity enhancement strategies, to identify the most effective policy to improve its productivity, and progress through to higher maturity levels.

Keywords: productivity dynamic model, productivity index, system dynamics modeling

Introduction

Productivity is one of the most common measures of an organization’s competitiveness. It has often been cited as a key factor in industrial performance, and actions to increase it are said to improve profitability and the wage earning capacity of employees (Cosmetatos and Eilon, 1983). The concept of productivity, generally defined as the relation between output and input, has been available for over two centuries and applied in many different circumstances on various levels of aggregation in the economic system (Jorgenson and Griliches, 1967). According to Kilic and Okumus (2005), productivity is one of the basic variables governing economic production activities, perhaps the most important one. Improving productivity is seen as a key issue for the survival and success in the long term. Recently, productivity has received growing attention, both in the manufacturing and service industries. Kilic and Okumus (2005), for example, investigated the factors influencing productivity in hotels in Northern Cyprus and found that factors such staff recruitment, staff training, meeting guest expectations, and service quality are the main factors in improving productivity. Attention has also been paid to improving productivity in the food industry in Thailand, as food is considered one of the important economic sectors, constituting 14 percent of the country’s total exports, and generating employment for 20 million people (Thailand Board of Investment, 2005). For example, Betagro group, one of the biggest food manufacturing companies in Thailand adopted a number of quality management tools, such as six sigma and kaizen, in planning for productivity improvement program. By implementing such a program, the company can reduce waste and rework,

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minimize work-in-process inventory, lessen transportation cost, and eliminate idle time, thus increase productivity (Thailand Productivity Institute, 2006).

Besides the above research, many researchers argue that productivity is often regarded to second rank, and neglected or ignored by those who influence production process (Tangen, 2002). A major reason is that there is no standard tool for assessing and measuring productivity. Increasing productivity requires that attention be paid to using and manipulating numerous factors, which is often a challenging task (Poetscheke, 1995). Moreover, neither the interactions among key factors influencing productivity, nor the consequences of productivity initiatives being undertaken over time is focused. This paper, therefore, focuses on developing a productivity dynamic model and productivity index, utilizing system dynamics (SD) modeling technique, to better understand the key productivity factors and plan for productivity enhancement.

Key Productivity Factors

To improve productivity, the organization may either consider reducing inputs while keeping outputs constant, or increasing outputs while keeping inputs constant. Inputs might include labor, capital, and management; on the other hand, outputs cover goods and services. According to Chinda (2010), five key productivity factors, under two elements (driver and system), are confirmed with the structural equation modeling. These five factors, with their 25 associated attributes, are detailed below:

1. *Process management* consists of 10 attributes, including job description, service quality, leader’s support, information technology investment, housekeeping, job allocation, two-way communication, inventory documentations, equipment effectiveness, and teamwork (Hoffman and Mehra, 1999; Peter et al., 2007; Thailand Productivity Institute, 2008b; Thailand Productivity Institute, 2008c).
2. *Leadership* is associated with five attributes, including top management commitment, performance appraisal, customer satisfaction, supervision, and operational audit (Hoffman and Mehra, 1999; Thailand Productivity Institute, 2008a; Batra et al., 2009).
3. *Strategic quality planning* is examined by three attributes, including advertisement and marketing, total quality management, and benchmarking system (Kilic and Okumus, 2005; Thailand Productivity Institute, 2008a; Hussain, 2008).
4. *People* consists of four associated attributes, including training, work pressure, personal recognition, and workers’ attitude (Black and Lynch, 1996; Marsidi, 2009).
5. *Data and information* is examined by three attributes, including knowledge background, workers’ experience, and workers’ recruitment (Kilic and Okumus, 2005; Asian Productivity Organization, 2007).

