CHAPTER I

INTRODUCTION

1.1 General Background

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 essential to balance and manage the lot size of the production order of each product for each period. The firm also needs to take into account of factors which change over time period, such as workstation capacity, raw material availability, production cost, raw material cost, etc. As a result, the firm has to determine a purchasing or procurement plan and a production plan with minimum cost while satisfying customer order due date or to find purchasing lot size and production order in each period for every item. 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 on what item and how much to hold in inventories. For multi-periods limited resource environment time-dependent parameters, decision of each period can be affected by how these parameters change. Moreover, by multi-level multi-item consideration, demands can be dependent demand. Thus, this situation is more complex and difficult to solve.

The purpose of this research is to find a solution for the problem with the aforementioned situations. The holistic view model (considering purchasing planning situation together with production planning situation while having warehouse capacity constraint) is appropriated and needed to find optimal plan. Such problem can be defined as Multi-level Multi-item Capacitated Lot Sizing Problem with Multi-workstation (MLCLSP-M). In another word, the solution of the developed model of this research is the plan for a number of stages (workstations) for multiple periods or the needed times together with total cost of materials (procurement or purchasing cost, production cost and item holding cost). This research model also emphasize on the reduction of inventories and related unproductive activities and costs by way of developing mathematical model to determine the minimization total cost of MLCLSP-M for purchasing and production lot size planning.

1.2 Statement of the Problem

With increasingly complicated situation as aforementioned, a firm manager needs a production plan to handle all constraints while minimize total cost. More competition a firm faces, more effective plan a firm needs. Although a feasible plan is necessary for operation, an optimal plan is also needed for higher effective. Since an optimal plan is somehow near to impossible to be perfectly performed, a practical one may be applied instead. One of the well-known techniques for planning is Material Requirement Planning (MRP). MRP is usable for processing in practice but (1) it lacks consideration of supply constraints, especially material constraints, and (2) it sometime generates an unrealistic supply plan (Eck, 2003).

Even if optimization models have helped many companies identify plans with significantly reduced costs, they are limited by one of two complementary deficiencies. On one hand, some emphasize warehouse decisions with insufficient detail about other supply chain decisions, such as those relating to facility location, manufacturing processes, transportation, and warehousing. On the other hand, other models emphasize these other decisions with insufficient detail about warehouse management. The industries in this research interest assume that products are made under make-to-order environment, i.e. customers must place an order in advance before production starts. With multi-level production, the demand for each period is a dependent demand and must be calculated with Bill of Material (BOM) including quantity usages.

Hence, a purchasing manager should bear in mind of a material availability limitation with varying price. For some industries such as food industry, an availability of materials is not certain but changes from period to period. As a consequence, the price of materials is also changed from period to period. Therefore, the developed model in this research inclusively considers this situation.

1.2.1 Problem description

A problem of multi-item multi-period in finite planning horizon with availability and price of raw materials vary over time periods situation is considered. An assembly system operates on a make-to-order basis. Customer demands vary in each period. Both of the production and purchasing have setup considerations regarding setup time and ordering cost respectively. The layout of the manufacture is a process layout of assembly production system. Various products are produced in the system. In addition, each product made from several parts and/or subassemblies requires a series of operations including assembly operations. The production has given Bill of materials (BOM) composed of both dependent demand (components and raw materials required by products production) and independent demand (customer's demands). Materials flow is in one way direction from upstream workstations to downstream workstations. In the problem considered here, the planning horizon is divided into several discrete time periods and what is needed as a solution is a workstation-level production plan, not a machine-level production schedule. The machine-level production schedule for each workstation can be solved using a parallel-machine, job shop or flow shop scheduling algorithm after obtaining the workstation level production plan. That is, the planning problem considered in this research is a higher-level problem than the scheduling problem for machines in each workstation. Since keeping due dates is a critical issue in the assembly system considered in this study (and many others), tardiness is not allowed in the problem, that is, due dates of orders are considered as constraints. Note that if shipping schedules of products are fixed or products made in a system are components needed at a downstream process, costs of tardiness are very high or tardiness is not allowed.

