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Original Article

Performance improvement tool for Thai make–to–order manufacturing

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Abstract

This paper presents a framework to improve a performance of shop floor control for Thai make-to-order (MTO) small and medium enterprises (SMEs). Integrated definition for function modeling is exploited to explore activities and relate of components. In-depth interview with experts and practitioners in the case study is provided useful information. The empirical study is evaluated to suit for using the finalized SHEN model as a benchmark. Factor analysis is performed to find simplified information from variables. The data are collected from experience respondents by using a designed questionnaire. Each observed variable is assigned to test validity and reliability by factor loading and Cronbach's alpha, respectively. The results show that finalized SHEN can use as a performance improvement tool for Thai MTO SMEs. For example principle 11 is tested. Each observed variable has covariance value between 0.380-0.873. The value of reliability Cronbach's alpha for this factor is shown 0.869. Based on the scree plot, it is asserted that 5 observed variables are correctly formed in the same principle.

Keywords: Thai small and medium enterprises, SHEN model, integrated definition for function modeling, factor analysis

1. Introduction

Small and medium enterprises (SMEs) have been an essential factor in Thailand's economic system. Looking at the ratio of gross domestic product (GDP) SMEs make up to 37.8% of GDP in 2008. SMEs are a very important element of the Thai economy as they account for 99% of the overall enterprise numbers causing them to be an essential foundation of the sustainable development (Office of Small and Medium Enterprises Promotion, 2009). From the definition, the make-to-order (MTO) sector of the industry consists of those companies that manufacture high variety products in relatively low volumes (Hendry, 1998). Hence, MTO is a characteristic of many Thai SMEs.

Many researchers have proposed approaches for improving the SMEs sector, e.g. Jina *et al.* (1997), Chutima and Nimsaard (2011), and Wanitwattanakosol and Sopadang (2012). Because SMEs are still not fully competitive, their production and management structures are weak. From this reason, Stevenson *et al.* (2005) addressed the specific requirements of the SMEs sector. They presented that shop floor control is a major factor in the development of an effective production system issue. The shop is responsible for the real time management of jobs and resource on the shop floor (Bauer *et al.*, 1994). This paper also focuses on the shop level as a hierarchical system.

Muda and Hendry (2002) introduced a modified world class manufacturing (WCM) model by deleting some assumptions which are not proper for the MTO field and by changing the emphasis for some cases were needed. This model is called a first version of the SHEN. This name combines parts of the pioneers' name: SHaladdin and HEndry. A final version of the SHEN model was presented later, which aimed to fill the gap by developing a comprehensive performance improvement model for the SMEs (Muda and Hendry, 2003). The final version can be used by companies as a benchmark. However, before applying this model, we should observe a process of business that suits the model or not.

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To select the right technique and the right tool is very important for the development of a business model. IDEF0 is a descriptive model and a powerful process modeling technique. Gong and Lin (1994) used this technique as a first steps towards determining the necessary controls for a shop floor control system. Presley and Liles (1995) implemented the concept of continuous improvement of SMEs by using this technique.

As stated above, Thai MTO SMEs have to improve their performance in terms of cost, quality, flexibility, and other factors. These companies need a comprehensive model not only to identify, but also prioritize the improvements needed. Unfortunately, comprehensive models, including total quality management (TQM) and world class manufacturing (WCM), omit issues that are pertinent to Thai MTO SMEs.

This paper describes the approach to improve shop floor control for Thai SMEs sector by applying a SHEN model with statistical methods. Also, an empirical study is presented to explain the application of this study. The remainder of the paper is organized as follows. Section 2 presents a literature review. A proposed method is described in Section 3. In Section 4 the empirical study, which has a characteristic of MTO, is illustrated. Results and discussion of the proposed framework are mentioned and analyzed in Section 5. Finally, Section 6 presents the conclusions of the paper and suggestions for future research.

2. Literature Review

The literature is used in describing the general context within performance schematic, especially for MTO industry. The basic concept of IDEF0 is established as a first step determining the necessary observation. Next, factor analysis indicates that results from questionnaire are adequate validity and reliability by analyzing with factor loading and Cronbach's alpha, respectively. This section also compares tools in terms of advantages and disadvantages.