Each of the five factors has its criterion weight i.e. ‘process management’ weighs 140 points, ‘leadership’ weighs 150 points, ‘strategic quality planning’ weighs 70 points, ‘people’ weighs 160 points, and ‘data and information’ weighs 80 points (Chinda, 2010). These criterion weights are developed based on one of the most widely used international quality models, the Malcolm Baldrige National Quality Award (MBNQA) framework (Chinda, 2010). These criterion weights are later used, together with a productivity index (PI), to assess the organization’s current productivity maturity level. The five productivity maturity levels, as shown in Figure 1, consists of initial, repeatable, defined, managed, and optimized levels (Chinda, 2010). The relationships between the five productivity factors are as shown in Figure 2 (Chinda, 2010). ‘Leadership’ is the main driver to productivity enhancement, and the strong commitment of leaders is crucial in promoting this goal. ‘Leadership’ also has an influence on ‘people’; however, it appears to be a relatively weak direct effect. It appears that most of its influences on this particular factor are mediated through 'data and information' and 'strategic quality planning'. The five key factors and their relationships are used in developing a productivity dynamic model and a PI to assess the current productivity maturity level, and plan for productivity improvement.

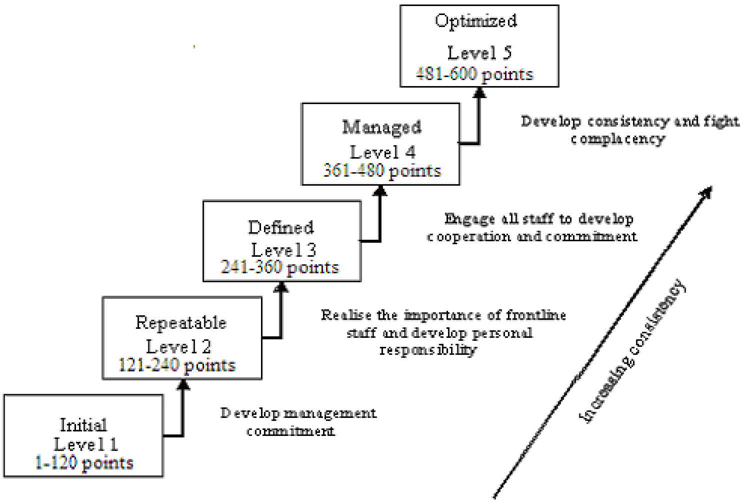

Figure 1. The Five Productivity Maturity Levels

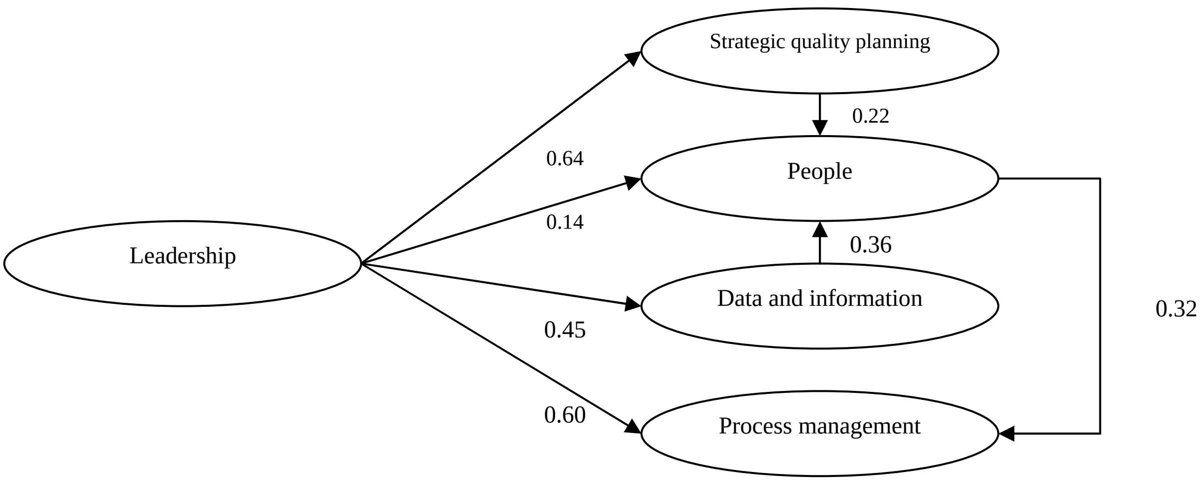

Figure 2. The Five Productivity Factors and Their Relationships

A Productivity Dynamic Model Development

Causal Loop Diagram

A productivity dynamic model is developed utilizing system dynamics (SD) modeling technique. This technique focuses on the structure and behavior (over time) of the system using multiple feedback loops (closed chains of cause-and-effect links, in which information about the result of actions is fed back to generate further action) (Rodrigues and Bowers, 1996). These feedback loops are presented graphically using a causal loop diagram to portray a feedback loop in an easy understanding diagram. A loop is a closed system, comprising a number of elements and causal relationships. The arrows (as shown in Figure 3) indicate the direction of influence, and plus/minus (+, -) signs indicate