The production planning problem under consideration is to determine the production quantities in each period under the constraints of due dates, precedence relationships among items, and resource limits. The objective of the planning problem is to minimize costs including purchasing, production and holding cost with setup consideration. Besides, this scenario has a capacity limitation both of its production and its warehouse.

An item is considered as inventory with holding cost from the moment it is entered into the system until it is used at a downstream workstation or until it leaves the system (when it is a final product that is delivered to a customer). The setup time or cost is included in the model. The varying overtime period production capacity can be calculated from available man-hour of labors. The production setup time is also considered as usage charges from production capacity because the setup time is using man-hour from labors. The production cost can be classified as setup cost and others cost that occurred by production except setup cost. Similarly, the purchasing cost can be classified as ordering cost and others cost that occurred by purchasing except ordering cost.

Moreover, the problem considered here includes case of multi-workstation consideration. This means that it also determines what workstation to process an item in each period. While operation time and setup item for operating an item on a workstation varied with time periods, the workstation selection must trade-off between available capacity for the lot size and increasing cost. With all limitations, the purchasing and production planning must fulfill all demands while total cost is minimized.

The proposed system focused in determine two decisions: Purchasing lot size and production lot size. The purchasing lot size indicates when and how much materials to be purchased. The production lot size indicates when and how much products to be made. Besides, the quantity of materials, parts, and products should be kept in warehouse (holding items) is affected from the two decision variables. The constraints placed in model are the availability of materials, the capacity of workstations and warehouse and the demand satisfaction.

Here, the total cost induces production cost, purchasing cost, setup cost and holding cost. In addition, while total cost is minimized, the decisions must satisfy all demands and limitations such as production capacity, warehouse capacity and raw material requirement as well as their availability in that period.

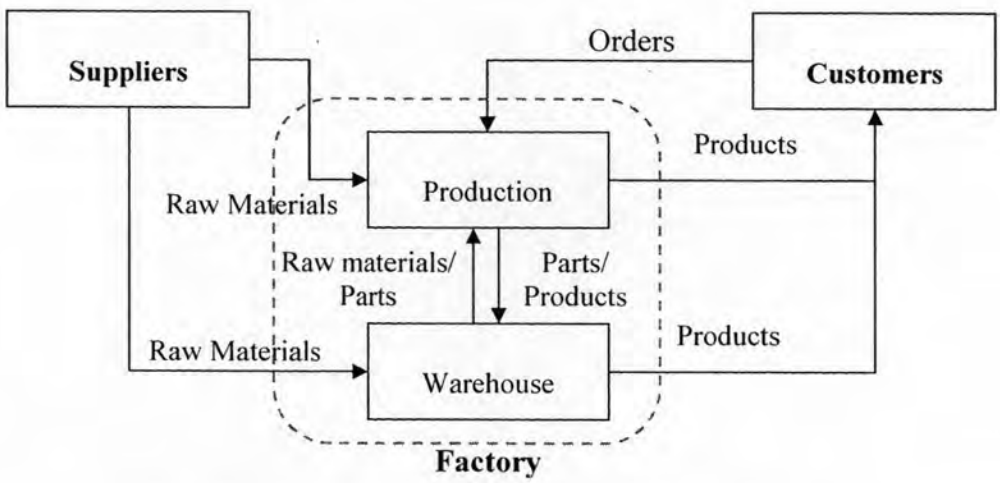
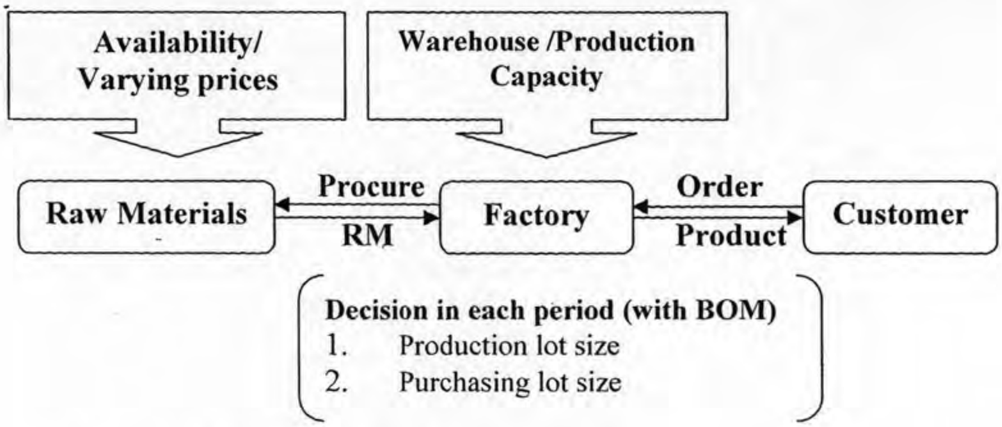


