Chapter 4

A Lean Roadmap

Muda and Hendry (2002) introduced a modified world class manufacturing (WCM) model by deleting some assumptions which were not proper for the MTO field and changing the emphasis for some cases were needed. This model was called a first version of the SHEN. 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).

However, before applying this model, the pioneers suggested that a process of business should be observed with care. A select procedure of the right technique and the right tool was very important for the development of a business model. IDEF0 is a descriptive model and a powerful process modeling technique. Many researchers applied it in many research fields. 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 had 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 and WCM, omitted issues that were pertinent to Thai MTO SMEs. Hence, this Chapter described the approach to elaborate lean manufacturing system for Thai SMEs sector by applying a SHEN model as a roadmap with statistical methods.

4.1 The Case Study Information

The case study was motivated by a problem faced by an actual manufacturer of precision tools engineering department for a gold and gems company. Its name had not been disclosed in order to protect the confidentiality. It was fictitiously referred to as a XYZ company where stated in northern region, Lamphun. This company was a leading designer of fine gem set and jewellery.

The engineering department was using the following computerized systems. Computer aided design (CAD) software packages were used for the purpose of designing the tools, fixtures and other parts. Computer aided manufacturing was also used to operate computerized numerical control (CNC) machines. It also had some types of manual machines to assist their productivity improvement activities.

The engineering department had suffered from highly-customized products as precision tools engineering industry. The ability to establish reliable delivery dates in the case study was a critical issue since it was related to both the timeliness and delivery reliability of orders. Figure 4.1 shows the distribution for lateness. Thus, the case study tried to stay competitive by adapting the approach of lean manufacturing.

4.2 An Exploratory Analysis in Applying SHEN Model

As concern from pioneers, the case study had to analysis its business activities before applying the SHEN. IDEF0 was adopted to explore the system as suggestions.

A-0 was a top level without and with detailed of IDEF0 which is depicted in Figure 4.2 and 4.3, respectively.