2.1 MTO manufacturing performance

Organizational performance plays a significance role for considerable influence on the actions of companies. Moreover, an accurately measuring this performance has been perceived as being an increasing in the practical and academic fields (Folan and Browne, 2005). Brown *et al.* (1997) defined some key words in the context of performance scheme as follows

A "Performance Measure" is a description of something that can be directly measured (e.g. number of reworks per day).

A "Performance Indicator" is a description of something that is calculated from performance measurement (e.g. percentage reworks per day per direct employee).

"Performance Measurement Data" are values or results for performance measures and indicators.

A "Performance Measurement System" is a complete set of performance measures and indicators derived in a consistent manner according to a set of rules or guidelines defined in a performance measurement system.

Many researches have emerged tools and techniques which can be used and applied in this field (Bititci *et al.*, 2001). Such as Taguchi loss function (Teeravaraprug, 2008), analytical hierarchy process (AHP) (Chaowarut *et al.*, 2010), fuzzy stochastic AHP (Wanitwattanakosol and Sopadang, 2010).

It is particular importance for MTO SMEs to select and utilize only the most critical performance indicators which comprise of on-time delivery, lead times, capacity utilization, quality levels, and cost calculations (Hvolby and Thorstenson, 2001). Soepenberg *et al.* (2008) developed a supportive tool for MTO companies to diagnose delivery reliability performance.

2.2 The integrated definition for function modeling (IDEF)

The IDEF is a family of methods that supports a paradigm capable by addressing the modeling needs of an enterprise and its business areas. The IDEF family is used according to different propose such as IDEF0 process modeling, IDEF1 information analysis, IDEF1X, IDEF2 dynamic analysis, IDEF3 process description capture, IDEF4 object-oriented design and IDEF5 ontology. However, for business process modeling, the most useful versions are IDEF0 and IDEF3 (Aguilar-Saven, 2004).

Colquhoun *et al.* (1993) reviewed relevant published literature of IDEF0. They reported strength and weakness points of the IDEF0 and compared with other techniques. This paper was decided to use the most popular processing-model, IDEF0. The IDEF0 model consists of a hierarchy of related diagrams. Each diagram is based on a diagonal row of boxes connected by a network of arrows. The boxes represent activities which are described by an active verb phase contained within the box. Arrows represent the relationship between activities in terms of the information or objects used, produced or required by activities. Arrows entering the left side of a box are inputs (I) to the activity, arrows entering the top of a box are controls (C) on the activity and arrows leaving the right side of a box are outputs (0) as a result of the

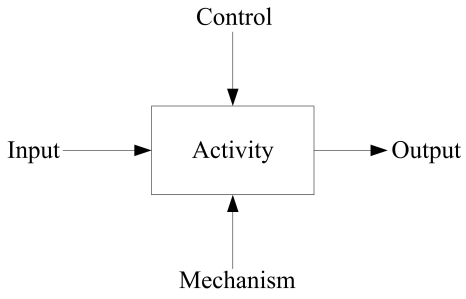

Figure 1. An activity box.

activity. Finally a mechanism (M) is a person, system or device associated with carrying out the activity and is shown as an arrow entering the base of a box. This arrow structure is depicted in Figure 1. Each activity can decompose into more detailed levels of analysis which is stated in Figure 2.

2.3 Factor analysis

Factor analysis is a statistical tool for grouping the variables that are related to the same group. It has two types that are exploratory factor analysis and confirmatory factor analysis. Confirmative factor analysis uses to identify a structure clearly, test the validity of the internal factors. As of exploratory factor analysis estimates the simple structure by rotation. Factor analysis is use covariance between a set of variables that cause variation and covariation among observed variables (Hox and Bechger, 1998).

Validity and reliability are two concepts in the testing method. They are fundamental measure between different variables that force to correlation. Validity is defined as an ability of the test to produce results consistent with other measures of the same characteristic. It is a study instrument to measure the systematic error inherent. Reliability is also known precision of a test and refers to an indicator of the amount of variability (Karras, 1997b).

Validity measures the correlation of the test. Validity assessment of questionnaires is a previously tool which requires definition of the scope carefully (Karras, 1997a). There are four concepts of validity, namely, face validity, content validity, criterion validity and construct validity (Burton and Mazerolle, 2011). Table 1 summarizes the meanings and aim of the terms for all concepts.

