# CHAPTER VII

# CONCLUSION AND FUTURE RESEARCH

In this chapter, the briefly summarize the findings of the research and the various parts of it are presented. A number of limitations and implications for further research are addressed as well. Finally, the discussion of some practical applications and new dimension of developments are provided. The purpose of this study was to develop the capacitated lot-sizing model for purchasing and production planning próblem with on-hand inventory consideration in multi-item; multi-period; and multi-workstation situation considering associated constraints of warehouse capacity, the minimization cost model was proposed. This will allow us to model manufacturing environments in a more realistic and intuitive way. The three heuristics are also proposed for solving the research problem.

## 7.1 Conclusion

In the introduction chapter I started with the research problem motivated by a real world situation. The chapter II shows the literatures that relevant to the research problem. Next in chapter III, the mathematical model was formulated to represent the problem with Mixed Integer Programming (MIP). The model was called MLCLSP-M. Because the mathematical model solving is not practical, the heuristics are proposed. Then, the subsequent chapters, which are chapter IV, chapter V and chapter VI, provided the heuristic description and discussion. In chapter VII, the experimental of the solution performance of the three heuristics are presented.

In total, the purpose of this study was to develop the capacitated lot-sizing model for purchasing and production planning problem with on-hand inventory consideration in multi-item; multi-period; and multi-workstation situation considering associated constraints of warehouse capacity, the minimization cost model was proposed. This will allow us to model manufacturing environments in a more realistic and intuitive way. The three heuristics are also proposed for solving the research problem. Then, this study was built around three main contributions:

- The research problem which is newly identified
- A Mathematical model that represent the research problem
- The solution method of the problem (Three proposed heuristics)

In the following sections, the study's outcome and discussion of the overall will be summarized.

### 7.1.1 The research problem

The research question of this study is addressed here. This research was motivated by problems arising from manufacturing of end product from various raw materials. Workstation (or production lines) needs to be promptly managed. To produce end product, components must be produced or assembled beforehand on workstations. In this research, firm stocks all items including raw materials, end products and components collectively in one warehouse. Besides, the firm produces multiple end products as such in connection with different bill of material (BOM) and experience capacity constraints for workstation and warehouse. That forces the firm to confront requirement for items that are varied and subjected to significant change over time on both internal demand of raw materials and components, and external demand of customer orders. Therefore, it is critical to balance production order lot size of each item for each period. The firm also needs to take into account of factors which change over time period, i.e. workstation capacity; raw material availability; production cost; raw material cost; etc. As a result, the firm has to find a purchasing or procurement plan and a production plan with minimum cost while keeping customer order due date or to find lot size of purchasing and production order in each period for all items. In nutshell, it is a major challenge for a manager to provide the optimal plan for any activity that effects manufacture of the firm. In addition, warehouse storage space is another constraint for managers to decide to hold inventories on what item and how much. For multi-periods limited resource environment and every parameter can change or vary by time period; decision of each period can be affected by how these parameters change. More important is that so far no study has been studied that problem and this concerns the second section which is the mathematical model formulation.

### 7.1.2 Mathematical Model

As the research problem, the holistic view model (consideration purchasing planning situation together with production planning situation while feasible warehouse capacity constraint) is appropriated and needed to find optimal plan (Brahimi et al., 2006; Karimi et al., 2003; Pochet, 2001; Suerie, 2005). Such problem can be defined as Multi-level Multi-item Capacitated Lot Sizing Problem with Multi-workstation (MLCLSP-M). The model was presented in Chapter III. Generally the lot-sizing MIP models are often very large in practice even advanced solvers such as CPLEX are unable to identify provably-optimal solutions in acceptable computational time (Clark, 2003; Silvio et al., 2008). That the developed model might be classified as a capacitated lot sizing with setup time model (Brahimi et al., 2006; Chinprateep and Boondiskulchok, 2007; Drexl and Kimms, 1997; Jodlbauer, 2006; Karimi et al., 2003; Kimms, 1996; Pochet, 2001; Suerie, 2005), which is NP-hard problem it can be solved to optimality only with a huge computational effort. Clearly it takes an impracticable amount of computer time and memory, motivating the development of the alternative approaches. Therefore, this research proposed three heuristic algorithms that can solve large-scale problems to near-optimality with a reasonable computational time.