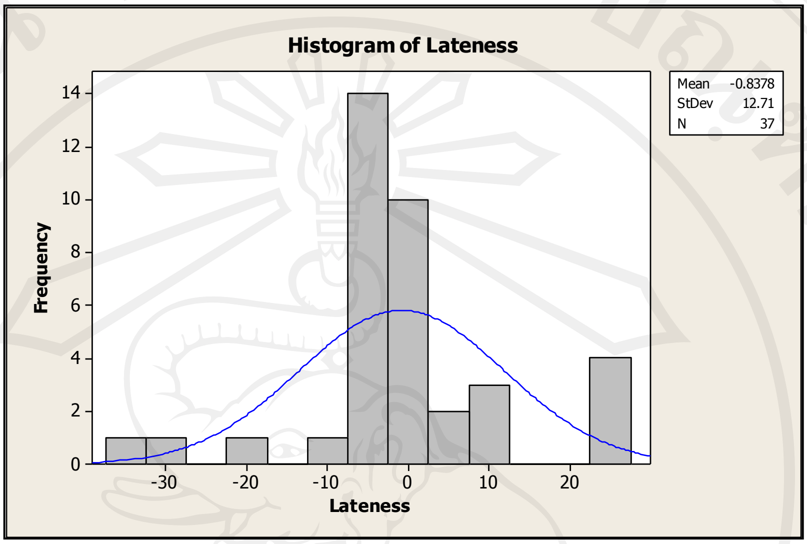

Figure 4.1 Histogram of reliable delivery problem

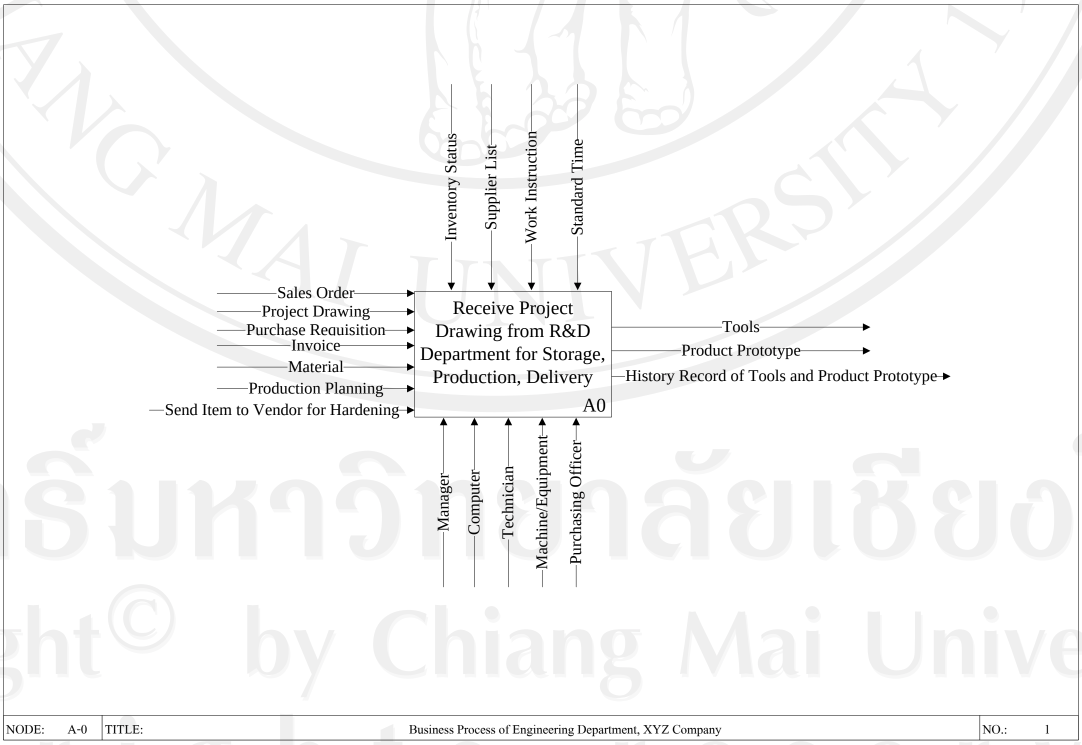

Figure 4.2 An overview activity model, A0

This A-0 level was decomposed into six main activities–receive order from R&D department (A-1), check stock and create production plan (A-2), consider purchase requisition by purchasing officer (A-3), store incoming material at warehouse (A-4), produce tool and product prototype (A-5) and store at finished product area (A-6).

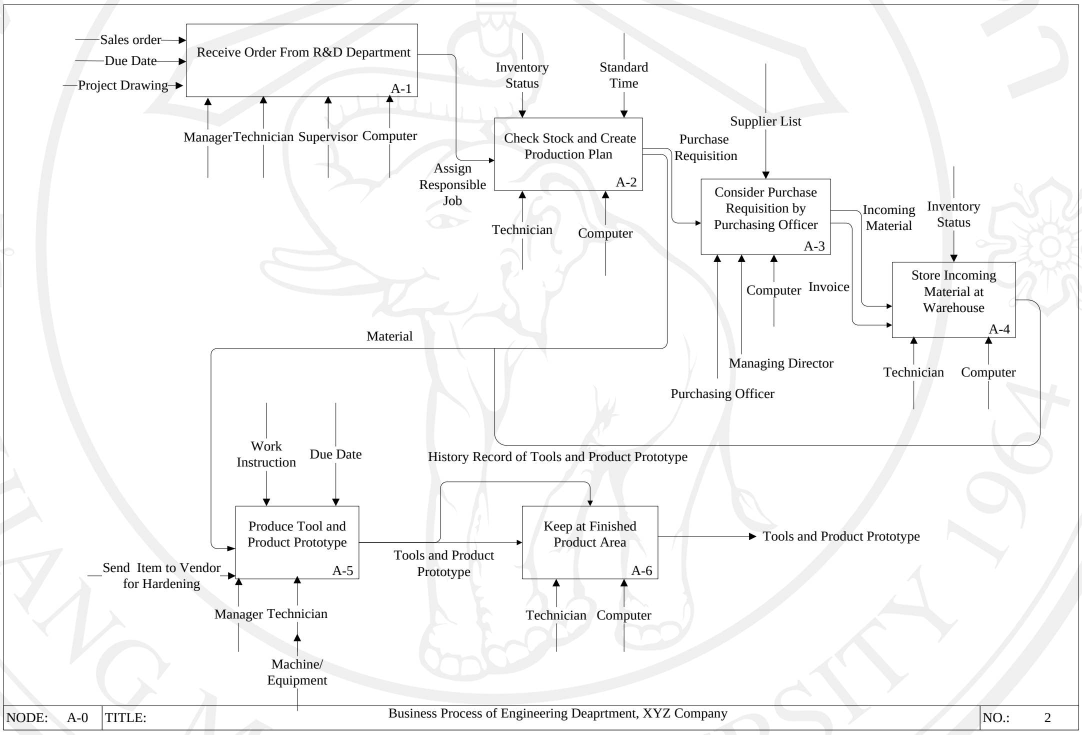

Figure 4.3 A detailed activity in A0 model

Figure 4.4 illustrates the detailed model, A-1 which could be briefly described as follows. Receive order, A-11: The engineering manager receives a project drawing from sales order from research and development department via company's intranet system with due date assignment. Next, distribute receiving order, A-12, this drawing is distributed to responsible persons comprise technicians and supervisors. Each person has to approximate a procedure with processing time of this project before a meeting time. Round up team, A-13: Technicians and supervisors prepare processing data comprise ordered projects and the new one for the manager. Then, the manager tries to assign this project to a specific working group in order to deliver this project on time.

