LITERATURE REVIEWS

There have been publications and research on scheduling problem at the beginning of this century with the work of Henry Gantt and other pioneers (Pinedo, 1995). The theory of scheduling has received a lot attention from Operations Research practitioners, management scientists, production and operations research workers and mathematicians. Some of the first publications appeared in Naval Research Logistics Quarterly in the early 1950s about “Johnson 's Problem”.

After Richard Karp's famous paper on complexity theory, the research in the 1970s focused mainly on the complexity hierarchy of scheduling problems. In the 1980s several different directions were pursued in academia and industry with an increasing amount of attention paid to stochastic. However, recent research papers are more concern on the cases of flow shop scheduling. The Scheduling literature ranges from the study of deterministic cases to stochastic cases, from single machine problem to the multi-machine problem and from static to dynamic problems (Nagar et al., 1995).

Scheduling problems can be classified as deterministic or stochastic, static or dynamic. An excellent classification of scheduling problem was provided by Reisman et al., in 1997, Figure 4

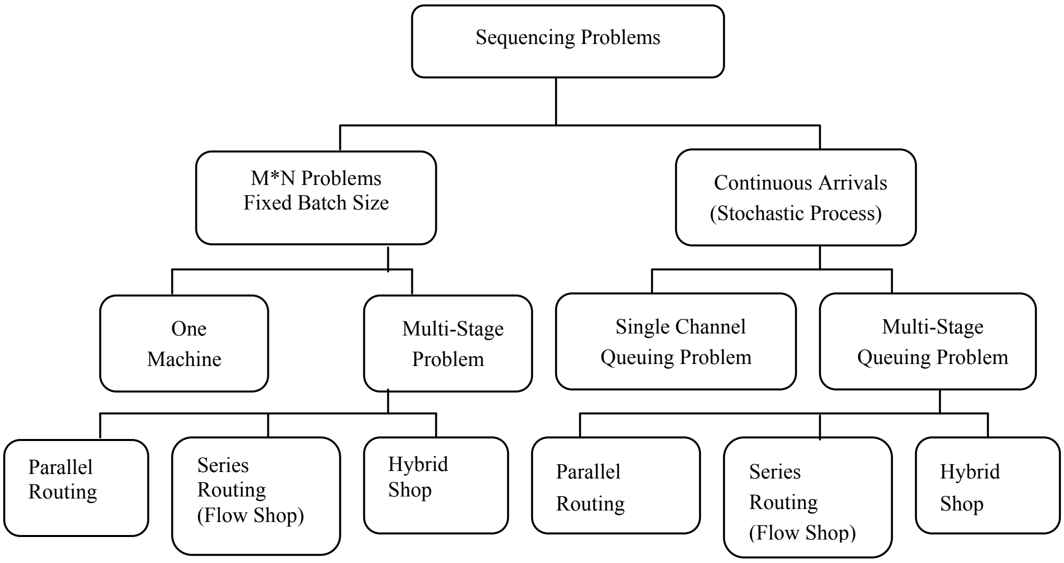

Figure 4 A classifications of Scheduling Problems

Scheduling Procedures

Some of the scheduling problems are inherently easy to solve because many of those can be formulated as linear programs, and that can be solved with using the existing efficient algorithms. Other easy problems can be solved by different algorithms that are also efficient. These efficient algorithms are referred to as polynomial time algorithms. These problems can be solved with short time by computer even if that problem has thousand of jobs, Pinedo and Chao (1990)

However, many more scheduling problems are very hard to solve. These problems are called NP-hard. They cannot be formulated as linear programs, and no simple rules or algorithms yield optimal solutions in a limited amount of computer time. For these problems, it may be possible to formulate them as integer or disjunctive program, but it requires too much computing time to get optimal solutions.

Then it is usually considered the "acceptable" feasible solutions that satisfy them, and those solutions are not far from optimal.

The following table 1 shows the relationship between data, objectives and basic dispatching rules those are one of the general-purpose techniques that have proven in industrial scheduling systems.