Figure 1.1 The demonstration of problem framework.

From Figure 1.1, buying quantity of raw materials is relation between suppliers, customer and factory (Production planning requirement information). Typically, an availability of raw materials and a requirement from production for the different periods do not match; therefore, a current period's requirement may be satisfied by (1) current period's purchasing (2) surplus purchasing in earlier periods. As raw material price varies from period to period, the cost of purchasing the same item can be varied in different periods, therefore, the total cost can be lower or higher by the purchasing decision. Similarly, because the production capacity and customer demand for the different periods do not match, a current period's demand may be satisfied in one of two ways (1) current period's production (2) surplus production in earlier periods. For the first case, only production cost will be considered. The second case, there is additional holding cost. The situation of the problem can be demonstrated in Figure 1.2.



- ✓ **Multi-item Multi-level Multi-period**
- ✓ **One warehouse**

- × **No Shelf-life consideration**
- × **No transportation or distribution factors or variables consideration**

Figure 1.2 The demonstration of the problem statement.

This nature of the industry situation can be classified as the Multi-level Multi-item Capacitated Lot Sizing Problem (MLCLSP). The lot sizing problem is the problem to determine quantity to produce or to purchase. The problem area is well-known and one of the most difficult problems in production planning (B. Karmi et. al, 2003). Therefore, this research develops a mathematical model to determine the minimization total expected cost of Multi-level Multi-item Capacitated Lot Sizing Problem (MLCLSP) for purchasing or procurement and production planning (Integrated concept). The developed model should be able to answer the problem, which have multiple items (materials, components and products), and multiple levels or stages consideration. In addition, as presented in the literature review section, MLCLSP focus on medium-term production planning to identify lot size in each item and to minimize total expected cost in the same time. Besides, the capacitated lot sizing problem with setup cost consideration can be formulated as Mixed Integer Programming (MIP). By MIP formulation, researches in the literature review (production lot size section) mention that this model is NP-hard (Clark, 2003; de Araujo, Arenales and Clark, 2008). The less computation time make this formulation more practical. Therefore, the problem statement as presented is worth for both of the practical contribution in industry nature and the theoretical contribution in the lot sizing problem area.

1.2.2 Example industry

Fish processing industry is one of the industries that have problem situation similar to the stated research problem. In this industry, a firm has to decide how much procurement and production quantity lot size should be. This industry has natural supply materials so that the materials have varying price and availability constraint. However, in this scenario Make to Order (MTO) situation is considered for production policy.

1.2.2.1 Characteristics of example industries

The main supply material for process in the fish processing industry is fish. The quantity and composition of the catch at sea varies from day to day and from season to season. Moreover, the demand and supply at the fish market in each period make it own daily price pattern. Such varying availability of the fish in each period and increasing competition of the market, purchasing and production lot sizes in multi-period decision making to minimize the total cost is usually a complex problem. In addition, some issues may make situation much more complex such as the product mix, on-hand items carried from one period to the next period (the holding cost is very high for the cooling room), and others support requirements such as the outsource component subject to the available capacity both of the production and warehouse.