Reliability assessment has several methods to measure. They have some unique strength and weakness for each method that should be considered before applying. Summary of each method for assessing reliability is shown in Table 2 (O'Leary-Kelly and Vokurka, 1998).

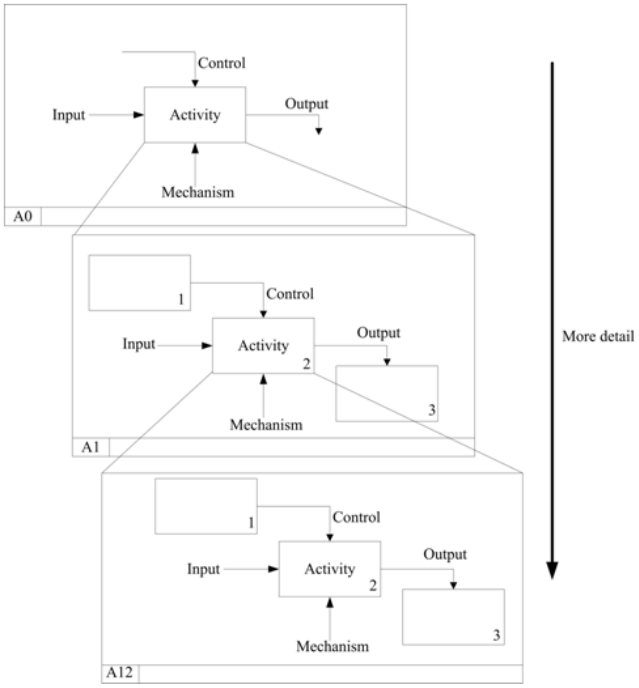

Figure 2. The hierarchy of IDEF0.

3. Methodology

First of all, in-depth interview is used with selected persons to establish a process modeling, IDEF0. This method is very useful to capture activities and explore the relationship between components. The validity of the model is endorsed by a manager. Second, the final version of SHEN model is created as the questionnaire for collecting data from the case study. We select almost principles, except principle no.12 (Promote/market/sell every improvement) because qualified persons do not stay in touch about the field of sales

Table 1. Definition and aim of validity

Validity Type	Definition	Aim
Face	Evaluates an instrument's appearance by a group of experts and/or potential participants.	Establishes an instrument's ease of use, clarity, and readability.
Content	Evaluates an instrument's representativeness of the topic to be studied by a group of experts.	Establishes an instrument's credibility, accuracy, relevance, and breadth of knowledge regarding the domain.
Criterion	Evaluates an instrument's correlation to another which is deemed unquestionable or identified as the gold standard.	Establishes an instrument's selection over another or establishing the predictability of the measure for a future criterion.
Construct	Evaluates an instrument's ability to relate to other variables or the degree to which it follows a pattern predicted by a theory.	Establishes an instrument's ability to evaluate the construct it was developed to measure.

Table 2. Summary of each method for assessing reliability

Reliability Method	Feature	Advantage	Disadvantage
Test–retest	It concern measuring at two different points in time (e.g., t and t+1) which using the same of scale and sample group.	Straightforward, intuitively appealing and measure with single indicators.	Variables are not stable over time. Effects of memory, learning, and reactivity confound in assessing reliability
Alternative forms	It is technique for reliability estimation. It involves two different measures at time t and another time at time t+1.	Minimizes effect of memory and measure with single indicators.	Variables are not stable over time. Effect of learning and reactivity confound in assessing reliability. Require to develop two unique measures.
Cronbach's coefficient	It is one of the popular methods to reliability assessment. It is base on correlation of indicators which range from 0 to 1	Multiple indicators, increasing the number of indicators may be improve measure of reliability	Measurement requires multiple indicators.
WLJ composite reliability	It employs CFA to derive a composite reliability index. It base on proportion of variance attributable to only the latent variable which range from 0 to 1.	Congeneric measures are the least limiting. Multiple indicators are straight of test assumption of congeneric measures by provide capability.	Reliability of measures is underestimates that are not congeneric. Measurement requires multiple indicators.

and marketing. This paper uses a five-point Likert item which is a popular format of questionnaires (Burns and Bush, 2007). The format of a typical five-level is strongly disagree (1), disagree (2), neither agree or disagree (3), agree (4) and strongly agree (5), respectively. Third, structure equation model (SEM) is set to imply a structure for the covariance between latent variables (factors). SEM is a convenient framework for statistical analysis that includes several traditional multivariate procedures. It can combine factor analysis and regression analysis (Hox and Bechger, 1998). Finally, we concentrate to find out information to add up in SEM on previous step. We analyze the validity and reliability of each factor by using factor loading and Cronbach's alpha.

