CHAPTER 6
SUMMARY AND CONCLUSIONS

This dissertation has reported on a number of production scheduling problems that were motivated by considering the testing of semiconductors. The research into these topics, summarized below, adds to the body of knowledge about scheduling. This work is especially relevant to the study of the harder and broader problem of job shop scheduling. Benefits of the work include results on specific one-machine class scheduling problems, results on three-machine look-ahead problems, and the use of genetic algorithms and new search spaces on different types of scheduling problems.

6.1 One-machine Class Scheduling Problems

The research on the three one-machine class scheduling problems has yielded a number of results. Most notably, the problem space genetic algorithm is a robust tool for finding high-quality solutions to difficult scheduling problems.

For the problem of minimizing total flowtime subject to deadline constraints (CFTS), we developed an multiple-pass heuristic that makes use of an optimal property for jobs in the same class. By considering the effect of wasted setup time, it is able to find reasonable solutions. We can improve upon these solutions with a problem space genetic algorithm that adjusts the job deadlines in order to create better schedules.

For the problem of minimizing the number of tardy jobs where the jobs have non-zero release dates (CSRDD), we extend a non-setup procedure to create a heuristic for the class scheduling problem. The average performance of the heuristic is good compared to a number of other dispatching rules. A problem space genetic algorithm is able to find better solutions on some especially difficult problems where the heuristic performs poorly.

Our extended heuristics for the problem of minimizing the total flowtime of jobs with non-zero release dates (FTSRD), were outclassed by a decomposition procedure and a problem space genetic algorithm. We developed a number of dominance properties for use in a branch-and-bound technique.

6.2 Look-ahead Scheduling

The three-machine problems that have been studied show that look-ahead rules can perform better than standard dispatching rules.

For the problem of minimizing makespan, the interleaving of the Johnson sequences is able to provide near-optimal solutions. The worst case relative error of this heuristic is fifty percent. There are, however, special cases of the problem that can be solved in polynomial time.

The problem of minimizing the total flowtime is more difficult. There do exist special cases where the lower bounds can be achieved. Look-ahead rules that consider the queue at the second-stage machines are able to find good solutions.

The last problem was that of minimizing the number of tardy jobs. Again, special cases exist where optimal solutions can be easily found. Look-ahead rules were able to find better schedules than other sequencing rules. A problem space genetic algorithm found improved solutions.

6.3 Searching for Job Shop Schedules

This research has investigated the development of a procedure for the job shop scheduling problem. The genetic algorithm makes use of known heuristics (dispatching rules) but increases their effectiveness by searching over combinations of rules to find a good schedule. This procedure provides a way to find good schedules under any objective function and in any scheduling environment, since it makes use of a detailed shop floor scheduler. These characteristics make this procedure unique.

In addition, this procedure has been implemented as part of a global scheduling system for a semiconductor test area. In this environment, it creates real-time schedules for the next shift using information about the current status of the lots, the current resources in the shop, and the manufacturing process. The system includes not only the simulation model and the genetic algorithm but also utility functions for the collection of data from multiple sources and the generation of performance reports. In addition, the system can respond to unforeseen events, and the test area planners can use the system to determine the effect of changing the shop resources.

6.4 Conclusions

The scheduling of a manufacturing process is a complicated problem. The static job shop scheduling problem is incredibly difficult to solve, and no system has been able to optimize the scheduling of an entire dynamic job shop, which is the environment present in many manufacturing facilities. Thus, continued research into procedures that can find good schedules is necessary.

Many researchers have studied this problem, introducing systems which range in scope from company-wide planning to machine scheduling. This research is concerned with efforts at the level of the shop floor and machine.

This research investigated production scheduling problems that are motivated by semiconductor test operations and are expected to hold widely in other production environments. Of particular concern are those problems that occur in the testing of semiconductor devices. Let us now take a moment to provide some perspective.

This dissertation is concerned with two types of operations research: *management science* and *management engineering* (the terms of Corbett and Van Wassenhove, 1993). Management science is the discovery of new results that add to the body of knowledge about a subject. Management engineering (a less active area of the field) is the solution of a practical problem by modifying existing tools or by using existing tools in original ways.

The scientific contributions are clear. While much research in the areas of scheduling and semiconductor manufacturing has been performed, this research investigated a number of previously unstudied problems and methods. Our research into these problems has yielded a number of useful properties and effective heuristics.

This research has shown that smart-and-lucky searches and the new problem and heuristic spaces can be used for the problems under consideration. Problem space genetic algorithms can find good solutions to machine scheduling problems. For the job shop scheduling problem, a genetic algorithm can search combinations of dispatching rules and use a shop floor simulation to determine a good schedule.

Additionally, this research ties together separate problems in an effort to improve the scheduling of the manufacturing process being studied. This is an engineering question. The cooperation of the semiconductor test facility motivated research into the problems of an actual system and provided an opportunity to implement our solution procedures. (This does not preclude the potential of our approach to solve problems in other manufacturing environments.)

Our global job shop scheduling system (with its detailed simulation model and heuristic space genetic algorithm) is a new technique for the problem of creating good shift schedules for a semiconductor test area in real-time. Since look-ahead dispatching rules can be more effective than standard rules, the results of the work into the three-machine subproblems have been used as dispatching procedures for the shop floor and as part of the job shop scheduling procedure.

This research opens some chapters of scheduling that need to further pursued. While the problem space genetic algorithm is a robust procedure that finds good solutions, better solutions to particular problems may be achievable through the use of solution-specific heuristics that can improve the schedules that the genetic algorithm constructs. Also, it may be possible to create searches that combine different spaces for other types of combinatorial problems.

The set of class scheduling problems includes a number of other interesting problems; so does the set of look-ahead problems. Even more interesting is the combination of these problems.

Look-ahead class scheduling problems may yield more insights into the job shop scheduling problem.

There also exist issues in global job shop scheduling that still need to be addressed: job release, resource planning, and uncertainty in the manufacturing process. It is difficult to obtain satisfactory solutions in these circumstances using current scheduling techniques.

The general approach of this research (problem and heuristic space searches) can be applied to almost any difficult problem. It may be profitable to consider this approach for problems where good solutions are hard to find.

Why investigate production scheduling problems motivated by semiconductor manufacturing? Because organizations and individuals often have difficulty meeting their goals efficiently, and this dissertation, which has applications beyond the problems contained herein,