Chapter 1

Introduction

1.1 Introduction

To be recognized as leading, outstanding customer service, and challenging organization in the highly competitive environment today, efficient management of resources shall be achieved. Scheduling is one of the main factors for efficient management since it is the main function which embeds in many activities in all type of organizations in both service and manufacturing. It helps an organization better manage people and resources.

Scheduling can be defined as "The allocation of resources over time to perform a collection of tasks". The definition of scheduling of Morton and Pentico (1993) is "Scheduling occurs in a wide range of economic activities. A scheduling system dynamically makes decisions about matching activities and resources in order to finish jobs and needing of these activities in a timely and high quality fashion while simultaneously maximizing throughput and minimizing direct costs".

This research emphasizes on two distinct types of scheduling, i.e., machine scheduling in manufacturing organization and manpower scheduling in service organization. In manufacturing organization, the scheduling is the determination of what to produce, when to produce, in what order, on which resources (machines, equipments). The rationale of the scheduling is to maximize the efficiency of operation, on time delivery, at the lowest possible cost. Whereas manpower scheduling is the allocation of employees to activities based on the consideration of available work hours, work shift, day off, location, competency of employee, etc. The main purpose is to maximize employee utilization and increase employee satisfaction. But both types of scheduling pursue mutual goals, an efficient operation, cost reduction, and customer satisfaction. Furthermore, they both can be classified as *NP*-hard (Non-polynomial time hard) scheduling problems.

In manufacturing, operations scheduling has to interact with other decision-making levels used in the organization. Decision made at higher planning level may affect the scheduling process directly. Generating a feasible schedule that best meets all management's objectives is a difficult job manufacturing firms face everyday. Since different organizations have different objectives, many scheduling objectives will be investigated in this paper.

One of the common objectives is to deliver goods within the due date of customer. Late delivery of goods may cause tardiness penalty. This penalty occurs due to customer dissatisfaction, and compensation or contract penalty. To develop the schedule to meet this objective, the performance measure is to minimize total tardiness penalty. In some cases, the tardiness may not be the same for all jobs. These penalties could be different among jobs based on the values, priority of jobs, and customers. In this case, the performance measure will be weighted tardiness penalty.

In some industry, only the tardiness criterion is considered. The examples of the situation that consider only the tardiness cost are: when the earliness cost is not significant compare to the tardiness cost, or when the scheduling is applied to a bottleneck resource, etc

Apart from tardiness penalty, finish jobs before time is also not desirable in many industries. When the job is finish before its due date, it must be held in the finished goods

inventory. The earliness cost may be incurred from inventory holding cost, i.e. storage cost, breakdown, interest, opportunity loss etc.

The arise of Just-In-Time (JIT) production philosophy motivates the study of scheduling problem with earliness and tardiness penalty. In JIT scheduling environment, jobs are forced to be completed as close to their due dates as possible. An ideal schedule is one in which all jobs finish exactly on their assigned due date. Many research efforts have been dedicated to solve this type of problem. The performance measure can be minimization of total earliness/tardiness penalty or weighted earliness/tardiness penalty.

Apart from many different scheduling objectives, improvement of efficiency can be achieved by reducing setup time and cost. Reduction of setup time and cost can successfully accomplished by standardization and automation of the setup procedure, or careful reconfiguration of the tasks in setting up the machinery for the next job. Moreover, reduction of setup time and cost can also be achieved by efficient scheduling of the processing job.

In many problems, setup consideration can not be ignored when the production consists of jobs from different ranges of product groups. The setup cost and time incur when production is switched from one job to another. There are two types of setup, which are sequence-independent and sequence-dependent. The setup that depends only on the job to be processed is called sequence-independent setup and the setup that depends on the job to be processed and its immediately preceding job is called sequence-dependent setup. The setup occurs due to the changing of mold, retooling, jigs and fixtures setting, facility adjustment, rearrangement of workstations, machine cleaning, or material inspection, etc. The setup durations are usually dependent of the degree of similarity between consecutive jobs, for example, sizes, shapes, and colors. However, setup time and setup cost may not always directly proportional. There are some situations in which setup cost is high while setup time is less, i.e. when setup required high-skilled labor. So, the separate consideration of setup time from setup cost may be needed in some situations.

The sequence-dependent setup problems are commonly found in production of different colors of paint, blended of fuel or chemical compound, flavors of ice cream, and strengths of detergent. Similarly, it can also be found in manufacturing industry in which production of different products has to use different types of molds. For scheduling applications that involve sequence-dependent setup Allahverdi *et al*. (1999) described textile, printing, paper bag, container, bottle, plastic, chemical, pharmaceutical, food processing, and paper industry applications.

