

## CHAPTER 8

### CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDIES

This chapter presents the summary and contributions of the dissertation. The contributions directly concerned with the objectives of the dissertation. The limitations of this dissertation are also stated in this chapter. The recommendations for the further study are discussed for other researchers who want to study in this area.

#### 8.1 Summary of the Dissertation

There are three objectives in the dissertation. The first objective is to study the current practice of the P&IC system in Thai SMIs. The second objective is to develop P&IC software which is appropriate for Thai SMIs following the results of the first objective. The third one is to remedy the capacity problem of the MRP logic by developing the algorithm of Finite Capacity Material Requirement Planning (FCMRP) system. The result of the dissertation confirms that these objectives are satisfied.

The dissertation is divided into four sections. The first section is the literature review of popular P&IC systems, namely, JIT, MRP, OPT, and Push/Pull systems (chapter 2). This section consists of a brief description of these systems, differences among these systems, short comings of MRP system, and the previous research works related to SFC, FCS, and FCMRP system. The literature review reveals that there is no single P&IC system that can be applied to all production environments. The users have to carefully consider the philosophy and advantage of each system to select the most appropriate system for their companies. The literature review also reveals that a capacity problem may occur by using the conventional MRP logic. The MRP logic is based on infinite capacity of work centers and fixed lead-time concepts. The production plan obtained by this logic may have the capacity problem of some work centers. This leads us to develop the algorithm of FCMRP for solving the capacity problem in MRP system.

The second section is the study of the current practice of P&IC system in Thai SMIs (chapter 3). A study was performed by interviewing the planning managers and their subordinates at some selected Thai SMIs. There are five Thai SMIs in this study which were discussed in chapter 3. Some of them calculate the production and material plan manually. Some develop the P&IC software by themselves. There are three common problems for these companies. This first problem is that they calculate the plan without considering the WIP data. All companies use only on-hand and on-order in their calculation. Therefore the plan may be over estimated. The second problem is that they need the software which can generate the production schedule with the limited resource capacity. The third problem is that they do not have enough funds to invest in the commercial software which is very expensive. Furthermore, the commercial software has a lot of features which is not required for Thai SMIs and it is difficult to use and understand. This leads us to develop the software which is appropriate for Thai SMIs, namely, Thai small-to medium-sized production and inventory control software (TSPICs).

The third section deals with the development of TSPICs (chapter 4). The features of TSPICs are discussed in this section. These are the features which are required from the selected Thai SMIs. TSPICs calculates the production and material plan based on variable lead-time which differs from the conventional MRP. TSPICs also generates the production schedule based on finite capacity concept. The production schedule obtained from TSPICs can be classified into two groups. The first group is the schedule generated by using the algorithm of the proposed FCMRP (NFCMRP, IMFCMRP, and OFCMRP) systems. The second group is the schedule which is generated by the conventional FCMRP (CFCMRP) systems, namely, Forward (F) and Forward-Backward (FB) scheduling systems.

The fourth section presents the NFCMRP, IMFCMRP, CFCMRP, and OFCMRP algorithms (chapters 5, 6, and 7). The design of experiment is also explained in this section. The performances of the NFCMRP, IMFCMRP, and OFCMRP systems are tested by using real data from the selected manufacturing companies. There are two main approaches of the proposed FCMRP systems. The first one is developed based on non-optimization technique corresponding to the NFCMRP and IMFCMRP systems. The IMFCMRP system is the extension of the NFCMRP system. The second one is developed based on optimization technique, which is the OFCMRP system. Both approaches have different characteristics. The schedule obtained from the NFCMRP and IMFCMRP system has some overtime on the non-bottleneck work centers. On the other hand, the overtime is not allowed on all work centers when the CFCMRP or OFCMRP system is applied. The performance measures of the NFCMRP, IMFCMRP, and OFCMRP system are compared to the conventional system, namely, variable lead-time MRP (VMRP) system, F, and FB scheduling systems. The result shows that the NFCMRP and IMFCMRP systems are better than VMRP system base on overtime, whereas, on earliness and tardiness, the VMRP system is better. The tardiness and earliness obtained from the IMFCMRP system are lower than that of the F, FB, and OFCMRP systems but the overtime and earliness obtained from the IMFCMRP system are higher.

## 8.2 Contributions of the dissertation

The contributions of the dissertation are directly related to the dissertation's objectives. There are two major contributions from this dissertation which are the contributions to the Thai SMIs as follows:

- Affordable P&IC software for Thai SMIs

Since TSPICs is developed based on the characteristics and requirements of Thai SMIs, then the companies can be confident that it will match the current practice of their companies. Furthermore, it is developed on Microsoft Access platform, which is relatively cheap, therefore Thai SMIs can afford and implement it. Although, the implementation cannot be completed since the TSPICs does not have the accounting module. At the beginning, the company accepts that it is not necessary to integrate the accounting module into TSPICs and decides to implement but during the implementation, it becomes a required feature. Therefore, it is not fair to conclude that the TSPICs software does not work. Without considering the double entering of some transactions, the result of the production and purchasing schedule obtained by TSPICs performs well. However, we agree that the modification of TSPICs to remedy the double entering problem should be done. That is to add a feature that can import or export the necessary information between the TSPICs

and accounting software. TSPICs can also get the First Prize of 50,000 Baht from “*Industrial Application Software Contest: Student Category*,” organized by Industrial Promotion Department, Ministry of Industry, and Institute of Electric and Electronics, December 19, 2003

- Proposed new finite capacity scheduling methods

The proposed finite capacity material requirement planning (FCMRP) methods are included in TSPICs software in order to increase the alternatives for the users. The user can select the appropriate method by considering the system performance of each method. The proposed FCMRP methods can remedy the capacity problem of the conventional MRP logic.