Table 1 Basic Dispatching Rules

Condition	Rule	Data	Objective
Rules dependent on release date and due dates	ERD	r_i	Variance in throughput times
	EDD	d_i	Maximum lateness
	MS	d_i	Maximum lateness
Rules dependent on processing time	LPT	p_i	Load balancing over parallel machines
	SPT	p_i	Sum of completion times, WIP
	WSPT	p_i, w_i	Weighted sum of completion times, WIP
	CP	$p_i,$ precedences	Makespan
	LNS	$p_i,$ precedences	Makespan
Miscellaneous	SIRO	--	Ease of implementation
	SST	s_{ik}	Makespan and throughput
Miscellaneous	LFJ	M_i	Makespan and throughput
	SQNO	--	Machine idleness

Notations;
ERD = Earliest release date first rule.
EDD = Earliest due date first rule.
MS = Minimum slack first rule.
LPT = Longest processing time first rule.
SPT = Shortest processing time first rule.
WSPT = Weighted shortest processing time first rule.
CP = Critical path rule.
LNS = Largest number of successors rule.
SIRO = Service in random order rule.
SST = Shortest setup time first rule.

LFJ = Least flexible job first rule.

SQNO = Shortest queue at the next operation rule.

Heuristics for flow shop scheduling with multiple operations and time lags.

By Riezebos and Gaalman (1996).

This paper considers a multistage flow shop where jobs require multiple operations at each stage and a finish-to-start time lag between any two consecutive operations of a job the next operation of a job cannot start until the time lag after the former operation of that job has elapsed. Since the problem of minimizing the make span is shown to be NP-hard even for the two-stage case, It present a lower bound based heuristic approach that is used to construct several heuristic procedures. These heuristics use lower bounds on the minimum make span to solve the problem. The effectiveness of these heuristics is empirically evaluated by solving a large number of randomly generated problems. The use of these lower bounds in the construction of heuristics results in an improvement of the make span performance of up to 50% as compared with the performance of some simple dispatching heuristics that take the presence of multiple operations and time lags into account. Furthermore, It show that the relative performance of the heuristics depends on the size of the time lag. If the ratio of mean time lag and mean processing time is 20% or more, heuristics that construct an active schedule perform less well than heuristics that construct a non-delay schedule. The opposite holds true if this ratio is smaller.

The performance of the widely used Shortest Processing Time heuristic (SPT) deteriorates quickly if the size of the time lags increases. It propose instead to use the Earliest Finish Time heuristic (EFT) in case time lags are present. EFT performs much better in this case and is identical to SPT if all time lags are zero.

Integrated project task and manpower scheduling.

By Alfares and Bailey (1997).

This paper present personnel scheduling, It is to determine how many workers must be assigned to each feasible days-off tour to satisfy a given labor-demand profile with minimum labor cost. The objective of project task scheduling is to determine task start dates and durations to complete a project on time with the minimum cost of performing tasks plus overhead. By assumption of altering task start dates and durations, the daily labor-demand profile can be changed. Integrating these two problems permits the simultaneous determination of start dates, durations, labor levels and required tours for a minimum-cost and on-time schedule. Both integer programming and heuristic solution procedures to solve the integrated problem are presented., the heuristic procedure outperformed the traditional two-step scheduling procedure by a project scheduling algorithm first determines the start time and duration, which is a function of labor level, for each task.

The task and personnel scheduling problems have been integrated in a model that seems to offer substantial savings in the overall cost of a project. The savings come as a result of selecting a start time and labor level for each task that reduces labor cost. The integer programming optimization formulation is, however, large for realistic problems. A much more efficient heuristic approach based on dynamic programming was presented and tested. The heuristic procedure produced near-optimal solutions in terms of total cost, labor cost, and labor productivity, while providing significant savings in computation time. Yet although the heuristic solution is easily obtained for real-world problems, the optimal solution is currently impracticable. When compared with the traditional two-stage approach, the heuristic procedure provided notable savings in total cost and labor cost, and substantial gains in labor productivity. In a series of 20 test problems, The heuristic solution procedure yielded an 8.6% reduction in total cost compared with the traditional two-step procedure. In the test cases, this percentage saving tended to increase as the average number of options for start time and labor level grew. By using the heuristic procedure, labor productivity was increased in the test cases by 14% to 98%. Relative to the integer programming procedure, the heuristic procedure reduced the computational time by 58%. The primary conclusion is that integrating the solutions of project task and personnel scheduling problems is both feasible and wise. Future research extensions include considering stochastic elements and sensitivity analysis of the solution. Although there are standard estimates for most construction tasks, equipment breakdowns, cost increases, and labor shortages can never be ruled out. Other reasonable follow-up efforts would be to explore refinements to the heuristic procedure presented here and to program user-friendly decision support tools for this scheduling activity.