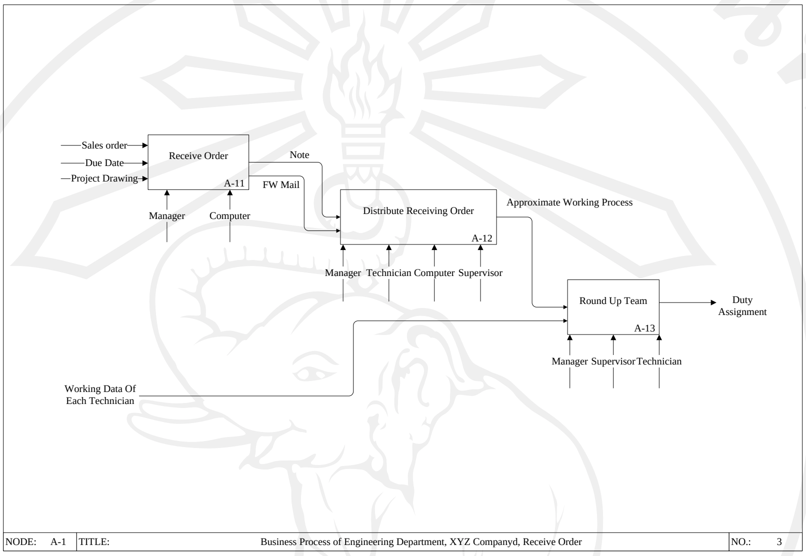

Figure 4.4 Receive order from R&D department, A-1

After duty assignment, on the one hand the supervisor creates a production plan which is controlled by due date and standard time. This plan is used to update a presently production scheduling. This activity is called plan to production, A-21. On the other hand the supervisor drafts this project drawing with a computer in CAD format, A-22. Next, this file is distributed not only to technicians as a wire cut technician and a machining center technician transform the CAD file to computer-aided manufacturing format in A-23 and A-24, respectively. These files are uploaded to a specific CNC machine.

But also to the material stock supervisor uses this data to monitor raw materials stock, A-25. An inventory status is activated whether the supervisor should order raw material or not. If the status is lower than a bottom line strategy, the supervisor uses material purchase request sheet (FP-CM-CM-01-01) to create purchase requisition, A-26. This sheet is forwardly submitted to purchasing department. A detailed activity in A-2 is depicted in Figure 4.5.

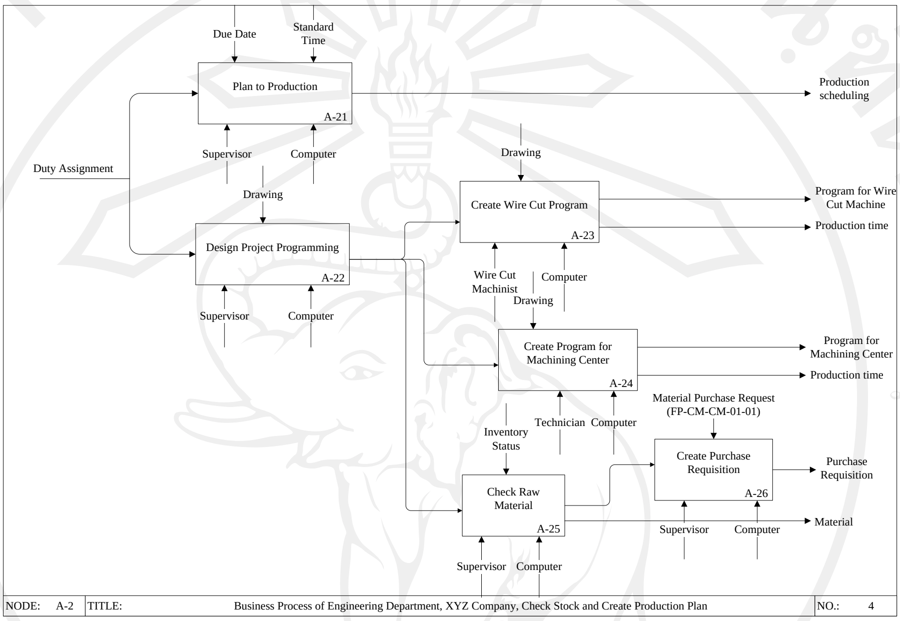

Figure 4.5 Check stock and create production plan, A-2

An activity of purchasing can describe in A-3, as shown in Figure 4.6. A purchasing officer creates purchase order by considering qualified suppliers. This document is affirmed by a purchasing manager and is approved by managing director. When this document is complete, it will return to the officer for sending the order document to suppliers. These activities are exploited in A-31 to A-34. Send ordered material, A-35: The supplier sends materials combine with invoice to the company.