By nature of this industry, labor is one of the most important factors to consider production plan. The company usually uses part-time or non permanent labor to manufacture its products; and, its production capacity varies from period to period. Moreover, the production of this industry usually proceeds through multi-product, multi-workstation and multi-level production system, although the process varies by the factory type. In this research, the small and medium sized companies with business contract nature for demands (demands are known in advance) are considered.

1.2.2.2 Discussion how complication to determine the lot size

The efficiency of procurement or purchasing function depends on timely and reliable input information such as the supply information and production requirement information. Therefore, in the industry based on varying availability resources, its purchasing task is very important and usually taken by the human resource.

For the purchasing decision, typically the decider tries to procure raw materials as many as possible which causes the unnecessary cost. Decision makers know the availability a few periods in advance. Day-to-day planning is a complex task in food processing industries due to restricted capacity and uncertainty of materials. Besides, nowadays the production planning is usually plan to satisfy order. With varying of raw materials availability, typically they have high level of on-hand raw materials. Therefore, the optimization for determining the lot size is essential to minimize total cost.

Moreover, in the multi-level production process, the products must be transformed into discrete units. One batch in the one level or one subcomponent can be used for multiple products in the next phase. Therefore, orders that can be created from one batch should be planned together to fill one such batch. Capacity and products mix are also the limitations that make the lot size consideration more complex. In conclusion, the decision maker must decide what and when item will be ordered on which workstation, together with planning requirement to satisfy demand.

1.3 Research Objective

The objective is to develop a mathematical model to determine the minimization total cost of Multi-level Multi-item Capacitated Lot Sizing Problem with Multi-workstation (MLCLSP-M) for purchasing and production planning with varying raw material prices and availability and with limited production and warehouse capacity systems, in order to satisfy demands from customers.

1.4 Research Scope

1.4.1 General scope and characteristics

This study focuses on Multi-level Multi-item Capacitated Lot Sizing with Multi-workstation (MLCLSP-M) problem in finite planning horizon study to minimize total cost which includes purchasing cost, production cost and items holding cost.

1. Production is make to order basis with know in advance order in the finite planning horizon.
2. Time-window rolls over one period at a time, remaining units and executed orders of raw materials, components, and products are considered as initial value for decision making.
3. The production capacity, the warehouse capacity and all unit costs are assumed to be known.

4. The warehouse holding cost is per unit per time and is assumed to be known (One unit of each item uses one space in warehouse).

5. The varying price and the availability of raw materials are known in advance.

6. The material and product characteristics including BOM are assumed to be known.

7. No alternated BOM's are considered in this research.

8. All transportation both internal and external firm, and the quality control or defect is not considered.

9. Reworks, defects or repairs are not considered in this model.

10. There are multiple produced items in a period.

11. The time bucket is considered as big bucket.

12. Total cost that this research considered includes production cost, items holding cost and purchasing cost.

13. Although a workstation can operate more than one item, the workstation can operate only one item in each period.

14. Similarly, in each period, an item can be operated only a selected workstation.

15. The demand of an item can be satisfied by a workstation capacity.

1.4.2 Planning characteristics

In the system considered here, various items are assembled or manufactured final products of various types. As the case with assembly systems, items for products can be preserved in a tree structure. That is, one or more (preceding) items may be used to produce an item, but an item can be used as a component of at most one (succeeding) item. It is assumed that demands for end items or products, which are determined by orders from customers, are known and deterministic but may vary over time periods. A customer order is characterized by the type, required quantity, and due date of an end item. It is assumed that there is no order for a component item from the customers. Therefore, production quantity of a component item can be computed from order quantities of end items that require the component items. The setup activities incur setup costs and consume setup time. Once a product is ordered, the setup of the production occurs. The setup time will reduce production capacity in the period that it occurs and will be considered as sequence independent between orders of different productions. Processing capacity at each workstation may depend on the number of machines or workers in the workstation. If the parts or products does not use in the next period, it must be kept in warehouse and charged with holding costs. BOM of production and capacity of workstation in production and capacity of warehouse are assumed to be known and concerned in the model. Here, the quality of production is neglected. The availability, varying price and ordering cost will be considered in the purchasing part of the model. Moreover, all unit costs, prices, and setup times or costs are assumed to be known.