A multiple-shift workforce scheduling model under annualized hours.

By Hung (1999).

Many manufacturing and service organizations in Europe have used annualized hours, also known as flexiyear, to successfully tackle seasonal demand. Under annualized hours, the employer has a certain number of labor hours available in a year and the employer can allocate the hours over the year according to manpower need. A problem in planning for annualized hours is the scheduling of the workforce over the year. This paper presents an algorithm to generate an annual schedule for a scenario in which a facility operates one or more shifts and manpower need may vary from week to week.

Assigning students to course sections using tabu search.

By Ramon ,Crespo and Tamarit (2000).

This paper describe a new student registration system which has been developed at the University of Valencia, Spain. The system has two steps. First, the students make a computer-aided course selection from the courses available at the University. Thereafter, an assignment procedure allocates students to sections in order to respect two criteria: to provide the students with satisfactory schedules and to get balanced section enrollments. The assignment process has two phases. In Phase I, obtain a set of the best solutions for each student. The algorithm is based on the construction of maximum cardinality independent sets. In Phase II, these solution sets are put together and a tabu search algorithm to obtain good feasible solutions for the balancing problem, and use tabu search combined with strategic oscillation in a way similar to that proposed looks for a satisfactory balance between course sections without causing the solution obtained for each student to worsen significantly. The system was used at the beginning of the academic year 1996/97 in the Faculty of Mathematics and could be extended in the near future to the rest of the University.

The results of the registration will be evaluated by the University in order to decide if the system will be extended beyond the Faculty of Mathematics. Some preliminary conclusions may be drawn at this moment. First, some kind of computer aided registration is necessary for large universities to speed up the process and reduce the staff requirements. The first phase of our procedure has shown to be well suited to the type of registration and the existing computer network. Second, the algorithm of Phase II produced good solutions which are currently being used by the Faculty. The course offer has been adjusted to the students' demands before assigning them to sections.

Finally, the results show that the quality of students' timetables depends critically on the structure of the master schedule. It would therefore be very useful to develop an algorithm to build the schedule. The new and the existing algorithms could be imbedded in a package for academic management.

<u>An algorithms for workforce scheduling and shift design optimization.</u>

By Gärtner ,Musliu and Slany (2001).

The typical process of planning and scheduling a rotating workforce in an organization consists in designing shifts and then assigning employees to these shifts and to periods of rest (days-off). Successfully solving these problems has high practical relevance. Results from ergonomics indicate that shift schedules have a profound impact on the health and satisfaction of employees as well as on their performance at work. The solutions must also satisfy legal requirements and should meet the objectives of the employing organization. In the research project , undertaken by the Database and Artificial Intelligence Group at the Vienna University of Technology in cooperation with Ximes Corp., systems for the design of shifts and assignment of employees to shifts and days-off were developed.

Complexity of Workforce Scheduling in Transfer Lines.

By Vairaktarakis and Xiaoqiang. (2003).

This paper consider a production system that consists of m assembly stations arranged in series. All jobs enter the assembly line at station 1 and proceed with subsequent stations in the same order as in a flow shop. Each job spends a fixed amount of time c in each station, known as the production cycle. This production system is synchronous or paced because jobs move one station forward synchronously, every c time units. To ensure that all required work is performed in precisely *c* periods, the appropriate number of workers is assumed to be known for every task in each station. Hence, each job is specified by an m-tuple of workforce requirements. There are interested in “level"” workforce schedules where workforce size fluctuations are minimal during the production horizon. In this article It define level workforce scheduling objectives and analyze the complexity status of the associated problems. That find that most of these problems are NP-complete even when m=2.