the type of the influence (Khanna et al., 2004). In addition to the signs on each link, the complete feedback loop also is given a sign. If a particular element starts the loop by changing its value in one direction (e.g. by increasing its value), and closes the loop with the value changed in the same direction (e.g. closes the loop by increasing the value), then the loop is called a positive loop. A negative loop is vice versa.

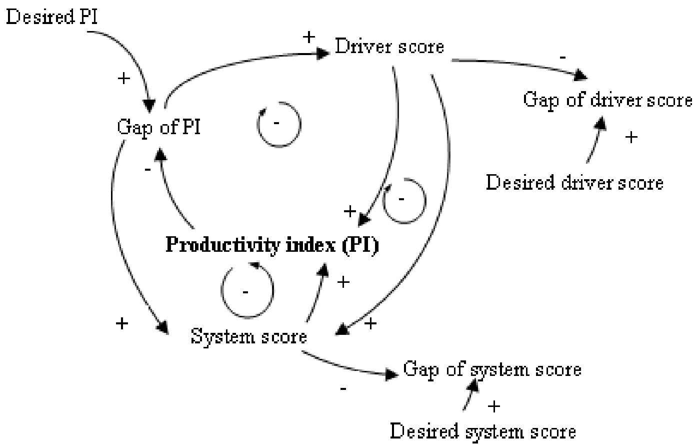

Figure 3. A Causal Loop Diagram of the Productivity Index

The causal loop diagram of the productivity index consists of nine elements to explain the relationships between the ‘driver’, ‘system’, and PI. These nine elements are:

- ‘Driver score’ at point (t) in time: This is the ‘leadership’ score at point (t) in time (maximum 150 points).
- ‘Gap of driver score’ at point (t) in time: It is equal to the difference between the ‘desired driver score’ and the ‘driver score’ at point (t) in time.
- ‘Desired driver score’: The score is set as 150 points.
- ‘System score’ at point (t) in time: This score is equal to the sum of the ‘strategic quality planning’ score (maximum 70 points), the ‘people’ score (maximum 160 points), the ‘data and information’ score (maximum 80 points), and the ‘process management’ score (maximum 140 points).
- ‘Gap of system score’ at point (t) in time: It is equal to the difference between the ‘desired system score’ and the ‘system score’ at point (t) in time.
- ‘Desired system score’: The score is set as 450 points.
- Productivity index at point (t) in time (maximum 600 points): This index is equal to the sum of the ‘driver’ and ‘system’ scores.
- ‘Gap of PI’ at point (t) in time: This index is equal to the difference between the ‘desired PI’ score and PI at point (t) in time.
- ‘Desired PI’: This score contains five values: 120, 240, 360, 480, and 600 points, to match the five productivity maturity levels. Deciding which value to be used depends on the PI at that point of time. For instance, if the PI at point (t) in time is 100 points, which is less than 120 points, then, the ‘desired PI’ at this point of time is set as 120 points (representing the threshold for the immediately following maturity level).

In this study, the productivity causal loop diagram is converted into a productivity dynamic model to enable the simulations.