The scores from questionnaire are analyzed by using confirmation factor analysis (CFA) that is conduct to clearly identify a structure of the SHEN model. This pilot study is tested validity and reliability of observed variable by using factor loading and Cronbach's alpha. The value of factor loading of each observed variable should be positive or negative (close to +1 or -1). It should be more than 0.300 to accept internal validity (Carr and Smeltzer, 1999). Its reliability value of each observed component must be more than 0.700 to accept internal validity which is measured from reliability Cronbach's alpha. Anyway, if reliability Cronbach's alpha value between 0.400-0.700, the internal factors have moderate relationship. (Humphreys *et al.*, 2004)

4. Empirical Study

The empirical study is motivated by a problem faced by an actual manufacturer of precision tools engineering for gold and gems. Its name has not been disclosed in order to protect the confidentiality. It is fictitiously referred to as a XYZ company where states in northern region, Lamphun. This company is currently using the following computerized systems. Computer aided design (CAD) software packages is used for the purpose of designing the tools, fixtures and other parts apart from generating the drawings and documents of their products. Computer aided manufacturing (CAM) is also used to operate computerized numerical control (CNC) machines as they possess one machining center, wire cut electric discharge machining (EDM). In addition, it also has some types of manual machines to assist their productivity improvement activities. We contact with a manager and 2 supervisors, who have experience more than 5 years in this field. We get some useful data from one-on-one in-depth interview and the questionnaire.

5. Result and Discussion

Results are structured according to improve shop floor control for Thai SMEs, by using the XYZ company as the case study. As concern from the SHEN's pioneer, it should

be assessed with care to ensure that it is all relevant. This examination can be described as below.

To explore activities of business process, IDEF0 is a widely used technique for analysis system. The top level of IDEF0 is depicted in Figure 3. This A0 level is decomposed into six main activities –receive order from R&D department (A1), check stock and create production plan (A2), consider purchase requisition by purchasing officer (A3), store incoming material at warehouse (A4), produce tool and product prototype (A5), and store at finished product area (A6).

Figure 4 is here, illustrated the detailed of an impact model, A5 which could be briefly described as below. Prepare material, A51: A raw material is loaded at manual machines such as a band saw machine, a milling machine etc. A prepared material tolerance is approximate plus 5 millimeters of dimensions which states in the drawing sheet. This procedure can reduce time-consuming in a next step, a precision machining procedure.

Operate by Machining Center, A52: A well-trained technician sets up a prepared material in a horizontal machining center. Then, a numerical code file is selected and tools such as drills, carbide end mills are inserted into a magazine slot. An estimate cycle time is showed on the monitor. If the cycle is finished, the machine is stopped automatically. The technician brings a finished material to check dimension by measuring instruments. This checking material is considered to send for hardening or transferring to an assembly unit directly.

Operate by Wire Cut Machine, A53: A method of this operation is likely a previous step, A52. But, this machine uses brass wires or copper wires instead of tools for the machining center.

Operate by Manual Machining, A54: This procedure is needed operating by a skillful technician. The technician always uses experience to set parameters and observes until the cycle is finished.

Treat Hardening, A55: Some parts which are specified for hardening treatment are sent to a selected vendor. This vendor has an experience and works with high technology machines to control parameters of hardness scale which is specified by customers. The result of hardness is showed on a certificate document. Overall performance seems to be delight, but this vendor locates in Chachoengsao province. From a long distance problem, time to deliver is always more than one week. The on-time delivery problem should be solved in the future.