Figure 4.7 states activities when the materials and attached invoices are arriving to the company as A-4. Receive material, A-41: The purchasing officer previously observes the materials in tern to match the purchase order document. Both materials and invoices are transfer to inventory zone where the technician has to check incoming material, A-42, before affirming the invoice to an accounting department. Finally, an accountant pays for the item on payment condition to the supplier.

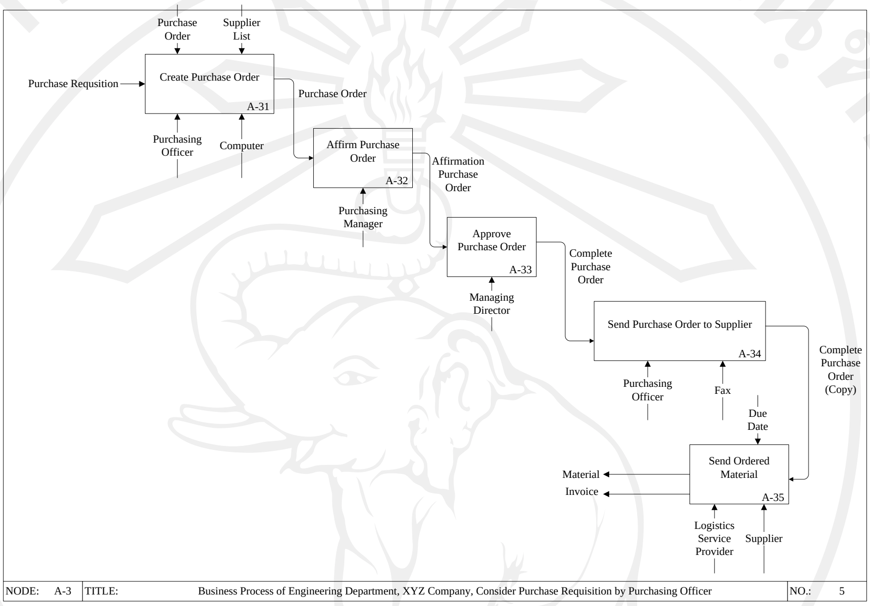

Figure 4.6 Consider purchase requisition by purchasing officer, A-3

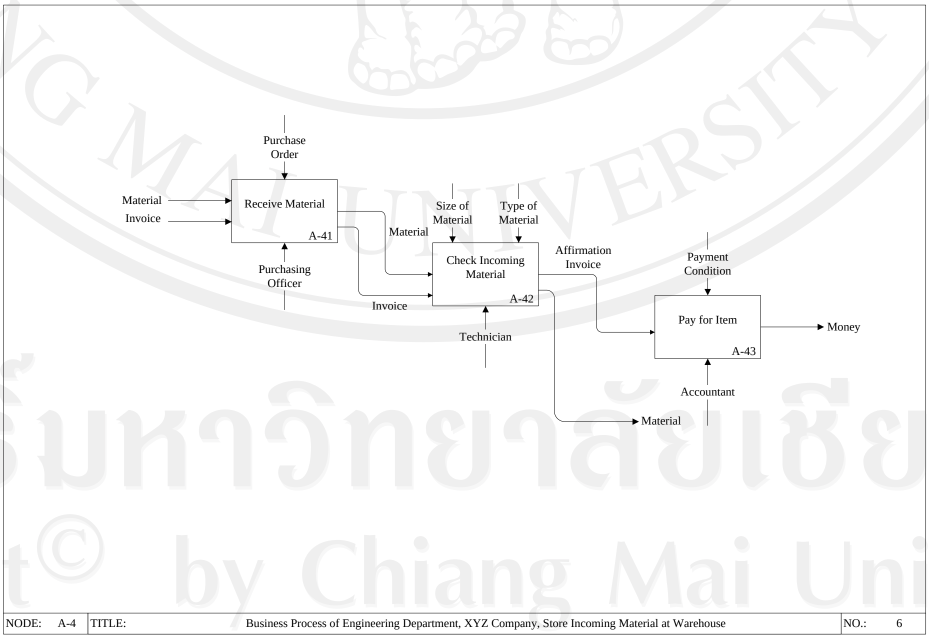

Figure 4.7 Store incoming material at warehouse, A-4

Figure 4.8 is illustrated the detailed of an impact model, A-5 which could be briefly described as below. Prepare material, A-51: 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, A-52: 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.

