Int. J. Production Economics 166 (2015) 119–128

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Developing a plant system prediction model for technology transfer

Yasuo Yamane [a], Katsuhiko Takahashi [a,*], Kunihiro Hamada [a], Katsumi Morikawa [a], Senator Nur Bahagia [b], Lucia Diawati [b], Andi Cakravastia [b]

[a] Faculty of Engineering, Hiroshima University, 1-4-1, Kagamiyama, Higashi-Hiroshima 739-8527, Japan
[b] Faculty of Industrial Technology, Bandung Institute of Technology, Jl Ganeca 10, Bandung 40132, Indonesia

ARTICLE INFO

Article history:
Received 2 January 2014
Accepted 19 September 2014
Available online 15 May 2015

Keywords:
Plant capacity
Technology level
Management of technology
Learning curve

ABSTRACT

Technology transfer (TT) is the process of transferring skills, knowledge, technologies, methods of manufacturing, and facilities. Successful TT demands an integrated approach in order to plan, implement, evaluate and improve the transfer process comprehensively. For quantifying the technology level, various models have been developed and applied, however the total performance of a plant has not been quantified by the model. It is necessary to develop a mechanism of integrating the quantified technology level of each process into the total performance of the plant. This paper develops a plant system prediction model. In the model, a V-process model is utilized for defining the whole procedure for analyzing the plant system, and the technology level quantification model developed by Yamane, Y., Takahashi, K., Hamada, K., Morikawa, K., Nur Bahagia, S., Diawati, L., Cakravastia, A., 2011. Quantifying the technology level of production system for technology transfer. Ind. Eng. Manag. Syst., 10(2), 97–103 is utilized for quantifying the technology level of each process. Also, to integrate the quantified technology level into that of the plant system, some functions are formulated. A case study in a manufacturing industry shows the effectiveness of the developed model.

1. Introduction

Technology transfer (TT) is the process of transferring skills, knowledge, technologies, methods of manufacturing, and facilities. Unsuccessful cases in TT frequently occur due to a failure in recognizing correctly technology embodiment, phases, and hierarchies involved in the transfer process of technology. Successful TT demands an integrated approach in order to plan, implement, evaluate and improve the transfer process comprehensively. Therefore, the main objective of our research is to develop an integrated TT model towards technology self-sufficiency and sustainable growth. In particular, in this paper, we develop a model to predict the technology level of a plant system.

For quantifying the technology level, various models have been developed and applied (e.g. Corbett et al, 1999; Lapré and Van Wassenhove, 2001). Based on the literature, Yamane et al. (2011) developed a technology level quantification (TLQ) model by utilizing a learning curve. In the model, the technology level, such as speed of production and quality of the produced items, is expressed as a function not of a cumulative number of units but of time, for increasing generality. Furthermore, for expressing each learning that consists of conceptual learning and operational learning, an S-shape curve is utilized in the model. By fitting the S-shape curve and/or decomposing into some of the activities, the model can be applied to approximate complicated organizational process.

Furthermore, Kim (1993) proposed the link between individual and organizational learning. Mukherjee et al. (1998) applies the idea of Kim (1993) to the activities of quality improvement. Lapré et al. (2000) analyzed the relationship behind the learning curve by linking learning activities to waste reduction. Also, Lapré and Van Wassenhove (2003) considered managing learning curves in factories by creating and transferring knowledge, and Terwiesch and Bohn (2001) considered learning during production ramp-up. Although the learning curve has been applied for analyzing the performance of an organization, plant or factory, only the technology level of a process will be quantified, and the total performance of the plant has not been quantified by the model. For this purpose, it is necessary to develop a mechanism for integrating the quantified technology level of each process into the total performance of the plant.

Therefore, in this paper, a plant system prediction model is developed. In the model, a V-process model is utilized for defining the whole procedure to analyze the plant system, and the TLQ developed by Yamane et al. (2011) is utilized for quantifying the technology level of each process. Also, for integrating the quantified technology level into that of the plant system, some functions are formulated. A case study in a manufacturing industry shows the effectiveness of the developed model.

* Corresponding author. Tel.: +81 82 424 7705; fax: +81 82 422 7024.
E-mail address: takahasi@hiroshima-u.ac.jp (K. Takahashi).

http://dx.doi.org/10.1016/j.ijpe.2015.05.014
0925-5273/

2. Literature review

For predicting the performance of processes or plants, learning curve models have been considered. After the conventional learning curve of a log-linear model was proposed by Wright (1936), various kinds of learning curves have been proposed, and there is a lot of literature on this subject. In the literature, Carr (1946) proposed an S-curve, and Badiru (1992) surveyed various univariate and multivariate learning curves. Vigil and Sarper (1994) investigated the effects of parameter variability on learning curve predictions, and Li and Rajagopalan (1998) proposed a learning curve with knowledge depreciation, that is a decreasing rate of learning. For more practical situations, Jaber and Kher (2002) proposed a dual-phase learning–forgetting model that consists of learning as a combination of cognitive and motor skills learning and forgetting based on the worker's learning rate, prior experience, as well as the length of the interruption interval. Jaber and Sikström (2004) analyzed comparatively three models of learning and forgetting. Plaza et al. (2010) also analyzed learning curves comparatively and discussed the implications for new technology implementation management. Lapré et al. (2000), Jaber and Bonney (2003), and Jaber and Guiffrida (2004, 2008) developed a learning curve for quality improvement and applied it to identifying rework time. Furthermore, Jaber and Khan (2010) proposed a quality learning model of a serial production line that consists of several stages and needs rework and scrap at each stage. Such literature on quality learning curve models are reviewed by Khan et al. (2011).