Productivity Dynamic Model

The formulated productivity dynamic model (as shown in Figure 4) captures the interactions among the five constructs, where the PI represents the sum of the ‘driver’ and the ‘system’ scores (with an overall score of 600 points, see Figure 1). This dynamic model reflects the assumption that the PI can be healthier, provided that the organization focuses on improving the five constructs to achieve better results. To illustrate, the ‘leadership’ dynamic model provides a simple representation of the stock (leadership) and flow (rlds = leadership rate) diagram. In this model the increase in the ‘rlds’ depends on: 1) the value of the leadership (used_lds); 2) the leadership rate fraction (rldsf); 3) the gap of PI (gpi); 4) the gap of leadership (glds); and 5) the percentage of more effort provided to improve the leadership score (plds) (in the initial base run of the model, the organization considers all five constructs as having equal significance in improving PI, so the ‘plds’ is set as zero), as shown in the equations below.

$$\text{Leadership}(t) = \text{Leadership}(t - dt) + (\text{rlds})*dt$$
$$\text{rlds} = ((\text{used\_lds} + \text{gpi})*\text{rldsf}) + (\text{glds}*\text{plds}) \quad = 0 \text{ (in base run)}$$

The percentage of more effort provided to improve the leadership score (plds) is the effort (rather than what is normally provided) that the organization dedicates to boost the value of leadership to achieve its maximum score, i.e. 150 points, in a shorter period of time. The value of the leadership rate fraction (rldsf) is constant at 0.08. Specifically, then, ‘leadership’ dynamic model may be explained as follows: when ‘gpi’ is large, leadership must try hard to reduce this gap by, for example, providing more feedback on how to improve productivity and having an operational audit. As a result, the ‘rlds’ increases. Naturally, the increased ‘rlds’ increases the ‘leadership’ stock, which, in turn, increases the ‘used_lds’ value. The maximum score of ‘used_lds’ is controlled by the maximum ‘desired value of leadership’ (dlds), which is equal to 150 points. Given that ‘leadership’ influences ‘strategic quality planning’, ‘people’, ‘data and information’, and ‘process management’; the newly obtained ‘used_lds’ value is transferred to these four connected dynamic models. This transferred value is, however, influenced by the strength of the path coefficients between ‘leadership’ and the four constructs (see Figure 2). For example, the ‘used_lds’ value that is transferred to the ‘strategic quality planning’ dynamic model will have a value equal to the value of the ‘used_lds’, multiplied by the path coefficient between ‘leadership’ and ‘strategic quality planning’, which is equal to 0.64 (0.64*‘use_lds’ value).

The simulations of the productivity dynamic model iterate as cycles, in which in each cycle, the ‘driver’ score, the ‘system’ score, and PI are calculated. The cycles continue until the PI reaches a maximum score of 600.

Dynamic Simulation Results

The productivity dynamic model is simulated with SD modeling. In the ‘base run’ simulation, the initial values of the five constructs are assumed as zero (representing the immature organization). The dynamic model is simulated, and the results are displayed graphically in Figures 5 and 6, and numerically in Table 1. At the starting point, the PI is zero. At this stage, the ‘gap of PI’ (gpi) is relatively large. This, then, boosts the value of ‘leadership’, which, in turn, increases the values of the remaining five factors, i.e. ‘strategic quality planning, ‘data and information’, ‘people’, and ‘process management’.