In this research, a single machine scheduling problem is considered. The first attempt is to develop the optimization algorithm to solve the single machine scheduling problem that is more general and more complex than many problems in the literature. The scheduling problem to minimize weighted earliness/tardiness penalties with sequence-dependent setup cost is considered. In this case, the setup time is assumed to be sequence-independent and the idle time can not be inserted into the job sequence. Branch and bound algorithm (B&B) is used to solve the problem. The original branch and bound is not efficient so the lower bound, upper bound, and dominance criteria are developed to improve the performance. This problem is more general and more complex than many problems except the problem investigated by Sourd (2005). The most recent paper by Sourd (2005) considered the problem where the idle time can be inserted and the setup time is sequence-dependent. The computational test has shown that the proposed method is limited to the problem with no more than 20 jobs. By relaxing some assumptions, the proposed technique can solve twice as large problem solved by Sourd (2005). The assumption that the idle time can not be inserted into the sequence is applicable when machine idle cost is greater than the earliness penalties, the capacity of machine is less than the demand, or the algorithm is used for scheduling the bottleneck machine. The proposed scheduling method can solve some special

cases in the literature by only modifying some input parameters and can be used as a benchmark for developing heuristic method for this type of problem.

The branch and bound technique is used since the main purpose of the first part aims at developing the global optimal solution for solving general and complex single-machine scheduling. However, the branch and bound technique seems to work well with only small to medium-sized problem. For larger size problem, the heuristic technique must be used. Heuristic method is probably faster and can be used to solve large-sized problem but it can not guarantee optimal solution. Development of heuristic that gives least deviation to the optimal solution will be very valuable.

In the second part of research, in order to enlarge the problem size, a meta-heuristic called particle swarm optimization (PSO) is investigated. PSO can be applied to small-sized problem as well. In this research, PSO is not tested for a small-sized problem because (i) the small sized problem is better be solved by the exact algorithm to obtain the global optimal solution (ii) if the meta-heuristic is efficient with large-sized problem, it will probably efficient for solving small-sized problem too. Many authors have been applying PSO to solve many types of problems. The review of previous works also reported the successful application of PSO over some heuristics to the scheduling problem. The review of previous applications of PSO is presented in chapter 2. Therefore, PSO algorithm is applied to single machine total tardiness problem with sequence-dependent setup time. Many solution techniques, i.e., simulated annealing (SA), random start pair-wise interchange (RS), genetic algorithm (GA), and ant-colony optimization (ACO), are proposed for this type of problem. PSO is applied to this problem since it will be able to compare with the result from these techniques. The advantage of PSO is computational efficient but it converges too fast. The modification and improvement techniques are studies in order to overcome the weakness and improve the solution quality of original PSO. Then, PSO is modified to solve the single machine earliness/tardiness problem with sequence-dependent setup cost as proposed in the first part of research.

In the third part of this research, PSO algorithm is extended to solve more complex scheduling problem which is care worker scheduling. Care worker scheduling problem is a part of home care service. Home care or domiciliary care is the provision of health care and assistance to people in their own homes, according to a formal assessment of their needs. The problem considered in this paper applied to a genuine situation arising in the UK, where the provision of community care service is a responsibility of the local authorities. The aim is to provide the care and support needed to assist people, particularly elderly people, people with physical or learning disabilities and people who need assistance due to illness to live as independently as possible in their own homes. Home care is a viable alternative to in-hospital, residential or institutional based nursing care and the underlying driver is that it leads to a higher quality of life for the clients as well as lower costs. Home care is primarily performed by means of personal visitations of care workers to clients in their homes, where they provide care assistance according to a pre-assessment of the clients' needs. The service includes not only simpler low-level tasks such as getting up, dressing, toileting, bathing, preparation of meals, housework, shopping, contact and befriending, but also high-level tasks such as assistance in taking medication and physical therapy, which require higher levels of skills.

In the past, UK home care was performed predominantly by care workers employed by the social service departments of local government authorities, i.e. in-house. However, local authorities are now increasingly outsourcing homecare from the independent sector, with some outsourcing as much as 100%. This is being driven in the first instance by central government seeking to achieve *Best Value* where value is seen as the ratio of quality to cost. The World Health Organization stresses that strategies should be drawn up for providing

support to patients and carers at the community level in order to avoid costly institutional care. This research aims to make a contribution to this by developing an algorithm to optimize care-worker schedules (or rosters). The potential benefits of efficient scheduling are:

i. to reduce the traveling distance and hence traveling costs of the care workers;
ii. to improve worker utilization by reducing the 'waste' of travel and consequently reducing the number of workers required;
iii. to increase customer service by satisfying all service requirements within their specified time windows;
iv. to free-up care managers' time, so that they can undertake a more regulatory and strategic role.