In this article defined a variety of objective functions for the workforce planning problem on synchronous production systems and determined the complexity status of the corresponding problems. All other problems are strongly NP-complete even for 2-station paced assembly lines. This means that workforce leveling is a very hard problem. Hence, increased effort is required to find reasonable solutions for such problems. In addition to the basic problems formulated in this article, future research should address cross-training issues in synchronous production systems. In this setting, workers are not trained to work on every single station of the assembly system, but only on a small subset of stations as dictated by the nature of the work. Evidently, this article also provides a complexity classification for many cross-training problems. Namely, if there is a skill with 3 or more stations, then the workforce planning problem is NP-complete for any objective f . Research on cross-training issues is important not only for tactical decision making but also for gaining insight on effective ways to form skill vectors (i.e., determine the stations on which workers of a particular skill are trained) so as to minimize cross-training costs.

Multi-Skilled Workforce Optimisation.

By Guy and Pantonand (2004).

This paper describes a problem faced by CS Energy's Swanbank Power Station in the Australian state of Queensland. It involved the personnel scheduling (rostering) of staff with multiple skill levels at the power station. Such a problem can be classified using the six stage construction process proposed by Ernst et al. It assume that the three processes of ‘demand modeling,’ ‘shift starting times’ and ‘task scheduling’ are specified. It are concerned with the essential processes of ‘day off scheduling,’ ‘line of work construction’ and ‘shift assignment to staff’ with requirements to maintain multiple skills. Several other authors have reported results for staff with hierarchical skills while the methods proposed in this paper are for non-hierarchical skill sets. The paper describes a set covering approach to the multi-skilled rostering problem. It proposes a number of solution strategies for the set covering approach and gives a comparison of the results.

Each of the three solution methods discussed have been based on a set covering model in which ‘tours of duty’ are generated so as to implicitly account for all workforce constraints. Problems involving workforces of a realistic size and skill-level combination are combinatorially complex and require considerable time and effort to find good or optimal solutions. Indeed the number of possible tours for such problems may exceed memory capacity requirements, let-alone our capacity to compute a feasible solution. In such cases It must be content to compute good feasible solutions and trade-off solution quality with the time taken for this computation. For these reasons have presented three alternative approaches which might be used to compute good feasible solutions to such problems. It have shown that the reduced column subset and column expansion methods, while not guaranteeing optimal solutions, are capable of providing acceptable solutions in a reasonable time. On the other hand, the method of branch and price has been shown to generate more cost effective solutions, but will generally involve more computing time.

Learning Curve Calculator,

By Milligan (2002).

The concept of the learning curve was introduced to the aircraft industry in 1936 when T. P. Wright published an article in the February 1936 *Journal of the Aeronautical Science*. Wright described a basic theory for obtaining cost estimates based on repetitive production of airplane assemblies. Since then, learning curves (also known as progress functions) have been applied to all types of work from simple tasks to complex jobs like manufacturing a Space Shuttle.

The theory of learning is simple. It is recognized that repetition of the same operation results in less time or effort expended on that operation. For the Wright learning curve, the underlying hypothesis is that the direct labor man-hours necessary to complete a unit of production will decrease by a constant percentage each time the production quantity is doubled. If the rate of improvement is 20% between doubled quantities, then the **learning percent** would be 80% (100-20=80). While the learning curve emphasizes time, it can be easily extended to cost as well.

The learning percent is usually determined by statistical analysis of actual cost data for similar products. Lacking that, you may use the following guidelines from "Cost Estimator's Reference Manual- 2nd Ed.," by Rodney Stewart:

- 75% hand assembly/25% machining = 80% learning
- 50% hand assembly/50% machining = 85%
- 25% hand assembly/75% machining = 90%

Piece rates and learning:understanding work and production in the New England textile industry a century ago.

By Leunig. (2006).