1.5 Research Contribution

The developed model emphasizes on the consideration of Multi-level Multi-item Capacitated Lot Sizing Problem with multi-workstation (MLCLSP-M) for purchasing and production planning with varying raw material prices and limited warehouse capacity systems in order to satisfy demands from customers. The developing model is not only formulated by integration of purchasing lot size, production lot size and warehouse capacity consideration, but also concern other limitations such as production capacity and raw materials availability limitation. This makes the model be more general than the existing model as in the literature review section. In addition, for the Multi-level Multi-item Capacitated Lot Sizing Problem with Multi-workstation (MLCLSP-M), although this area has been investigated and researched for a long time but no existing including all factors and elements considered in a model like in this research present as can be seen in the Table 1.1.

Table 1.1 Comparison of journals related to the research

Literature	Method	Horizon		Number of multi-level				Item		Capacity		Demand					Supply	
		Finite	Infinite	Single -level	Serial	Assembly	General or MRP	Single-item	multi-item	uncapacitated	Capacitated	Static	Dynamic	Deterministics	Setup	Backlog or back order	Limited availability	Varying Price
Aggarwat, A., Park, J.K.,(1993)	WW	✓		✓				✓		✓			✓					
Armentano et al.(1999)	CLSP	✓		✓					✓		✓			✓	✓			
Bahl. H.C., et al(1981): review	DCLSP	✓		✓							✓		✓					
Barany et al.(1984)	CLSP	✓			✓				✓		✓	✓		✓	✓			
Belvaux and Wolsey (2000)	CLSP	✓		✓					✓		✓			✓	✓	✓		
Belvaux and Wolsey (2001)	CLSP	✓		✓					✓		✓			✓	✓	✓		
Clark, A.R., (2003)	CMRP	✓					✓		✓						✓	✓		
Dellaert N, et al (2000).	MLLS:GA	✓					✓				✓			✓	✓			
Dixon and Silver (1981)	Heuristics	✓		✓				✓			✓							
Dobson, G., (1987)	ELSP		✓	✓					✓		✓	✓						
Elmaghraby(1978): review	MATH		✓	✓					✓		✓	✓						
Erlenkotter (1990)	EOQ		✓	✓				✓		✓		✓						
FederEruen. A., Tzur, M.,(1991)	WW	✓		✓				✓		✓			✓					
FederEruen. A., Tzur, M.,(1994)	WW	✓		✓				✓		✓			✓					
FederEruen. A., Tzur, M.,(1995)	WW	✓		✓				✓		✓			✓					

Table 1.1 Comparison of journals related to the research (cont.)

Literature	Method	Horizon		Number of				Item		Capacity		Demand					Supply	
					multi-level													
		Finite	Infinite	Single -level	Serial	Assembly	General or MRP	Single-item	multi-item	uncapacitated	Capacitated	Static	Dynamic	Deterministics	Setup	Backlog or back order	Limited availability	Varying Price
Gallego. G., Joneja, D.,(1994)	ELSP		✓	✓					✓		✓	✓						
Hsu. W.L., (1983) :complexity	MATH		✓	✓					✓		✓	✓						
Kimms., A.,(1996)	MLSP		✓			✓				✓				✓	✓			
Maes, J, et al (1988) :review	Heuristics	✓				✓					✓			✓	✓			
N.P. Dellaert, J. Jeunet, (2003)	Randomized	✓					✓		✓	✓				✓	✓			
Pochet. Y., Wolsey. (1991)	MLSP		✓			✓				✓				✓	✓			
Rogers, J.(1958)	ELSP		✓	✓					✓		✓	✓						
Roundy, R.O.(1993)	MLSP		✓			✓				✓				✓	✓			
Stadtler, H.(1996):	MLCLSP	✓					✓		✓		✓			✓	✓			
Tempelmeier, H., Derstroff, M., (1996)	MLCLSP	✓					✓		✓		✓			✓	✓			
Voros, J., (1995)	MLSP		✓			✓				✓				✓	✓			
Wagelmans, A.,et al(1992)	WW	✓		✓				✓		✓			✓					
Wagner, F.M., Whitin, T.M.(1958)	WW	✓		✓				✓		✓			✓					
Zipkin, P., (1991)	ELSP		✓	✓					✓		✓	✓		✓				
This research	MLCLSP	✓					✓		✓		✓			✓	✓		✓	✓