The work has been conducted in collaboration with the *The Welsh Systems Consortium*; a partnership between seven local government authorities in Wales. They would welcome a scheduler as part of their fully integrated health and social care information system. Currently, local authorities typically use a manual approach to develop feasible and sound rosters. The Advanced Internet & Emergent Systems (AiMES) Centre at the University of Liverpool (www.AiMES.net) has been providing help to the Consortium and identified the potential for improvement in the scheduling of care workers. AiMES applied the proprietary software ILOG™ Dispatcher (http://www.ilog.com) and utilized its embedding features to develop a scheduling engine.

The third part of this research seeks to improve the existing results by using PSO algorithm to schedule the dispatch of care workers to clients in an efficient manner under time and capacity constraints. PSO algorithm along with the improvement techniques are developed to schedule the care workers on a daily basis to minimize the total distance traveled.

Finally, it is expected that this dissertation will have both theoretical and practical contribution to a scheduling research area. Next section will be the objective of dissertation, followed by the scope of dissertation, and the organization of this proposal.

1.2 Objectives of Dissertation

- To develop an optimization technique for single machine earliness/tardiness problem with sequence-dependent setup cost.
- To develop the techniques, i.e., lower bound, upper bound, and dominance criteria, to improve the performance of original branch and bound algorithm in order to solve larger problem size.
- To develop particle swarm optimization algorithm with solution representation and translation technique as an alternative mean to solve the single machine total tardiness problem with sequence-dependent setup cost.
- To investigate heuristic techniques or modification techniques to incorporate into PSO algorithm in order to improve the solution quality for single machine scheduling problem.
- To apply particle swarm optimization algorithm for care worker scheduling problem by developing the problem mapping assignment technique, and solution generation to establish the care worker schedule.
- To examine heuristic techniques or modification techniques to integrate into basic PSO algorithm to improve its performance for care worker scheduling problem.

1.3 Scope of Dissertation

- The algorithm for solving single machine scheduling problem will be developed. For the single machine scheduling problem, each job must be available at the beginning of the planning period and has distinct due date.
- Two objectives will be considered, which are minimize weighted earliness/tardiness penalties with sequence-dependent setup cost and minimize total tardiness with sequence-dependent setup time.
- Branch and bound algorithm with efficient lower bound, upper bound, and dominance criteria will be developed to solve the weighted earliness/tardiness penalties with sequence-dependent setup problem.
- Particle swarm optimization algorithm will be applied to solve single machine total tardiness problem with sequence-dependent setup time.
- Three heuristic techniques, i.e., *regroup & resize*, *local improvement procedure*, *variable neighborhood search*, will be studied in order to find the best heuristic to incorporate into basic PSO
- Particle swarm optimization algorithm will be extended to solve care worker scheduling problem.
- The initial solution heuristic and local improvement heuristic will be developed to improve the performance of PSO algorithm for care worker scheduling

1.4 Organization of Dissertation

This dissertation consists of six chapters as follows:

Chapter 1 is the introduction of the research. It provides an insight to the background of this research, significance of scheduling problem, objectives and scopes of this dissertation.

Chapter 2 is the literature review where previous research works are discussed. The relevant research topics presented are single machine scheduling research, vehicle routing problem with time windows, and staff planning and scheduling and home care research. The review of scheduling approaches used in this research, i.e., branch and bound algorithm, and particle swarm optimization algorithm, are also presented in this chapter.

Chapter 3 illustrates branch and bound approach for single machine sequencing with weighted earliness/tardiness penalties and sequence-dependent setup cost including lower and upper bounding procedure.

Chapter 4 presents a particle swarm optimization for the single machine total tardiness problem with sequence-dependent setup time. It also provides experimental results of Hybrid-PSO with various improvement heuristics.

Chapter 5 introduces a particle swarm optimization to care worker scheduling problem including the solution representation, and solution mapping using heuristic assignment technique. This chapter also presents the initial solution heuristic and local improvement heuristic to improve the performance of PSO algorithm for care worker scheduling problem.

Chapter 6 is the conclusions of the research. This chapter includes summary, the key contributions of the research, and recommendations for further studies