Chapter 7

Conclusion and Suggestion

The use of lean manufacturing system within stochastic environments is a challenge. The lean performance improvement presented in this research offered new views on lean tools for the proposed objective fulfillments. : to design and develop supplier selection and workload control for job scheduling in the stochastic environment lean system, to analyze influential factors on product delivery and variation reduction and to improve makespan time by using a hybrid algorithm.

The lean roadmap comprised of developed lean tools that were elaborated in this inventive lean manufacturing system as proposed in Chapter 4. The second objective had been satisfied by developed lean tools which presented in Chapter 5 and 6. Finally, the third objective was discussed in Chapter 6. Figure 7.1 presents an overview schematic diagram of the proposed methodology.

In this Chapter, the conclusion regarding the contents of this thesis was briefed in Section 7.1. Research contributions, limitations, and suggestions for future work were provided in the rest of this Chapter.

7.1 Conclusions

This research was arisen from the main research question "How will lean manufacturing system practices affect on delivery in stochastic environments?" First of all, an understanding of the case study's business processes was an important part to design and develop the roadmap for the lean system. IDEF0 played a significant role in exploring and capturing activities in hierarchy of related diagrams.

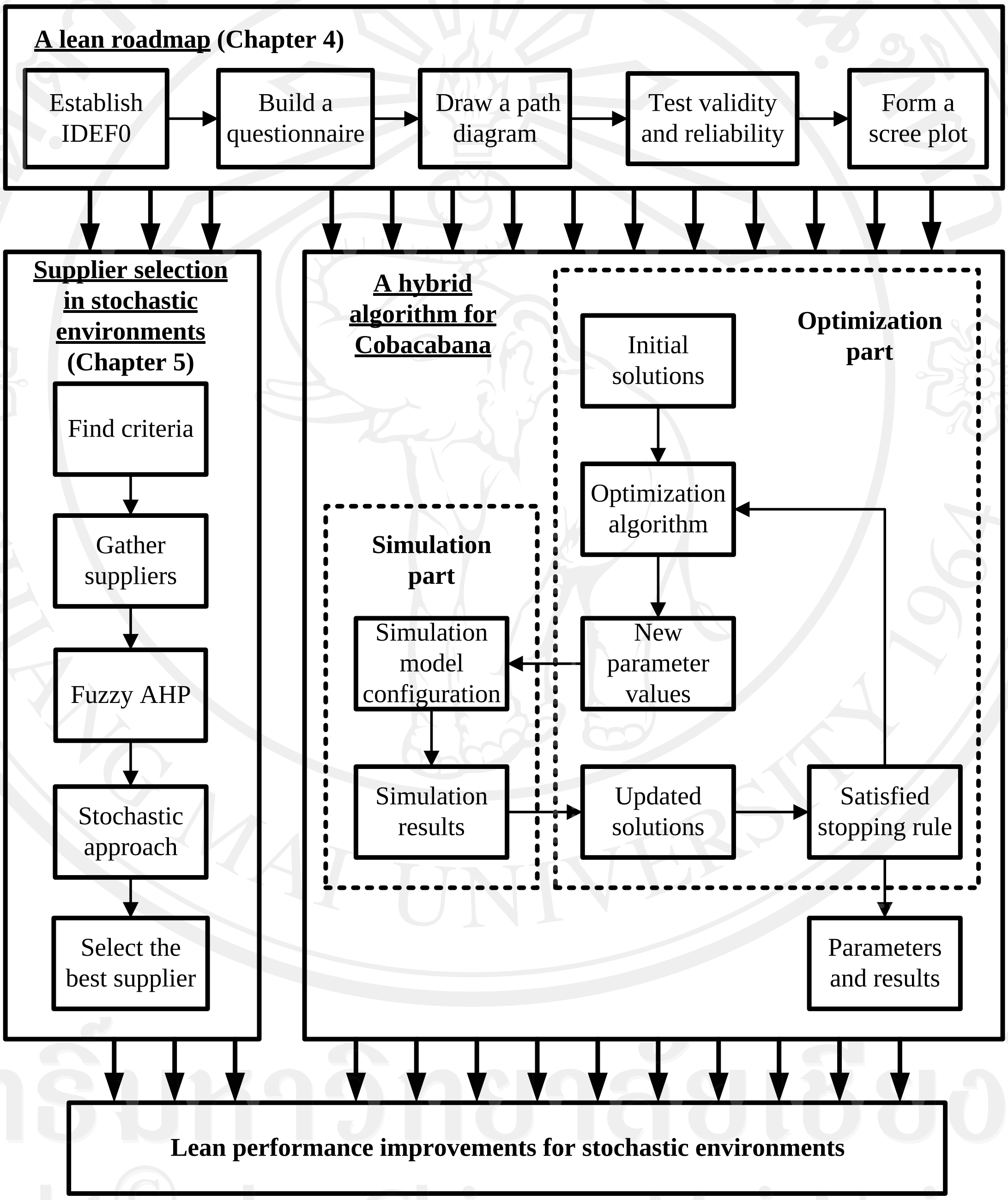

Figure 7.1 Overview of an essentially proposed algorithm

36 activities were summarized in Section 4.2. The validity of the IDEF0 was endorsed by the qualified personnel. The performance improvement model based on the modified world class manufacturing for the MTO environment was formed as the questionnaire. SEM, which is a convenient framework for statistical analysis, was set to imply a structure for the questionnaire. The validity and reliability were evaluated by using factor loading and Cronbach's alpha, respectively. Moreover, the scree test was used to classify the optimum number of factors satisfactory. As shown in results, supplier selection and scheduling improvement and workload were involved in the developed lean system. These results related to the first objective "To design and develop supplier selection and workload control for job scheduling in stochastic environments lean system". Two research questions were formulated to drive the redesign of supplier selection and workload control.

(1) What factors will have influence effect on product delivery and variation reduction?

(2) Which approach should be suitable to find a job shop scheduling of minimum length for stochastic lean system environment?

The proposed fuzzy AHP of supplier selection was split in two approaches. The first approach was the classical method. For the second approach, the extent analysis method was developed. Relevant criteria, which have been widely discussed in the literature, especially for selection of material suppliers were collected as shown in Section 5.1. The conjunctive constraint method was applied for initial screening to indentify candidate alternatives from eight suppliers by qualified DMs. From this screening, three candidate suppliers were used for the final selection. Based on the comparison of suppliers and the methods applied, it could be found that supplier A was the favored from both approaches. Next, both approaches integrated with stochastic phase for handling uncertainties from inconsistent pairwise comparisons.