1.6 Research Methodology

This research is conducted in term of an operations research approach as follows: 1) defining the problem 2) formulating the problem 3) constructing a model and 4) solving the model. However, the research methodology is categorized in steps as follows.

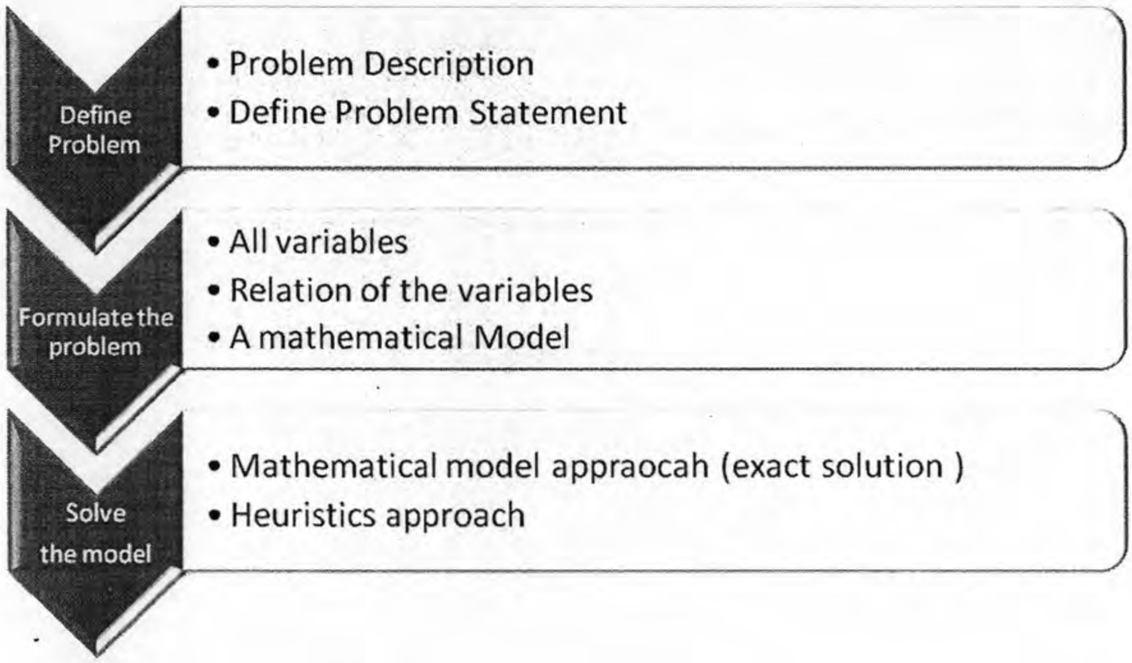


Figure 1.3 Methodology Flow of this research

1.6.1 Problem Description Stage

The problem, defined in the first stage, is the real world situation. However, it would be impossible to circumscribe the entire breadth of circumstances that might be appropriate for this discussion, because problem situations that are amenable to objective analysis arise in every area of human activity. Therefore, we investigate the problem in the area that is discussed in the problem statement section (only in research scope). The result of this stage can be called verbal term of the problem and is translated into logical term as mathematical model later.

In this stage, the problem is defined as present in aforementioned. The decision elements can be defined as follows:

- Decision purchasing lot size and production lot size for the given situation (as presented in the problem statement in section 1.6.3)
- The objective of this study (objective of research in section 1.6.4)
- Specification of the limitations under which the modeled system operates. (as presented in section 1.6.5)

In conclusion, this research focuses on a production planning problem in an assembly system operating on a make-to-order basis. Due dates are considered as constraints in the problem, that is, tardiness is not allowed. The capacity of production and warehouse is determined as constraints in the model. The next analytical step of the solution process is to formulate the problem in precise terms.