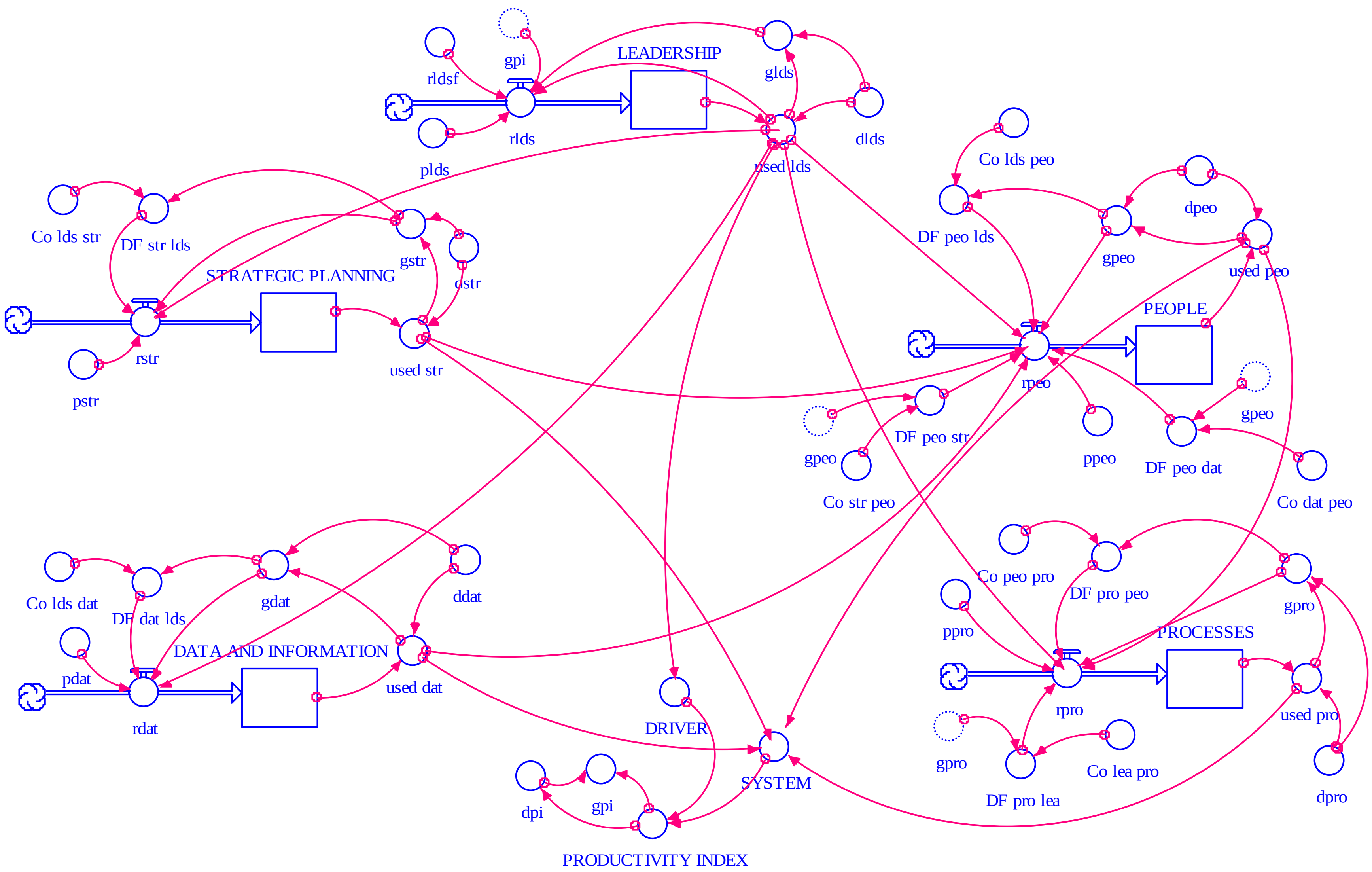

Figure 4. The Productivity Dynamic Model

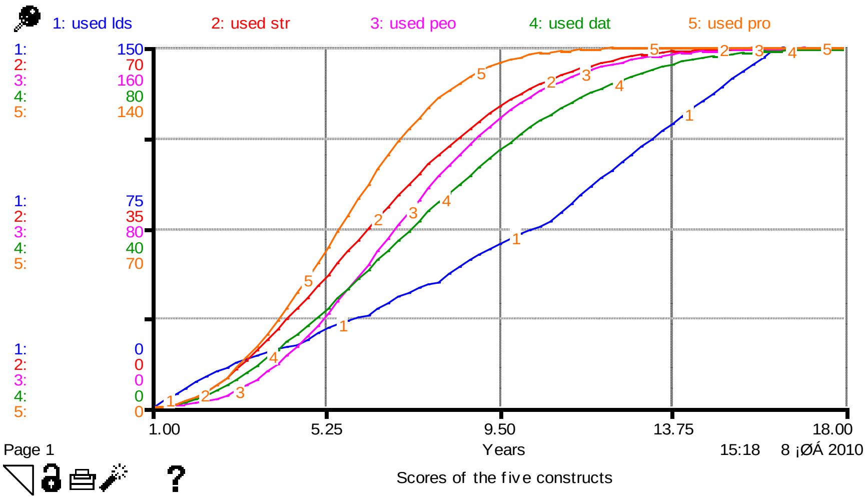

Figure 5. Graphical Results of the Scores of the Five Productivity Factors Over Time

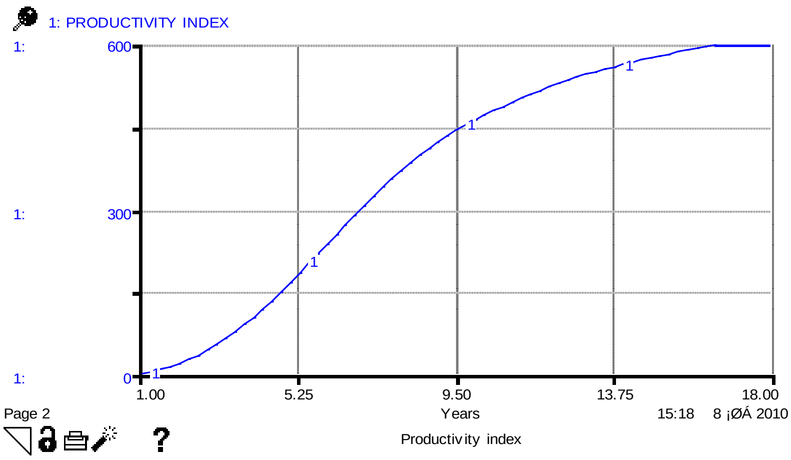

Figure 6. Graphical Results of the Productivity Index Over Time

As the five constructs' values increase, the PI increases. The simulation continues until the PI reaches the maximum score of 600 points. Table 1 shows that it takes 10 years for the organization, with no productivity concerned, to progress from the first to the fifth productivity maturity levels (the PI reaches 481 points or more at the end of year 10). The graphs shown in Figures 5 to 6 show similar S-shaped patterns, with a slow increase at the beginning of the simulation. It takes four years for the organization to progress from the first to the second levels of maturity. This result demonstrates it is hard to improve the PI in the early stage of the productivity-enhanced implementation. After the organization reaches the second maturity level, however, the PI increases rapidly, as depicted by the sharp rises in the curve shown in Figure 6. The organization progresses from the second to the fifth maturity levels over six years (at the end of year 10), showing a significant