This paper shows that workers' earning increased over time, and that this increase was caused by learning rather than by poor workers leaving the mill more quickly thatn the more able. The data are drawn from the records of Lyman Mills and covered the period 1903 – 1912. Productivity plots over the period shows that experienced workers produced more than inexperienced ones. Even simple task like ring spinning, the skill appears to have taken two years to master fully. The effect of experience on worker output could increase the labour productivity to as much as 15% to 125%. Although such simple skill takes up to two year to master and in some case can double the output, once learnt the ability does not appear to have been forgotten.

Incremental changes in the workforce to accommodate changes in demand

By Bard. and Purnomo (2006).

In many service organizations, rosters must be constructed weekly or monthly as demand and available personnel change. Once the permanent workforce is fixed, it may not be possible to alter its composition easily, implying that expensive contract labor may be the only option to cover shortages. With respect to nursing resources, this means calling in part-timers, casuals, or agency nurses on a daily basis, or hiring travelers for up to several months at a time. This paper addresses the latter option and presents two models that can be used to solve what It call the nurse addition problem. The first was originally developed to solve the midterm preference scheduling problem and is based on a pattern-view formulation. The second is derived from a shift-view formulation and is solved with a branch-and-price algorithm. In either case, the objective is to hire up to some predetermined number of nurses and assign them midterm schedules that minimize the maximum amount of uncovered shifts per day in the planning horizon. Each roster selected for a new nurse must satisfy a set of hard constraints related to the total working hours, work stretches, time between shifts, and weekend requirements, and a set of soft constraints related to days-on and days-off patterns and transitions from one shift type to another. Extensive testing with data provided by a 400-bed hospital indicated that most instances could be solved in a matter of minutes. In the face of rising healthcare costs and a growing nursing shortage, hospitals are constantly reexamining their staffing needs to determine the optimal mix of full-timers, part-timers, and temporary personnel. As demand fluctuates over the year, it often makes better economic sense to hire nonpermanent staff for weeks or months at a time, rather than rely on expensive agency nurses to handle the peaks on a daily basis.

In this paper, It proposed two models to help nurse managers make temporary hiring decisions. Extensive testing was done on the second model using a modified version of a branch-and-price algorithm originally developed to solve a related cyclic scheduling problem. The results showed that high quality solution could be obtained quickly for the most difficult instances. This is especially important in an environment in which scenario analysis is an integral part of the planning process.

Literature Review Summary

From the literature reviews above, conclusion can be made about the work done related to this study with regard to this point.

Table 2 Literature Review Summary

Year	Heuristic Rule			Detail
	Job scheduling	Workforce scheduling	Skill level	
1990	●			Basic Dispatching Rules
1996	●			Heuristics for flow shop
1997	●	●		Task and manpower scheduling
1999		●		Multiple-shift workforce
2001		●		Shift design optimization
2000		●		Assigning students using tabu search
2003		●	●	Complexity of Workforce Scheduling for flow shop
2004		●	●	Scheduling of staff with multiple skill levels (non-hierarchical skill)
2006		●	●	The nurse addition problem
2006			●	Piece rates and learning

Most of the studies were done on jobs scheduling or workforce scheduling in both of industrial and service system. Only one paper present two-step scheduling procedure by Integrated project task and manpower scheduling (Alfares K.H.**,** 1997). The problem are presented heuristic solution procedures to solve the integrated problem but not interested in the workers skill. It is reducing the cost of labor and overhead. Until 2003, Vairaktarakis L. and X. Cai defined a variety of objective functions for the workforce planning problem on synchronous production systems and determined the complexity status of the corresponding problems. In 2006,from the study of Piece Rate and Learning found that experienced workers can have % increase in output ranging from 15% - 123%. The assumption that all workers have the same skill level is certainly a misconception.

To the best of the knowledge no other leveling objectives have been presented before in the literature for day-to-day tactical scheduling operations. They survey of related literature shows that there is very little research done on workforce measures even though leveling issues are of practical importance in manufacturing settings.

Independently, most of the previous researches for workforce scheduling are based on the assumption that all workers have unified skill level and most of the jobs scheduling researches for flow shop are focused on the method to solve the optimize solution of other criteria. Hence a jobs scheduling considering differentiation in workforce skill levels is a relatively new problem and not yet understudied.