Various learning curves have not only been developed, the effects of learning curves in production systems or enterprises have also been investigated. Andrade et al. (1999) considered activity-based costing for learning. Anderson (2001) analyzed the impact of high market growth and learning on productivity and service quality. Terwiesch and Bohn (2001) considered learning in a production ramp-up, and Glock et al. (2012) looked at production planning for a production ramp-up with learning in process and growth in demand. Ngwenyama et al. (2007) used a learning curve to maximize IT productivity. Lieven et al. (2005) considered managing learning resources for consecutive product generations. Plaza and Rohlf (2008) considered learning and performance in ERP implementation projects. Armbruster et al. (2007) dealt with bucket brigades production lines with worker learning. Tarakci et al. (2009) looked at learning effects on maintenance outsourcing. Jaber and Bonney (2003), Jaber et al. (2009), and Jaber and Khan (2010) considered the lot-sizing or lot-splitting problem with learning. Jaber et al. (2010) coordinated a three-level supply chain with learning-based continuous improvement.

As explained above, various learning curves have been developed, and the developed curves have been applied to analyze various activity-related technologies. However, there is still room to research the general learning curve for general activity-related technology transfer.

The necessity of performance evaluation has been stated by Gunasekaran, et al. (1994) and Mefford and Bruun (1998), and performance measurement systems have been proposed by Hsu and Li (2009) and de Lima et al. (2013). However, in the performance model, the plant capacity is not a performance to be estimated but a decision variable, or the qualitative necessity to consider the performance is stated. The model to formulate the performance of process has not been considered. Also, Gavronski et al. (2012) considered a learning and knowledge approach to sustainable operations, and Bivin (2003) considered firm performance under just-in-time and traditional proxies for profit maximization. However, they do not consider the quantitative performance of plant systems.

As the criteria to evaluate the efficiency of a process or plant, productivity has been studied, and many papers considered the criteria. Recently, Oral et al. (1999) looked at linking industrial competitiveness and productivity at the firm level. Hannula (2002) proposed a total productivity measurement based on partial productivity ratios, and Zelenyuk (2006) proposed an aggregation of Malmquist productivity indexes. In addition, Genius et al. (2012) considered measuring productivity growth under factor non-substitution and an application to US steam-electric power generation utilities. However, productivity is a criterion for evaluating output compared with input, and the activities in the process or plant have not been considered. An exception to this is the paper by Usubamatov et al. (2013), who took into count idle time caused by machine failures at each process for evaluating the productivity of automated lines. However, the collected idle time in each process is accumulated in order to calculate input resources for productivity.

In the literature on evaluating the effects of various factors upon the performance of organization, Henderson et al. (2004) proposed empirical models of the effect of integrated manufacturing on manufacturing performance and return on investment, and Vinodh and Chinthaa (2011) evaluated leanness using the multi-grade fuzzy approach. In these papers, the relationship between the factors and the performance is studied, however, the model is empirical and the degree of relationship is evaluated by experts. The relationship cannot be evaluated by any qualitative facts.

Models to evaluate technologies based on quantitative facts were proposed by Li and Hamblin (2001), Karsak and Ahiska (2008), and Wang and Chin (2009). In their models, decision-making models for evaluating and selecting advanced manufacturing technologies (AMTs) are developed based on quantitative facts; however, it is assumed that it is possible to utilize the specified inputs and outputs of all AMTs and the relationship between the inputs and outputs has not been considered.

The relationship between the inputs and the outputs has been investigated in the literature on learning curves, and the relationship is applied to evaluate the performance of organizations by Ngwenyama et al. (2007) and Yamane et al. (2011) as explained above. Ngwenyama et al. (2007) used the learning curve to maximize IT productivity and a decision analysis model for timing software upgrades. Yamane et al. (2011) proposed a TLQ model. However, in their papers, the performance of organization has not been evaluated and estimated on the basis of the performance of each process. The relationship between the performance of each process and that of the whole organization should be formulated.

Therefore, in considering technology transfer, it is necessary to develop a mechanism for integrating the quantified technology level of each process into the total performance of the plant; however, this issue has not been considered in the previous literature.

3. The plant system prediction model

Based on the literature review, a plant system prediction (PSP) model will be proposed in this section. Even if the technology-level performance in each process is quantified, a mechanism to integrate the quantified technology level into the total performance is necessary to quantify the performance of the whole plant. The integration depends on processes in the plant and the requested performance criteria. In this section, after explaining an overall framework for predicting the performance of a plant system based on the various requests, the detailed methods for each step in the overall framework are explained.

3.1. Overall framework

Previous designs usually utilize a waterfall type approach, such as top-down or bottom-up approach. In the top-down approach, the overall architecture is determined first, the structure and