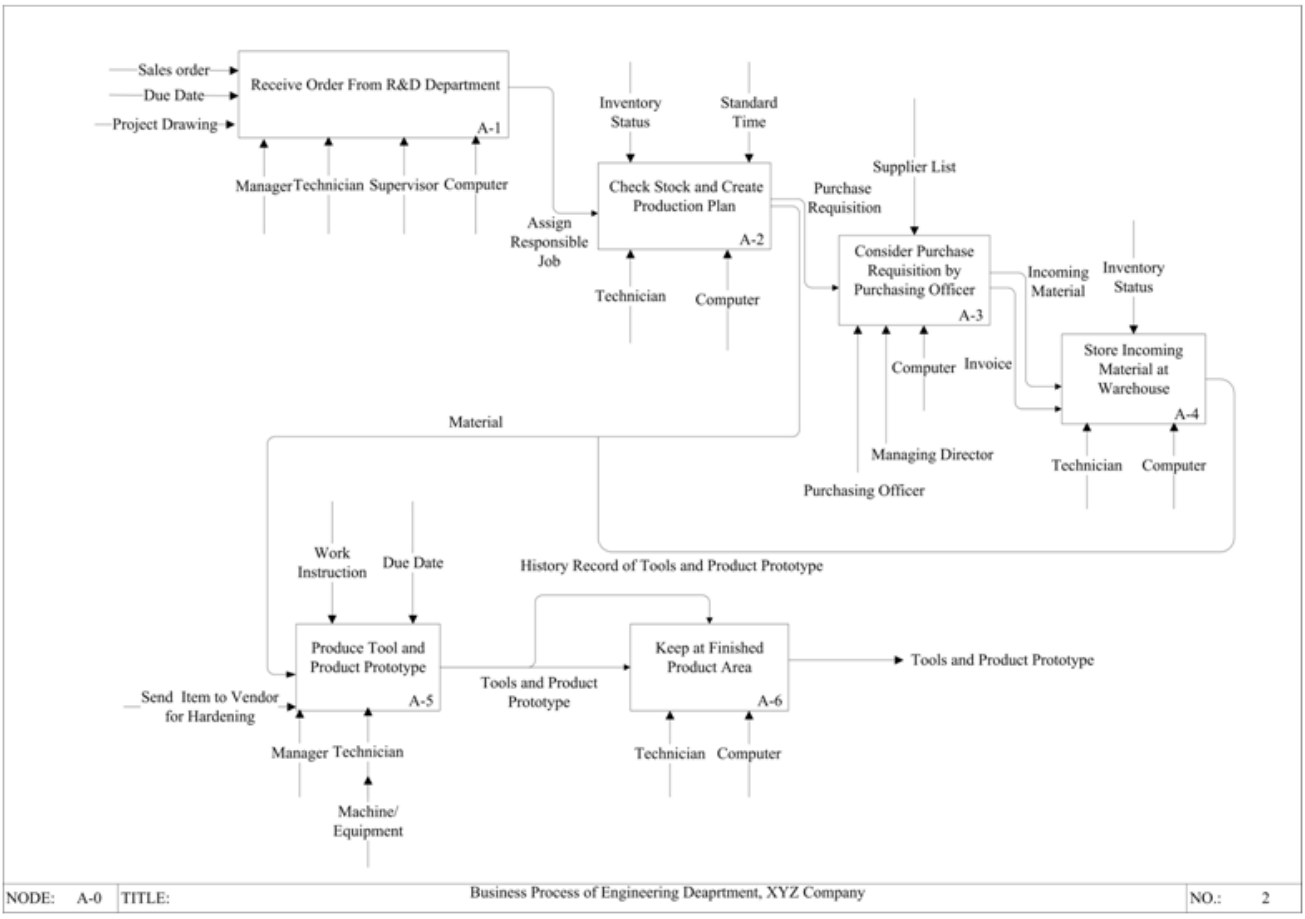

Figure 3. An overview activity model, A0.