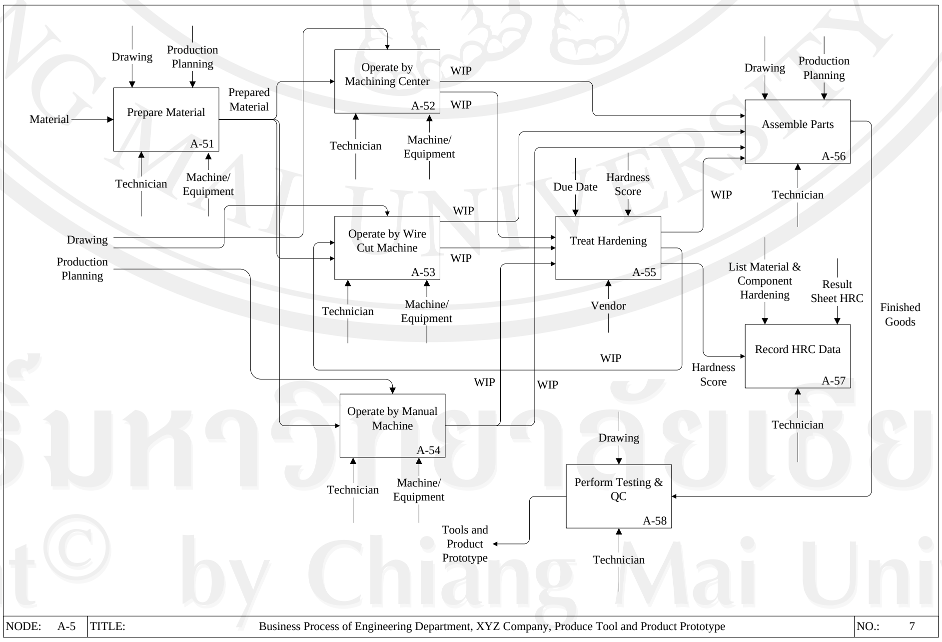

Figure 4.8 Produce tool and product prototype model, A-5

Operate by Wire Cut Machine, A-53: A method of this operation is likely a previous step, A-52. But, this machine uses brass wires or copper wires instead of tools for the machining center.

Operate by Manual Machining, A-54: 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, A-55: 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.

Assemble Parts, A-56: All parts from previous step are collected at the assembly unit. An experience technician assembles parts by using tools and equipments.

Record HRC Data, A-57: 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, A-58: 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.

Figure 4.8 shows store at finished product area, A-6. The technician stores finished tools and prototypes with a prototype tooling history form (FP-F0-EN-01-

01/Rev.02) as stated in A-61. Prototypes and novel tools are sent to register with ISO document by a product development officer, A-62. After that, prototypes are tested before using in production line, A-63. A-64 states that the familiar tools are also submit to the product development officer. Finally, these tools will be launched in production line.

36 activities of business process from engineering department are summarized in Table 4.1. This case study was observed that character could be assessed by applying the final version of SHEN. Each principle of the SHEN model comprised of five steps. Level one was the initial step on the improvement way and level five related to existing best practices.

Table 4.1 Activities Summary of shop floor system from the case study

Node	Activity
A0	Business process of engineering department
A1	Receive order from R&D department
A11	Receive order
A12	Distribute receiving order
A13	Round up team
A2	Check stock and create production plan
A21	Plan to production
A22	Design project programming
A23	Create wire cut program
A24	Create program for machining center
A25	Check raw material
A26	Create purchase requisition
A3	Consider purchase requisition by purchasing officer
A31	Create purchase order
A32	Affirm purchase order
A33	Approve purchase order
A34	Send purchase order to supplier
A35	Send ordered material
A4	Store incoming material at warehouse
A41	Receive material
A42	Check incoming material
A43	Pay for item

Table 4.1 Activities Summary of shop floor system from the case study (continue)

A5	Produce tool and product prototype
A51	Prepare material
A52	Operate by machining center
A53	Operate by wire cut machine
A54	Operate by manual machine
A55	Treat hardening
A56	Assemble parts
A57	Record HRC data
A58	Perform testing and QC
A6	Store at finished product area
A61	Store tool
A62	Receive prototype
A63	Test production
A64	Receive tool

4.3 Statistical Results from Designed Questionnaire

From the "finalized SHEN", the SEM was formed as a guide for the statistic analysis which is illustrated in Figure 4.9. Eleven independent variables and a dependent variable (performance improvement tool; PIT) were obtained by using factor analysis to find simplify information from variables. A sample principle of SHEN model as principle 4 "Simplify the shop floor" is demonstrated in Table 4.2.