In the stochastic phase, the variances of local relative weights and the variance of the global relative weights were calculated to find judgmental errors resulting from inconsistent pairwise comparisons. The proposed stochastic approach was capable of calculating the variances as well as handling the uncertain behavior of them using Monte Carlo simulation. The results rankings were exhibited into the probabilistic interpretation for final rankings. This research also found that the influential main factors comprise of compatibility and service, respectively. Moreover, flexibility in operation and delivery, flexibility in billing and payment, technical assistance and support, cooperation and communication, on time delivery, and appearance and functions played an important role in term of the influential sub-factors. These results related to the second objective “To analyze influential factors on product delivery and variation reduction”.

A number of production control concepts were reviewed in Chapter 2. It was found that Cobacabana had filled the gap for the job shop. Cobacabana’s mechanism elaborated on the WLC concept to apply workload norms into numbers of cards transformation. The release procedure of WLC fulfilled two functions, a timing function and a load balancing function. Good timing of release should lead to small dispersion of due date deviations. Load balancing should improve the throughput of the system. However, this card-based has a number of topics which require further research. This research bridged the gap to improve lead time and due date in term of delivery reliability as follows.

In Section 6.1, VNM was applied to support data for order entry phase of WLC concept by developing the complete flow network in a value stream for a complex product, a complex bill of material and several levels of assembly by integrating and enhancing basic industrial engineering tools. Moreover, the complete assembly structure of the product was revealed instead of focusing only the key components. These data were used to develop the Cobacabana via simulation study.

The simulation study for the workload norms and release period lengths was investigated. These factors related to the second objective "To analyze influential factors on product delivery and variation reduction". Simulated model characteristics were displayed in Table 6.4. Input random variables were determined by the Input Analyzer, literature reviews, and interviews. This simulation model was verified by adopting the structured walkthrough technique. Event validity was done by comparing results from the simulation model and actual system. Simulated results of WLC phenomenon were shown in Section 6.2. Next, the hybrid algorithm was used to find value parameters for the workload norms and release period lengths.

This research employed the Antcoba algorithm to deal with the model parameter identification issue. The Antcoba algorithm worked well on setting good parameter as stated in Table 6.6. Ten independent simulation testing replications of for each parameter were used as the construction graph for Antcoba. The algorithm generated the best pathway as workload ratio equals 1.5 and release period length equals 4.5. However, the half width of this experiment represented 5.03 days or a 22.73% error in the point estimate 22.1304 days. Based on the lead time unit, one day was considered as the base period. Hence, three hundred replications were replaced to run the simulation model for updating lead time and delivery reliability. Internal validity was done by several replications of the simulation model. The best value obtained by the hybrid algorithm was 29.22 days for lead time and 68.65% delivery reliability. In addition, workload ratio and release period length related to 2 and 2, respectively. Moreover, the proposed algorithm was compared to EDD rule. The proposed algorithm controls lead time, throughput time and delivery reliability better than EDD as shown in Table 7.1. The proposed algorithm controlled lead time, delivery reliability and throughput time better than 4.35%, 24.62% and 79.51%, respectively. These results related to the third objective "To improve makespan time by using a hybrid algorithm".