productivity improvement in the organization. After year 10, it is difficult for the organization to increase the PI, as most of the productivity improvements are accomplished. As shown in Table 1, the organization achieves its PI of 600 points (representing the perfect productivity enhancement) at the end of year 23. It appears to be very challenging to reach a perfect productivity implementation; however, an organization can plan its implementation to progress through to the fifth level by using the time frame shown in Table 1.

Table 1. Simulation Results of the Five Productivity Factors and the Productivity Index

Year	Score					
	Leadership	Strategic Quality Planning	Data and Information	People	Process Management	PI
Initial	0.00	0.00	0.00	0.00	0.00	0.00
1	9.51	1.60	1.29	1.02	3.06	16.48
2	17.87	7.03	5.72	6.55	14.37	51.55
3	23.54	14.81	12.27	18.33	32.76	101.71
4	30.07	23.17	19.61	35.68	55.30	163.83
5	36.67	32.29	28.08	57.29	80.44	234.77
6	45.31	40.94	36.69	80.32	102.95	306.21
7	51.50	48.89	45.31	102.17	120.01	367.89
8	63.22	55.52	53.29	120.60	130.60	423.21
9	71.78	60.77	60.44	134.77	136.17	463.93
10	80.50	64.44	66.20	144.64	138.60	494.38
11	94.91	66.92	70.82	151.09	139.55	523.30
.	.	.	.	.	.	.
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23	150.00	70.00	80.00	160.00	140.00	600.00