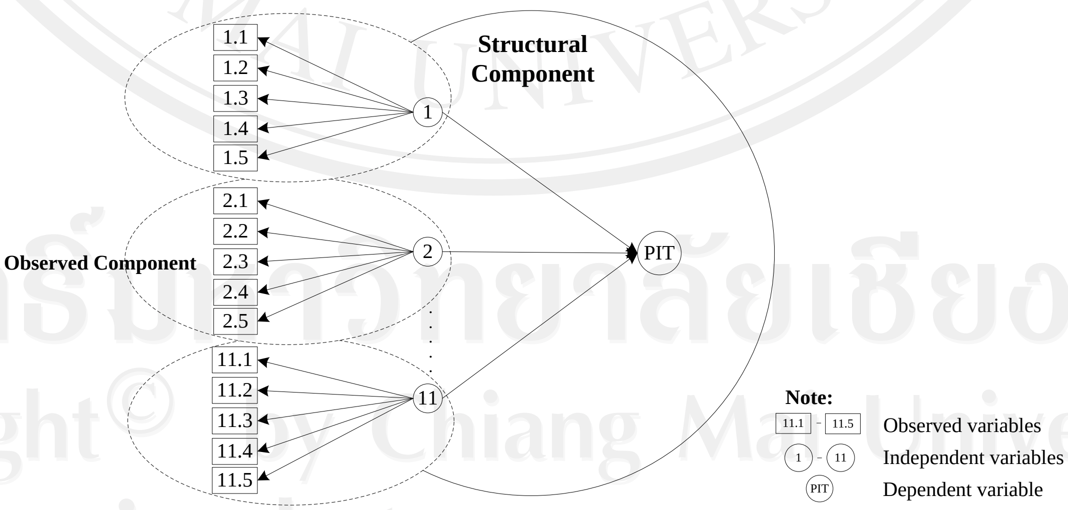

Figure 4.9 Structure equation model for MTO

Table 4.2 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

Anyway, the case study had solely three respondents. It had to collect more data for testing this procedure. The others respondents in this research were supervisors and managers who worked in the same field. For example, results from questionnaire of principle 11 (Gather customer feedback and benchmarking) are displayed in Table 4.3 (all questionnaire answer stated in Appendix B).

Table 4.3 Results from seven respondents for principle 11

Principle 11	**Respondent**						
	1	2	3	4	5	6	7
1. Gathering customer-satisfaction data, review complaints and make continuous improvement on products and services	4	3	4	3	5	4	3
2. Gathering data on future customer needs	4	4	4	2	5	4	3
3. Gathering competitive samples and best practice data	5	3	5	3	5	4	4
4. All associates involved in customer/competitive best practice	4	5	5	4	5	4	3
5. The company implement full-scale benchmarking for its processes	4	4	5	4	5	4	4

These observed answers were tested the validity and reliability by using the MINITAB® 15. The software computed factor loading values for each observed components as depicted in Figure 4.10.

Each observed variable had covariance value between 0.380 and 0.873. The Cronbach's alpha could be calculated by adopting Equation 3.3 with input data in Table 4.3, but this Equation had to prepare some data before apply as in Table 4.4.

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Session

Factor Analysis: 11.1, 11.2, 11.3, 11.4, 11.5

Principal Component Factor Analysis of the Covariance Matrix


Unrotated Factor Loadings and Communalities

Variable  Factor1  Communality
11.1        0.704        0.495
11.2        0.873        0.762
11.3        0.751        0.564
11.4        0.460        0.211
11.5        0.380        0.144
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Figure 4.10 Factor loadings of observed components

Table 4.4 Raw data for Cronbach's alpha calculation

Respondent	Principle 11					Summary
	11.1	11.2	11.3	11.4	11.5	
1	4	4	5	4	4	21
2	3	4	3	5	4	19
3	4	4	5	5	5	23
4	3	2	3	4	4	16
5	5	5	5	5	5	25
6	4	4	4	4	4	20
7	3	3	4	3	4	17
$\sum X_i$	26	26	29	30	30	141
$\sum X_i^2$	100	102	125	132	130	2,901
$\sigma^2_{Y_i}$	0.490	0.776	0.694	0.490	0.204	2.653

$$\sigma_{Y_1}^2 = \frac{n\sum X^2 - \left(\sum X_1\right)^2}{n^2} = \frac{(7\times 100)-(26)^2}{7^2} = 0.490$$

The other $\sigma_{Y_i}^2$ used the same calculation and their result were shown in Table 4.4.

$$\sigma_X^2 = \frac{n\sum X^2 - \left(\sum X\right)^2}{n^2} = \frac{(7\times 2901)-(141)^2}{7^2} = 8.694$$

From Equation 3.3, then

$$\alpha_{11} = \frac{K}{K-1}\left(1-\frac{\sum_{i=1}^{K}\sigma_{Y_i}^2}{\sigma_x^2}\right) = \frac{5}{5-1}\left(1-\frac{2.653}{8.694}\right) = 0.869$$

Then, the value of reliability, Cronbach's alpha for this factor was shown 0.869 which meant that the data was reliable and each observed variable had relationship to each other. Figure 4.11 shows factor loading which consists of 5 observed variables and Cronbach's alpha of principle 11 in a part of the SEM.