Based on this dissertation, one international journal paper and one international conference paper were published, one international journal paper was accepted for publication, one international journal paper was first revised based on reviewer comments, one international journal paper is under reviewed, and a paper is under preparation. List of publications is shown as follows:

1. Published papers

Wuttipornpun, T. and Yenradee, P., 2004. Development of Finite Capacity Material Requirement Planning System for Assembly Operations. *Production Planning and Control*, 15, (5), 534-549.

Wuttipornpun, T. and Yenradee, P., 2003. Performance Analysis of Finite Capacity Material Requirement Planning System for a Capacity-Constrained Flow Shop. *In Proceedings of the 12<sup>th</sup> International Pacific Conference on Automotive Engineering, 1-4 April 2003, Bangkok, Thailand.*

2. Accepted paper

Wuttipornpun, T., Yenradee, P., Beullens, P., and Oudheusden, D. L., (Accepted). A Finite Capacity Material Requirement Planning System for a Multi-stage Assembly Factory: Goal Programming Approach. *Industrial Engineering and Management System.*

3. Submitted papers

Wuttipornpun, T., Yenradee, P., Beullens, P., and Oudheusden, D. L., (under review). A Bucketless Finite Capacity Material Requirement Planning System for a Multi-stage Automotive-Part Assembly Factory in Thailand. *Computers and Industrial Engineering.*

Wuttipornpun, T. and Yenradee, P., (first revision based on reviewer comments). A New Approach to Finite Capacity Material Requirement Planning System. *Journal of Manufacturing Systems.*

Wuttipornpun, T. and Yenradee, P., (under review). Finite Capacity Material Requirement Planning System for a Multi-stage Automotive-Part Assembly Factory. *Journal of Science Asia*.

#### 4. Paper under preparation

Wuttipornpun, T. and Yenradee, P., (under preparation). A Comparison Study of Finite Capacity Material Requirement Planning System for a Multi-stage Automotive-Part Assembly Factory in Thailand.

### 8.3 Limitations of TSPICs software

TSPICs software has some limitations as follows:

- Software Platform

Since TSPICs has been developed on Microsoft Access Platform, the auto number of the records of this platform may be full very fast if there are many complete or incomplete transactions in the system. By this platform, the users have to replace the current database with the blank database when the current database is full. The system will run slower if the users run the system with the larger database. Whenever the users want to replace the current database, if there are some incomplete transactions in the current database, they have to enter these transactions into the blank database also. For the other databases such as Oracle, this task can be performed easier than this platform. The transactions can be copied to the safe place automatically whenever they are taken place. For the security of database, the Microsoft Access platform has low security. Although the security of the database in Microsoft Access platform is not quite good, fortunately, it is not necessary for Thai SMIs.

- Lot-sizing options

TSPICs provides only lot-for-lot method in calculation of the production and purchasing plan. Although the lot-for-lot method is very easy to understand, some companies need other lot-sizing rules, for example, EOQ, PPB, etc. Thus other lot-sizing rules should be added into TSPICs.

- Finite Capacity Scheduling options

TSPICs provides three scheduling options, namely, proposed FCMRP, Forward, and Forward-Backward systems. These systems may not appropriate for all Thai SMIs. Therefore, if the provided scheduling could not work well, we should study the scheduling direction of each company and develop the appropriate one for that company.

- Overlapping of batch

The overlapping of orders is not allowed in TSPIC. This means that the order must be finished by the whole lot before starting the next order. Overlapping of batch is necessary for some companies to reduce the lead-time and make-span in the system.

- Accounting Feature

TSPICs does not provide the accounting module for the users. The users must enter the same transaction to both TSPICs and accounting software. TSPICs should be modified to solve this problem.

#### 8.4 Recommendations for Further Studies

There are some recommendations for further studies as follows:

- Develop the software on other platforms

Since there are limitations of Microsoft Access platform, therefore, TSPICs should be developed on other platforms which are not quite expensive. For example, the Microsoft SQL server and My SQL are the candidates in this case. Furthermore, the TSPICs should be developed to be an application on the internet. By this way, the users can use TSPICs on internet browsers to perform the transactions at different places. The limitation of the distance in the LAN system will not be the problem anymore.

- Develop more Lot-sizing methods

So far TSPICs has only one lot-sizing method. We should develop other lot-sizing methods which are appropriate for Thai SMIs.

- Develop more Finite Capacity Scheduling options

The scheduling options provided in TSPICs may not be sufficient for all Thai SMIs. The new concepts which are useful and appropriate for Thai SMIs should be studied and developed.

- The overlapping of batch

The overlapping of batch should be allowed and developed into TSPICs since some Thai SMIs need this function.

- The Gantt chart

This feature should be developed into TSPICs since many Thai SMIs want to manage and control the schedule by looking at this chart in stead of looking at the records in the scheduling report. By this chart, it helps the users to make a decision easier and faster.

- Accounting module

The selected Thai SMIs do not want to enter the same transactions on both TSPICs and accounting software. Thus the accounting module should be developed into TSPICs. An alternative is to develop an interface between TSPICs and accounting software that can avoid double-entry of data.