By observing the increasing rate of the five constructs' values at the early stage of the simulation, it is clear that 'people' and 'leadership' are the weakest constructs in boosting the PI, as they produce the least scores compared with the other three constructs. To achieve higher PI in the early stages, thus, an organization should focus more on improving these two constructs. To confirm whether the organization should concentrate on improving the implementations of 'people' and 'leadership', a number of model runs are needed. First, the organization is said to allocate 5% of more effort to focus on 'people' improvement, i.e. apart from normally implementing this factor, the organization puts more time and effort (by 5%) into further enhancing this particular factor's implementation. This means that the organization maintains its improvement of the five constructs, but more attention is given to 'people'. Consequently, the 'ppeo' value is set to 0.05, while the 'plds', 'pstr', 'pdat', and 'ppro' are still set as zero. The productivity dynamic model is then simulated, and the results are recorded. Next, the 'ppeo' is set back to zero, then the 'plds' is set as 0.05 (meaning that the organization now changes its focus, from improving the 'people' to 'leadership' implementations). The model is re-simulated, and the results are recorded, then the 'plds' is set back to zero. The simulations are performed for all five constructs; the results (shown in Table 2) demonstrate that, by focusing more on 'people' or 'leadership', the organization reaches the second maturity level in a shorter time (three years). By focusing more on 'leadership' implementation, the organization can also achieve the fifth level of maturity three years earlier (seven instead of 10 years). Therefore, for the organization starting at level one of productivity maturity, attention should be paid, in the main, to improving the key attributes of 'leadership' and 'people' to successfully progress through to higher maturity levels. The leaders should thus take issues of productivity improvement seriously through, for example, providing more support on training (Teo et al., 2005), giving useful feedback (Lardner et al., 2001), and ensuring that the workload is reasonably balanced among workers to avoid excessive work pressure (Glendon and Litherland, 2001).

Table 2. Experimentation with Extra Efforts to Improve the Five Productivity Factors

Year	Lds		Str		Dat		Peo		Pro	
	PI	Level*	PI	Level	PI	Level	PI	Level	PI	Level
Initial	0.00	1st	0.00	1st	0.00	1st	0.00	1st	0.00	1st
1	28.89	1st	20.20	1st	21.10	1st	25.27	1st	22.97	1st
2	87.45	1st	59.00	1st	61.90	1st	69.33	1st	61.98	1st
3	**170.08**	2nd	111.73	1st	117.17	1st	**124.78**	2nd	112.26	1st
4	267.25	3rd	178.26	2nd	185.68	2nd	194.52	2nd	174.84	2nd
5	360.97	3rd	249.30	3rd	259.57	3rd	264.78	3rd	242.33	3rd
6	440.64	4th	321.45	3rd	332.22	3rd	332.83	3rd	312.88	3rd
7	497.13	5th	381.73	4th	393.57	4th	390.76	4th	371.45	4th

Note: (*) Level = productivity maturity level

Conclusion

Productivity has often been cited as a key factor in industrial performance, and actions to increase it are said to improve profitability and the wage earning capacity of employees. This paper develops a productivity dynamic model based on the five key productivity factors, including ‘leadership’, ‘strategic quality planning’, ‘data and information’, ‘people’, and ‘process management’ to capture the interactions and causal relationships among the five constructs over a period of time. Base run results reveal that an organization with no productivity-concerned should primarily focus on enhancing the ‘leadership’ and ‘people’ constructs to successfully progress through to higher maturity levels in the future. The productivity index, developed through the dynamic model, is used together with the five productivity maturity levels, to indicate the current maturity level of an organization. The organization can then experiment, with different productivity enhancement strategies, to identify the most effective policy it can apply to improve its productivity, and progress through to higher maturity levels.

Future research is recommended in monitoring the behavior of the model when the weight of each productivity factor is changed.

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