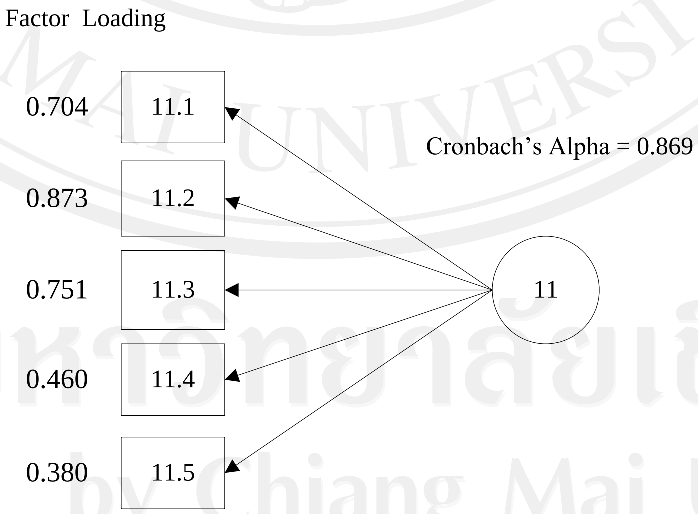

Figure 4.11 Validity and reliability of Principle 11

Based on the scree plot and the number of eigen value greater than one, one factor was found. It is asserted that 5 observed variables were correctly formed in the same principle, as illustrated in Figure 4.12. All of main factors were tested validity and reliability. All principles results of factor loading and reliability Cronbach's alpha are shown in Table 4.5.

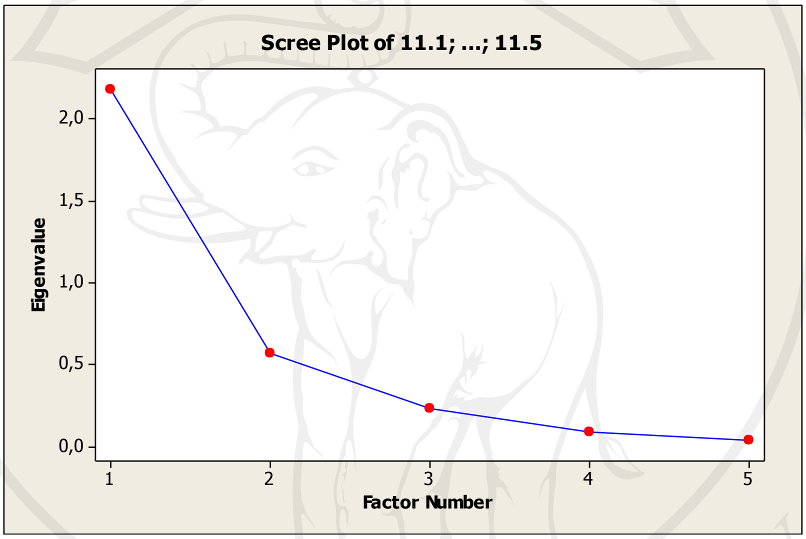

Figure 4.12 A scree plot of Principle 11

Table 4.5 Factor loading and Cronbach's alpha of all principles

Independent variable	Observed variables	Factor Loading	Cronbach's Alpha
1. Integrate the functions of production and marketing in all processes	1.1 Initial understanding between production and marketing	0.632	0.788
	1.2 Production and marketing functions work together in responding to customer enquiries	0.731	
	1.3 Having a systematic database system to enable MTO companies to respond to customer enquiries	0.782	
	1.4 Achieve 50 percent reduction in time to respond to customer enquiries	0.383	
	1.5 Understanding its competitors and having a systematic method for calculating price and delivery lead-time	0.834	

Table 4.5 Factor loading and Cronbach's alpha of all principles (continue)

Independent variable	Observed variables	Factor Loading	Cronbach's Alpha
2. Design for products, processes and improved supplier relationships	2.1 Train employees in understanding all the product specifications, product design rework and purchasing process/knowing their suppliers	0.614	0.617
	2.2 Having a minimum number of parts, forgings or suppliers for each product	0.379	
	2.3 Having a computerized design database with designs that can be altered for new orders and a direct computer link with the customer and the shop floor	0.445	
	2.4 Achieve 50 percent "repeat business" which makes it possible to establish partnerships with some of the suppliers	0.670	
	2.5 Achieve 80 percent "repeat business"	0.563	
3. Collaborate with customers	3.1 Company helping the customers define their current needs in the form of product specifications and design	0.298	0.639
	3.2 Establish a personal relationship between employees and customers	0.635	
	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	
4. Simplify the shop floor	4.1 Improve visibility, use simple storage systems to reduce search times	0.626	0.655
	4.2 Improve locations of raw materials, WIP, etc., to cut distances for movement of materials and tools	0.662	
	4.3 Train shop floor employees on the importance of using the storage systems and of taking responsibility for their own housekeeping	0.400	
	4.4 Implement housekeeping so that work areas are clean as well as ensuring that the storage systems are properly used	0.470	
	4.5 The operator takes over his own housekeeping	0.631	
5. Improve scheduling and workload control to cut flow times	5.1 Having a practical, simple manual scheduling system that meets company objectives	0.341	0.866
	5.2 Having a simple computerized and easily implemented scheduling system	0.491	