### 7.1.3 The heuristics

The three proposed heuristics are based on concept of decomposition the research problem into two phases consisting of the assignment with given lot size phase and the lot size with given assignment phase. The target of the first phase is to find the assignment matrix to be used as input data for the second phase. The second phase used data from the first phase as given assignment and then solves the lot size próblem. The extensive experiments conducted in this research to show empirical evidence that the resultant algorithms outperform their original versions while keeping low computational demands.

The first heuristic is Assignment - Lot Size (A-LS), which is addresses in chapter IV. The key elements of the heuristic are the two phases of iteration, which are Assignment and Lot Sizing. The computational experiment of the heuristic based on standard library has been done. The result indicates the solution performance is good within very fast run time. However, there is an improvement of the solution only in early iteration. Therefore, it has a room for increase its solution performance.

The second heuristic is Partial Assignment - Lot Size (PA-LS). This heuristic differs from A-LS in the part of Assignment. Its assignment phase concern móre original problem. The assignment matrix composes of two types which are Full Assignment and Partial Assignment. The Full Assignment matrix is absolutely same as the matrix of A-LS, while the Partial Assignment matrix is changed some column to original problem matrix. The detailed has been described in chapter V. Although this heuristic gives a great solution performance, it uses run time almost equally to original problem.

The last heuristic is Max Cover Period - Lot Size (MCP-LS).This approach creates a new concept which is Max Cover Period. Obviously, the more change assignment matrix to original matrix, the more run time solution is used. As in large problem PA-LS has too much time for a solution, one way to reduce the run time is to decrease number of periods in a Partial assignment matrix. The Max Cover

Period is a number of periods that the capacity of workstations in the considered period can provide future demand.

These heuristics have some advantages and disadvantages. The comparison of these heuristic is presented in Figure 7.1. To determine what heuristic should be used, it's based on decision criteria used. On minimum time effort criteria, Assignment- Lot size (A-LS), the first proposed heuristic, should be the best heuristic. On the best solution performance criteria, the best heuristic is Partial Assign-Lot size (PA-LS) heuristic. With time and solution performance considered together, the best heuristic is Max cover period– Lot size (MCP-LS).

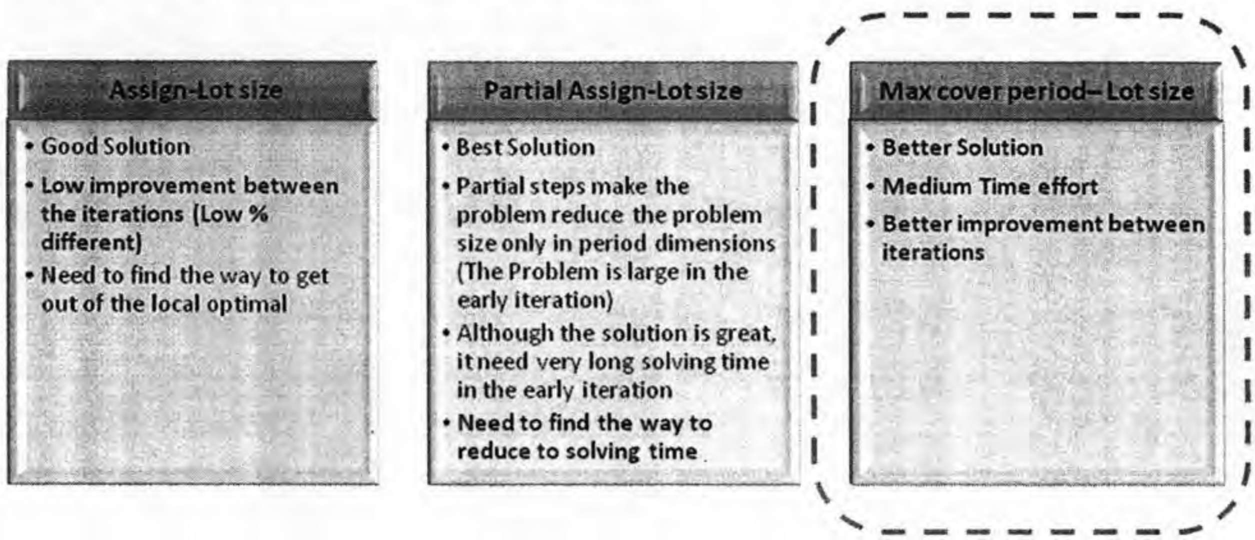


Figure 7.1 The comparison of three heuristic

In practical, A-LS heuristic is useful for a situation that has a lot of items, workstations and periods and needs a fair solution. The application of PA-LS is the situation that has a little items, workstations and periods and needs very good solution. The MCP-LS is proper for the medium situation in term of items, workstations, periods and solution performances. For example, the planner want a 1000-item 1000-workstation 12-period plan within 10 minutes. It's impossible for other heuristics. If the planner want the better solution within a couple hours, the MCP-LS heuristic is more suitable. However, if the planner really wants the great solution and doesn't care how long it takes, he/she should use PA-LS heuristic.