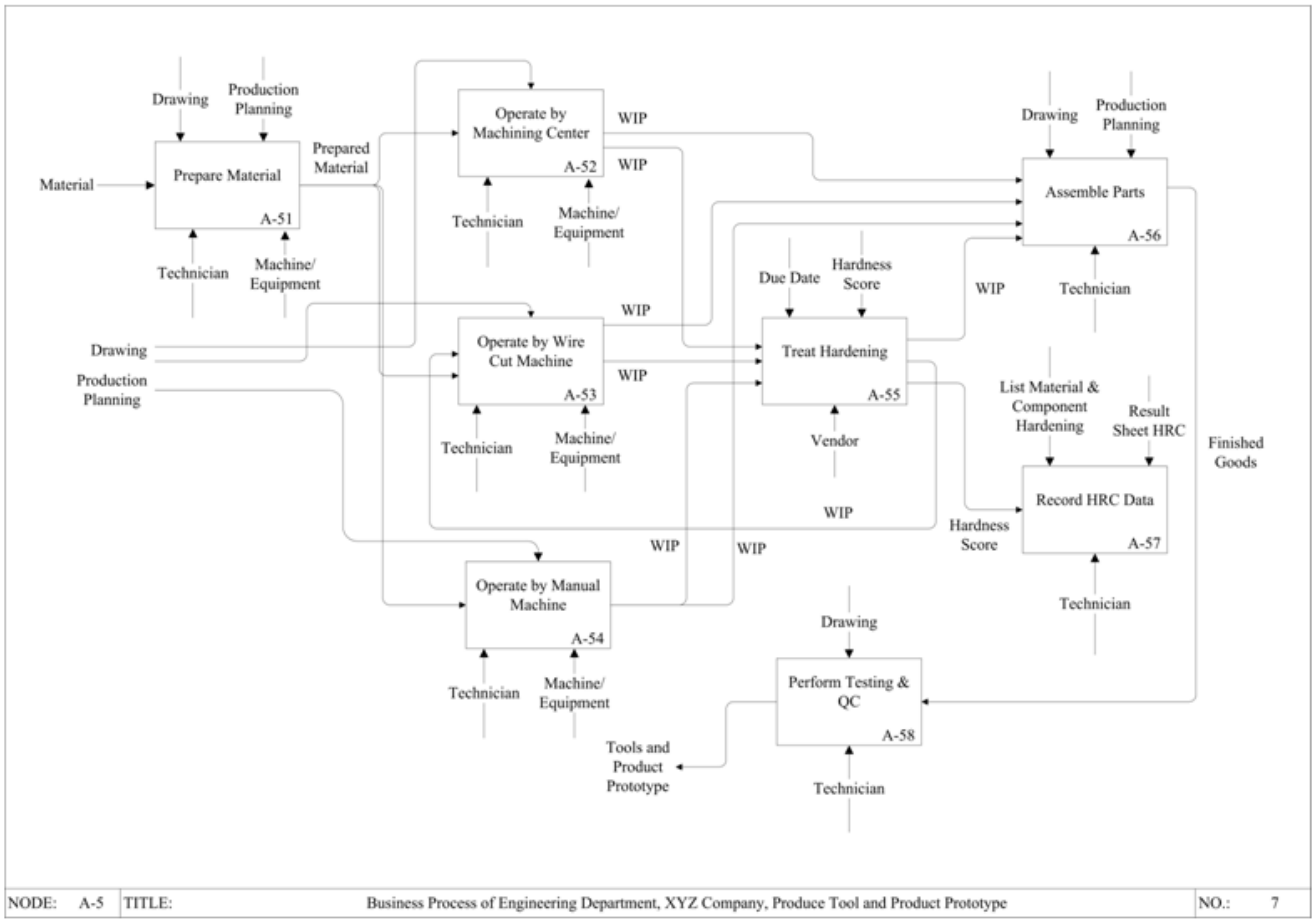

Figure 4. Produce tool and product prototype model, A5.

Assemble Parts, A56: All parts from previous step are collected at the assembly unit. An experience technician assembles parts by using tools and equipments.

Record HRC Data, A57: A certificate HRC documented is shipped with the treatment product. This result is recorded in a folder. A technician also adds this data in a "List material and component hardening" file.

Perform Testing and Quality Control, A58: Finally, a technician tests and checks a finished good. All data are compared with a customer requirement sheet. All products must pass a quality control activity before sending to customers.

36 activities of business process from engineering department are summarized in Table 3. We observe that this case study character could be assessed by applying the final version of SHEN. Each principle of the SHEN model comprises of five steps. A sample of SHEN model as principle 4 "Simplify the shop floor" is demonstrated in Table 4. Then, we form a SEM as a guide which is illustrated in Figure 5. 11 independent variables and a dependent variable (performance improvement tool; PIT) are obtained by using factor analysis to find simplify information from variables.