Table 4.5 Factor loading and Cronbach's alpha of all principles (continue)

Independent variable	Observed variables	Factor Loading	Cronbach's Alpha
	5.3 Having an effective method of workload control to aid the company to reduce flow times	0.669	
	5.4 Achieving average reduction of flow time by 30 percent	0.832	
	5.5 Achieving average reduction of flow time by 50 percent	0.845	
6. Cut the start up/changeover time and improve preventive maintenance	6.1 Train associates in set-up/ changeover reduction and basic preventive maintenance	0.607	0.800
	6.2 Achieving 10 percent average reduction in set- up/changeover time	0.520	
	6.3 Operators can take over their own preventive maintenance	0.437	
	6.4 Achieving 30 percent average reduction in set-up/changeover time	0.605	
	6.5 Employees achieve 50 percent reductions in set-up/changeover times across all processes	0.366	
7. Improve information flow	7.1 Job priorities are understood by all and everyone is working to the same plan	0.315	0.830
	7.2 Having a systematic method to communicate the plan including manual systems such as a planning board or "work to lists" produced by an appropriate software package	0.859	
	7.3 Office transactions, labor transactions cut by 25 percent	0.884	
	7.4 Internal transactions cut by 50 percent and 80 percent of external transactions are done by fax/Internet/EDI	0.736	
	7.5 Internal transactions cut by 80 per cent and 99 percent of external transactions are done by fax/Internet/EDI	0.592	
8. Make essential improvements in skills and flexibility	8.1 Implement a training programmed for all associates to increase relevant skills	0.690	0.855
	8.2 80 percent of associates are flexible in appropriate skills and able to work on other machines when needed	0.611	
	8.3 99 percent of associates are flexible in appropriate skills and able to work on other machines when needed	0.604	
	8.4 Experts teach operators to do repairs; downtime cut by 50 percent	0.585	
	8.5 Operators become technicians; downtime cut by 80 percent	0.664	

Table 4.5 Factor loading and Cronbach's alpha of all principles (continue)

Independent variable	Observed variables	Factor Loading	Cronbach's Alpha
9. Everybody involved in change and strategic planning – to achieve a unified purpose	9.1 Encourage employees to make suggestions to improve the process	0.548	0.782
	9.2 Having strategic planning	0.356	
	9.3 Sharing information and records with shop floor employees	0.602	
	9.4 Systematic public recognition/ celebration of achievement	0.557	
	9.5 Variety of low-cost awards to both teams and individuals	0.898	
10. Improve quality and implement appropriate performance measures	10.1 Practice the principles of quality	0.365	0.674
	10.2 Understanding (through training if necessary) in universal customer wants: speed, flexibility, quality or value (QSFV)	0.474	
	10.3 QSFV are dominant performance measures	0.696	
	10.4 Second order performance measures (e.g. labor productivity, variance) no longer managed	0.406	
	10.5 Maintain a culture that supports continuous improvement in all processes	0.730	
11. Gather customer feedback and benchmarking	11.1 Gathering customer-satisfaction data, review complaints and make continuous improvement on products and services	0.704	0.869
	11.2 Gathering data on future customer needs	0.873	
	11.3 Gathering competitive samples and best practice data	0.751	
	11.4 All associates involved in customer/competitive best practice	0.460	
	11.5 The company implement full-scale benchmarking for its processes	0.380	

4.4 Conclusion

This chapter aimed to apply the final version of SHEN model as the roadmap for lean system. This study began with an exploration activities and a relationship between components by IDEF0. The engineering department of XYZ company could be appropriated to use SHEN as a benchmark. 11 principles were formed as the questionnaire and SEM, respectively. Finally, the factor analysis part, validity and reliability were tested by using factor loading and Cronbach's alpha in this pilot study, respectively.

As shown in the roadmap, a main research question was arisen as "How will lean manufacturing system practices affect on delivery in stochastic environments?" This research focused on two directly separate research topics which comprises of supplier selection and scheduling and workload control improvement. However, the manufacturing planning decision responsible for determining the production schedule should be integrated with the supplier selection decision concerning (Cakravastia and Takahashi, 2004). Chapter 5 proposes a systematic and scientific approach to select suppliers. Selected suppliers play an important role in term of cost, quality and delivery. Chapter 6 presents the hybrid algorithm to deal with parameter values of Cobacabana in order to schedule and control production operations.