1.6.2 Model Formulation Stage

In this stage, the statement of the objectives, constraints on solutions, appropriate assumptions, descriptions of processes, data requirements, alternatives for action, and metrics for measuring progress are introduced. The scope of the system under investigation will be identified. Although the broad implications of the problem using a system approach are valuable, a model cannot include every aspect of a situation. It is always an abstraction that is, by necessity, simpler than the reality. Elements that are irrelevant or unimportant to the problem are to be ignored; but leaving sufficient detail so that the solution obtained with the model has value with regard to the original problem still. The statements of the abstractions introduced in the construction of the model are called the assumptions. It is important to observe that assumptions are not necessarily statements of belief, but are descriptions of the abstractions used to arrive at a model. The appropriateness of the assumptions can be determined only by subsequent testing of the model's validity. Models must be both tractable (capable of being solved) and valid (representative of the true situation).

Therefore, in the operation research modeling, we usually approximate something by assuming some variables in real world situation. The assumed real world situation will be translated into a mathematical model. This mathematical model will represent relation of variables and behaviors of the assumed real world situation (Taha, 2003). Although the problem statement with slightly more definition that the situation; however, greater simplification is still necessary before a computer-based analysis can be performed. The formulation of the model will affect how solution should be.

In this research, the lot sizing problem for purchasing, production and warehouse concerned have been investigated. The research problem can be identified as the problem statement and can be classified as the MLCLSP. The MLCLSP is a simplified version of the production planning and scheduling problem under real world production environment. Besides, the lot sizing problems are also investigated in various aspects such as the formulation, algorithm, classification or solution techniques.

1.6.3 Constructing Model Stage

In this stage, the problem must be translated from verbal, quantitative terms to logical. A logical model is a series of rules by which the impact of alternative decisions can be predicted and evaluated. A mathematical model is a collection of functional relationships by which allowable actions are delimited and evaluated. Model construction is primarily the function of the analyst. In this stage we have intentionally represented the model with well-defined boundaries to indicate its relative.

To represent the problem, the modeling techniques both of mathematical and computational method have been investigated and developed. As the best of our knowledge, there are several kinds of models that exhibit a special structure that can be exploited in the construction of efficient algorithms for their solution. The motivation for taking advantage of their structure usually has been the need to solve larger problems than otherwise would be possible to solve with existing computer technology. The development of an efficient solution procedure for each problem resulted in the first widespread application of mathematical programming to problems of industrial logistics. More recently, the development of algorithms to efficiently solve particular large-scale systems has become a major concern in applied mathematical programming.

Going beyond the internal supply chain by including external suppliers and customers often exposes new opportunities for internal operations improvement. This leads to the need for holistic modeling of the purchasing and production planning. In this research, the purchasing and production planning in multi-item multi-period multi-workstation capacitated lot size situation is discussed and formulated as a mathematical programming model. 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 (Berretta et al., 2005; Brahimi et al., 2006; Federgruen et al., 2007). Such problem can be defined as Multi-level Multi-item Capacitated Lot Sizing Problem with Multi-workstation (MLCLSP-M). In the lot size circumstance, Mixed Integer Programming (MIP) model has been used for problem formulation (Chaudhry and Luo, 2005; Comelli et al., 2008; Hung and Chien, 2000; Miller et al., 2003; Pochet, 2001; Pochet and Wolsey, 1988; Sahinidis and Grossmann, 1992; Stadtler, 1996; Sung and Maravelias, 2008; Ustun and Demi'rtas, 2008; Wolsey, 1989; Wu and Golbasi, 2004). 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 (Berretta and Rodrigues, 2004; Silvio et al., 2008). That the developed model might be classified as a capacitated lot sizing with setup time model (Armagan and Kingsman, 2004; Berretta et al., 2005; Brahimi et al., 2006; Chinprateep and Boondiskulchok, 2007; Federgruen et al., 2007), 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 a heuristic algorithm that can solve large-scale problems to near-optimality with a reasonable computational time. Although there is more than one way to tackle the problem, the effective one is decomposition (Aardal and Larsson, 1990; See-Toh et al., 2006; Vercellis, 1999; Wu et al., 2003; Zapfel, 1996), consequently, the problem can be solved more efficiently. The next, we will show how to obtain a solution to the problem.