Anyway, the case study has solely 3 respondents. We need to get more data for testing this procedure. The others respondents in this research are supervisors and managers who work in the same field. For example, the validity and reliability of principle 11 (collect responses from customers) are tested. It consists of 5 observed variables and a scree plot as illustration in Figure 6 and Figure 7, respectively. Each observed variable has covariance value between 0.380 (11.5, the measure and compare the best in all aspects of the company) and 0.873 (11.2, collect information about the requirements of customers in the future). Then, the value of reliability Cronbach's alpha for this factor is shown 0.869 which meant that the data is reliable and each observed variable had relationship to each other. Based on the scree plot and the number of Eigen value greater than one, one factor is found. It is asserted that 5 observed variables are correctly formed in the same principle. All of main factors are tested validity and reliability. The sample results of factor loading and reliability Cronbach's alpha are illustrated in Table 5.

We confirm that the finalized SHEN model can apply as a guideline to improve especially for the shop floor control. The XYZ company' respondents output from questionnaires

Table 3. Activities Summary of shop floor system from the case study

Node	Activity	Node	Activity
A0	Business process of engineering department	A4	Store incoming material at warehouse
A1	Receive order from R&D department	A41	Receive material
A11	Receive order	A42	Check incoming material
A12	Distribute receiving order	A43	Pay for item
A13	Round up team	A5	Produce tool and product prototype
A2	Check stock and create production plan	A51	Prepare material
A21	Plan to production	A52	Operate by machining center
A22	Design progressive die and/or raising die	A53	Operate by wire cut machine
A23	Create wire cut program	A54	Operate by manual machine
A24	Create program for machining center	A55	Treat hardening
A25	Check raw material	A56	Assemble parts
A26	Create purchase requisition	A57	Record HRC data
A3	Consider purchase requisition by purchasing officer	A58	Perform testing and QC
A31	Create purchase order	A6	Store at finished product area
A32	Affirm purchase order	A61	Store tool
A33	Approve purchase order	A62	Receive prototype
A34	Send purchase order to supplier	A63	Test production
A35	Send ordered material	A64	Receive tool

Table 4. Principle 4 "Simplify the shop floor"

Step	Description
1	Improve visibility, use simple storage systems to reduce search times
2	Improve locations of raw materials, WIP, etc., to cut distances for movement of materials and tools
3	Train shop floor employees on the importance of using the storage systems and of taking responsibility for their own housekeeping
4	Implement housekeeping so that work areas are clean as well as ensuring that the storage systems are properly used
5	The operator takes over his own housekeeping

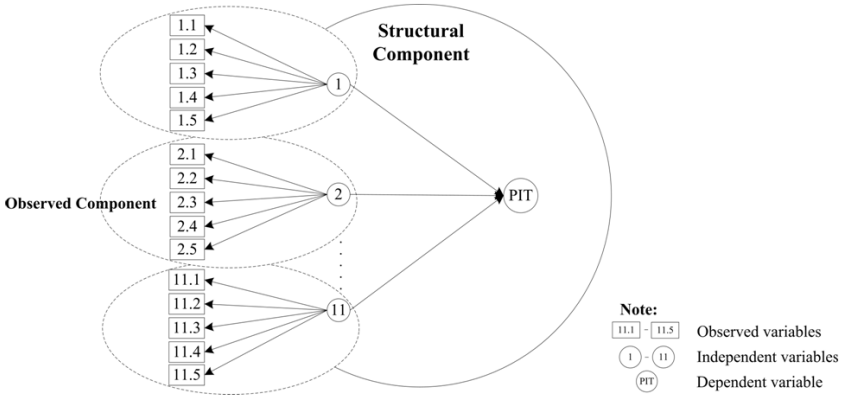

Figure 5. Structure equation model for MTO.

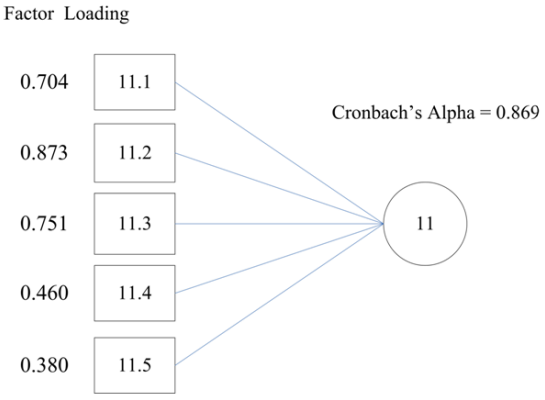

Figure 6. Validity and reliability of principle 11.