Therefore, these research contributions are both mathematical model and heuristics. Besides, the proposed heuristic algorithms are using constructive algorithm and using the solver for finding the solution. As the solution is improved on the problem, the proposed heuristics can be applied on the specific criteria as presented. There are more rooms for improvement of the heuristic in both time and solution performances.

The research summary of this dissertation is depicted in Figure 7.2.

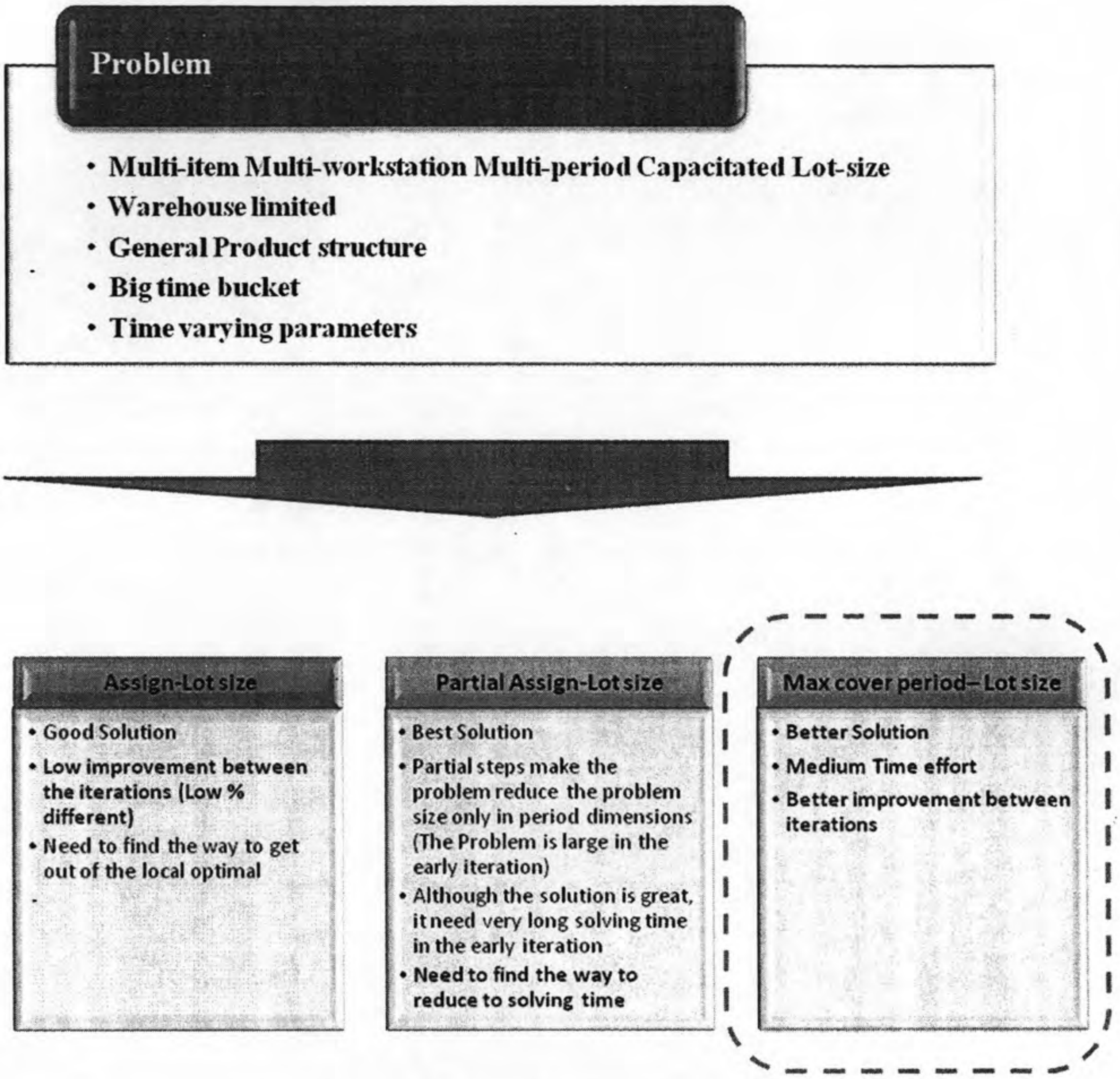


Figure 7.2 Research summary

## 7.2 Discussion

To provide insight into the limitation of this research, the strengths and weaknesses of this are presented.