1.6.4 Model Solution Stage

After the model is formulated correctly, an effective tool or solution method is selected for problem. Today, lot size problems have various extensions and various solution methods (Aksoy and Erenguc, 1988; Brahimi et al., 2002; Brahimi et al., 2006; Chandra and Grabis, 2001; Chaudhry and Luo, 2005; Comelli et al., 2008; Drexl and Kimms, 1997; Helber, 1995; Jans and Degraeve, 2007; Jans and Degraeve, 2008; Karimi et al., 2003; Pochet, 2001; Robinson et al., 2009; Schmidt and Wilhelm, 2000; Simpson and Erenguc, 1996). Two basic approaches to the multi-level lot-sizing problems have been offered in the literature. The first one is to develop optimization algorithms yielding the optimal solutions. The second one is to develop heuristic algorithms yielding the acceptable approximate solutions.

The optimization algorithms solving lot-sizing problems usually make use of techniques of integer programming and/or combinatorial optimization, such as dynamic programming, branch and bound or other related methods (Afentakis and Gavish, 1986; Berretta et al., 2005; Brahimi et al., 2006; Chen et al., 1994; Chen et al., 1994; Chen et al., ; Schwarz and Schrage, 1975; Zangwill, 1969).

Unfortunately, all these optimization algorithms for multi-stage lot-sizing problems are only applicable to unrealistically small scale problems because of their time-consuming enumeration nature. So, the second approach, using heuristic lot-sizing techniques, may be more potential when developing the decision rules for the lot-size plan in MRP systems. Some presented an improved heuristics by modifying the cost parameters between different stages (Pitakaso et al., 2006; Pratsini, 2000; Zheng et al., 2006). The meta-heuristics algorithms such as the simulated annealing algorithm and genetic algorithm are also suggested to tackle the multi-level lot-sizing problems (Berretta et al., 2005; Brahimi et al., 2002; Comelli et al., 2007). For example, Tang (2004) applied the simulated annealing algorithm to solve the lot-sizing problems. Hindi (1995) proposed Tabu Search (TS) for the single item, capacitated dynamic lot-sizing problem with start up and reservation costs for the LP relaxation lot sizing model.

However, the both aforementioned approaches are complicated and difficult to apply in practice. This research proposes the new way based on the decomposition with a heuristics applied. The developed model is formulated by Mixed Integer Programming (MIP). As aforementioned, that the developed model might be classified as a capacitated lot sizing with setup time model (CLSP), which is NP-hard problem and can be solved to optimality only with a huge computational effort. Consequently, in this research proposes the heuristics in two phases which are the assignment with given lot size and the lot size with given assignment. The target of the first phase is to find the assignment matrix to be used as input data for the second phase. The second one used the data from the first one as given assignment and then solves the lot size problem. The computational analysis will also be proposed and discussed in this dissertation.

1.7 Thesis Structure

The outline of this research is as follows. The relevant literature is reviewed in Chapter 2. In Chapter 3, the model of a Multi-level Capacitated Lot-sizing Problem with Multi-workstation is formulated under the policy studied as a set partitioning problem. Based on the complexity of the problem, the Assignment – Lot size heuristic (A-LS) is proposed, developed and analyzed in Chapter 4. In Chapter 5, the Partial assignment – Lot size heuristic (PA-LS) which is an improvement of the A-LS is proposed and discussed. However, the PA-LS take very large solving time. The Max

Cover Period – Lot size heuristic (MCP-LS) with lesser solving time is proposed and Analyzed in Chapter 6. Finally, in Chapter 7, the summary and future research directions are provided.