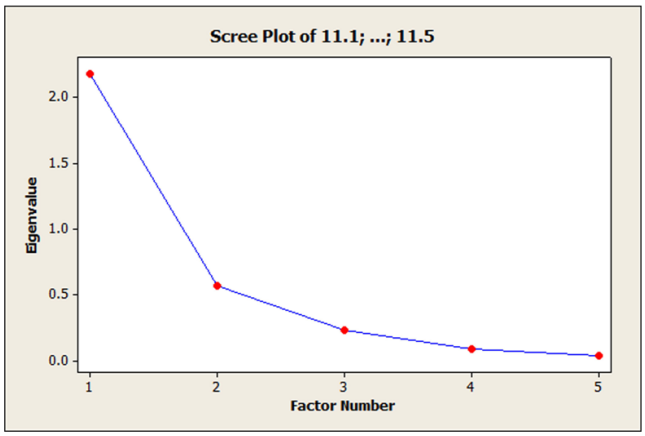

Figure 7. A scree pbt of principle 11.

state that all observed variables have average score at least 3 point (From Likert item; 3 is agree).

6. Conclusions

This paper is one of the lean enterprise transformations (LET) project, has aimed to apply the final version of SHEN model for Thai MTO SMEs. This study began with an exploration activities and a relationship between components by IDEF0. We found that the XYZ company could be appropriated to use SHEN as a benchmark. Next, 11 principles were formed as the proposed a structural equation modeling. Finally, the factor analysis part, we tested validity and reliability by using factor loading and Cronbach's alpha in this pilot study, respectively. The main contributions of this research are as follows:

1. We explored the necessary functional requirements and their relationships of the precision tools engineering industry which is one of the Thai MTO SMEs. This functional architecture was developed for an unambiguous basis guiding to implement a complex system.

2. We tested validity and reliability with real data from experts and practitioners in the field and found that each observed variable had the validity structure and not only had relationship to each other, but also make all main factor structures reliable.

3. We assessed the final version of SHEN with care by using a statistical method to ensure that it is all relevant to the empirical study. The finalized SHEN can apply to support shop floor control system in the context of the precision tools engineering industry. Additionally, the statistical approach might be applied to test a pertinent of SHEN in other industries.

A limitation of this study is that it should collect more observation data for formulating a relationship between dependent variable and each of individual independent variables by the regression analysis. In order to improve Thai MTO SMEs, much works remain to be done. Further research, the case study will be used this finalized SHEN model as a check list and move toward a final step in each relevant principle. Also, future research could integrate this work with the others concepts in the LET project. An issue is considered whether and how this can be accomplished.

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Table 5. Sample covariance values of factor loading and Cronbach's alpha

Independent variable	Observed variables	Factor Loading	Cronbach's alpha
3. Collaborate with customers	3.1 Company helping the customers define their current needs in the form of product specifications and design	0.298	
	3.2 Establish a personal relationship between employees and customers	0.635	0.639
	3.3 Having good communication among employees, a common understanding of organizational objectives and customers' current needs	0.577	
	3.4 Getting customer representatives on the project	0.972	
	3.5 Helping the customers meet their goals, rather than providing customers' wants	0.395	
7. Improvement of the information flow	7.1 Employees understand and the priority of tasks and work under the same plan.	0.315	
	7.2 Process to communicate the plan to work from a manual such as planning boards or task sequence generated by a computer program.	0.859	
	7.3 Target to reduce the transaction by 25%.	0.884	0.830
	7.4 Target to reduce the transaction within the company by 50%, and fax/ internet/ Electronics Data Exchange (EDI) by 80% in transactions outside the company.	0.736	
	7.5 Target to reduce the transaction within the company by 80%, and fax/ internet/ Electronics Data Exchange (EDI) by 99% in transactions outside the company.	0.592	
11. Collect responses from customers as well as measured and compared.	11.1 Collect satisfaction of the customer data, review of complaints, and continuous improvement both of terms of products and services.	0.704	
	11.2 Collect information about the requirements of customers in the future.	0.873	0.869
	11.3 Collect samples of competitors and best practices.	0.751	
	11.4 Collaboration with the customer/ competitors to the best in the industry.	0.460	
	11.5 The measure and compare the best in all aspects of the company.	0.380	

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