### 7.2.1 Strengths

Firstly, the research problem needs a model to represent the holistic view of the integrated planning of purchasing and production. Few studies had available such a holistic view in planning. A production and purchasing planning is unfortunately lacking in most of the integration in the field of modeling and identifying.

A second strength of this study is its second contribution. The mathematical model is formulated to represent the problem and the optimal solution can be provided. This enables the consideration of parameter effects as they are impossible in past.

For third strength, as the mathematical model is unpractical for using, this research proposes three heuristics to solve the problem. The A-LS is very fast to use and very suitable for large problem. Whenever planner want a plan with less accuracy solution in short time, it is perfect. A weakness in solution performance of A-LS is fixed in PA-LS. Although the time effort is very large, the solution is the best. Unfortunately, with the long run time, it is useful in the case of the planner can wait or a small size problem. The last one is MCP-LS. The lacking of solution performance in A-LS and the large run time in PA-LS are solved. However, it uses more run time than A-LS but less than PA-LS and gives better solution than A-LS but worse than PA-LS. Likewise, it is a more practical way of working than PA-LS but less than A-LS. This heuristic is useful for a medium size problem and needs an acceptable solution.

The fact that this study was also theory testing is a final strength. It uses an adapted standard library in all computational experiments. This library is used to analyze the heuristic sensitivity in literal way. As a result, the result of computational experiments is convincible.

### 7.2.2 Weaknesses

A weakness of the study is that it has been carried out within the standard library only and therefore raises questions about the generalize ability. The wonder is that if the standard library is comparable to that at real situation. However, the fact that at a variety of varying parameters and calculation behind the data generation makes it likely that similar outcomes and its effects will be observed in same pattern of industrial sites elsewhere. Then, Similar behavioral and outcomes may be expected.

Another weakness is the explorative character of the situation, which regarded only deterministic manners. Doing so make more complexity, but provides valuable new inputs for further research. Since the defined list of real world extensions may be specific for research problem, it could still gain from further variation of various parameters such as demand, price, cost, etc. However, the generally applicable approach for the planning, defined by the total cost, may be useful in all type of industries.

The last weakness is the lacking of robustness testing. The computational for all heuristics are based on one size which is 10-item 10-workstation 8-period. However, with the standard library, the result is still convincible.

## 7.3 Future Research

This study has provided new insights into the integration of purchasing and production planning. A mathematical model is formulated and three heuristics are proposed. The outcomes provide interesting perspectives for further research with the same data set as well as further validation of the model in other settings.

First of all, in the area of theoretical research, there is more room for the improvement of the mathematical model basis such as Cutting plan, Lagrange transformation, Mathematical Reformulation etc. (Alfieri et al., 2002; Chen et al., 1994; Chen and Thizy, 1990; Clark and Scarf, 1960; Constantino, 2000; Hwang and

Jaruphongsa, 2008; Jodlbauer et al., 2006; Sambasivan and Yahya, 2005) Then, the here presented model could be formulated in other ways.

Secondly, the research can be extended to the real world implement or more closely to real world situation formulation. The significant extension is a consideration of non-deterministic manner. So far the study presents with a known parameters assumption. However, no one can say exactly and accurately of those parameters. However, the researchers have to trade-off between the applicable and the complication.

Thirdly, the here proposed heuristics also might be further elaborated. Especially the input data can easily be elaborated, including aspects such as replacing by real situation data. Concerning the effect of varying, a start can be made by studying the effects of different real data sets. The simulation and parameter study researches can useful in this case.(Jodlbauer, 2006; Kampf and Kochel, 2006; Kim et al., 2007; Moon and Christy, 1998; Pratsini et al., 2001; Schmidt and Wilhelm, 2000)

Next, as aforementioned in the weaknesses, this research is lacking of the robustness testing. Therefore, the testing of three proposed heuristic is still valuable. Consequently, there will be the strongly proved how applicable of the heuristics.

The last is suggested by recurring solution approaches in more effective way. Based on the decomposition concept presented in this study, there are two sub problems which are assignment problem and lot sizing problem. Both of them have many more effective algorithms or heuristic methods. Then there is a room to apply those valuable to the sub problem. As a result, the total run time and solution performance can be better.