Table 7.1 Comparison results of the proposed approach and EDD

Type	**Lead time (Days)**	**Delivery reliability (%)**	**Throughput time (Min)**
Proposed algorithm	29.22	68.65	7.30
EDD	30.55	44.02	35.64
Improvement	4.35%	24.63%	79.51%

7.2 Research Contributions

This thesis had been developed to answer the research questions and fulfilled the research objectives. This Section summarizes the research contributions to bridge gaps and briefs in Table 7.2.

1. The developed lean roadmap was assessed with care by using a statistical method to ensure that it was all relevant to the empirical study. Validity and reliability with real data from experts and practitioners in the field were tested. Each observed variable had the validity structure, relationship to each other and made all main factor structures reliable.

2. Influential factors (criteria) of lean manufacturing system in stochastic environments were addressed from widely discussion in the literatures. The proposed approaches were presented to handle the uncertain behavior in fuzzy MCDM by using Monte Carlo simulation. It was found that, compatibility and service, which was main factors, played an important role to selection the best supplier. Moreover, flexibility in operation and delivery, flexibility in billing and payment, technical assistance and support, cooperation and communication, on time delivery and appearance and functions played an important role in term of the influential sub-factors.

3. An adaptation of VNM for supporting data in order entry level of WLC was fruitful to handle multiple products in complex bill of material and became easier to visualize for anticipation a bottleneck.

4. The hybrid algorithm was applied for obtaining model parameters of Cobacabana. The proposed algorithm performed shorter lead time, greater delivery reliability, shorter throughput time and lower level of WIP, than EDD.

7.3 Limitations

This thesis conducted by the researcher had many limitations. Although the methodologies used in this research presented interesting results, the results from questionnaires should be reexamined. It should collect more observation data for formulating a relationship between dependent variable and each of individual independent variables by the regression analysis.

Next, the case study had limited sources for data. The exponential distribution was adopted for inter-arrival times. Practical ways should use to justify the job arrival such as data should be collected by developing electronic databases.

Table 7.2 Thesis contributions

Research Gap	**Approach for filing the gap**	**Results and Contributions**
1. Performance improvement tools for SMEs	The developed lean roadmap was assessed with care by using a statistical method.	- The roadmap can apply to improve the shop floor control system.
2. Imprecise weight point estimate and subjective judgmental error.	Two approaches were developed based on fuzzy stochastic AHP.	- The proposed can handle the uncertain behavior in MCDM. - The influential main factors comprise of compatibility and service, respectively.
3. An approach for supporting data in order entry level of WLC.	Adaptation VNM for supporting data.	- All necessary data are clearly shown for production planner.
4. Parameters setting in Cobacabana.	A metaheuristic approach combined with simulations.	- The hybrid algorithm performs short lead time, great delivery reliability, short throughput time and low level of WIP

Another limitation was that this research was the specify problem. The quantitative analysis of this research made with certain assumptions such as all machine have 100% uptime, materials were ready for all products. If such assumptions were wrong, the results would be misleading. The percentage of urgent orders, transportation time, inspection time, etc. should be included in the simulation model.

Lastly, this research was not implemented to obtain realistic results. However, each phase was verified by the related persons, especially for the engineering manager as represented in a research paper “An application of value network mapping in workload control concept”.

7.4 Suggestions for Future Work

1. There exist a plethora of different tools and techniques developed for different objectives and waste elimination. However, a number of lean tools have to specifically develop for stochastic environments such as value stream mapping, supplier relationship management, synchronized total productive maintenance etc.

2. Proposed production control and supplier selection should be considered simultaneously under demand disruptions. Moreover, the production control policy for different suppliers varies under different demand scenarios is an interesting issue.

3. Traditional lean tools such as kaizen, workplace organization (5S) and general visual management should be involved for a successful implementation.

4. Different heuristics should be applied for competing

Figure 7.2 displays a number of gaps to be bridge in the future.

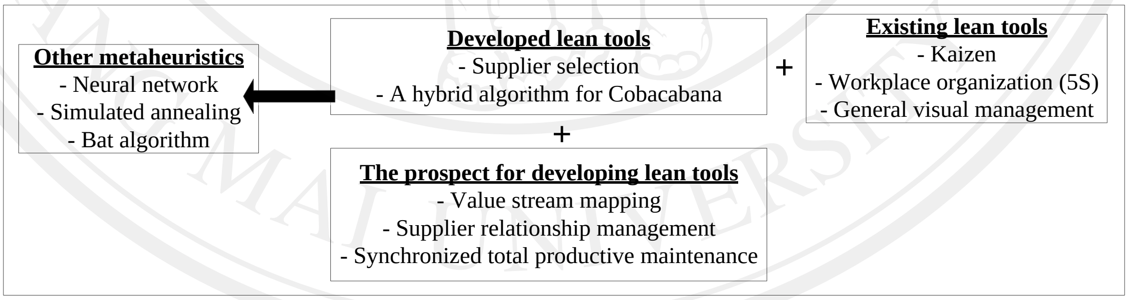

Figure 7.2 Summarized of further researches