SCHEDULING PROBLEMS - AN OVERVIEW

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Abstract

There seems to be a significant gap between the theoretical and the practical aspects of scheduling problems in the job shop environment. Theoretically, scheduling systems are designed on the basis of an *optimum* approach to the scheduling model. However in the practice, the *optimum* that is built into the scheduling applications seems to face some challenges when dealing with the dynamic character of a scheduling system, for instance machine breakdown or change of orders. Scheduling systems have become quite complex in the past few years. Competitive business environments and shorter product life cycles are the imminent challenges being faced by many companies these days. These challenges push companies to anticipate a demand driven supply chain in their business environment. A demand-driven supply chain incorporates the customer view into the supply chain processes. As a consequence of this, scheduling as a core process of the demand-driven supply chain must also reflect the customer view. In addition, other approaches to solving scheduling problems, for instance approaches based on human factors, prefer the scheduling system to be more flexible in both design and implementation. After discussion of these factors, the authors propose the integration of a different set of criteria for the development of scheduling systems which not only appears to have a better flexibility but also increased customer-focus.

Keywords: Job Shop, Scheduling Algorithms, Scheduling Techniques, Scheduling Support System

1. Introduction

Production scheduling as one of the key elements of the micro level supply chain system, plays perhaps the most important role in the manufacturing performance. Any improvement in the scheduling process will consequently have a positive impact on the other functions of the micro level and the macro level supply chain systems (see figure 1). In the last decade, the need for an efficient scheduling system has become a common requirement due to the increased demand for higher product quality, flexibility, and order flow times. Even though there are numerous scheduling applications now available in the market place, successful implementations of scheduling techniques are still uncommon. According to Bermudez (2002), only 15 % of the scheduling applications can be classified as successful. Several other authors e.g. Stoop and Vincent (1996), Wortman and Taal et al (1996), and Wiers and Van Der Schaaf (1997) have consistently referred to these problems in the past.

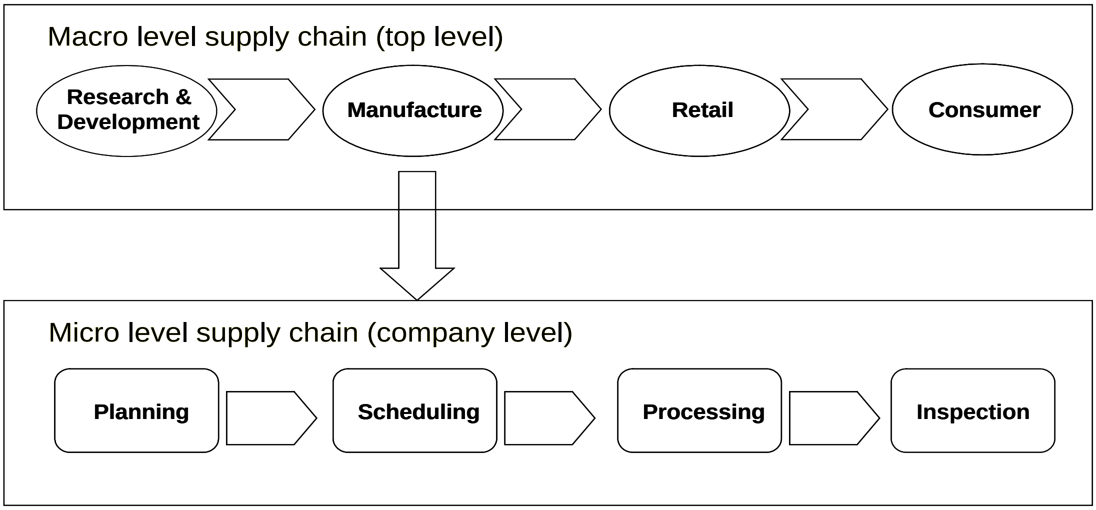

Figure 1 Scheduling as one function of a supply chain system

In this paper, main causes of a scheduling system failure have been discussed and recommendations given for the practical application of a scheduling model. The practical application view of a scheduling system is a crucial aspect of the development of the scheduling models. This aspect may include components such as the scheduling algorithms, decision support system, or the human factors. In order to provide a direction for the development of scheduling support system (which ideally is a realistic implementation case), the authors are proposing a framework which is believed to overcome the gap between the theoretical and practical aspects of the scheduling problems.

This paper is structured as follows: Section 2 describes the nature of the production scheduling problems while Section 3 discusses the analysis of the scheduling problems. Section 4 purposes a framework based on the four main categories identified in Section 3.

2. Production Scheduling Problems

Production scheduling is a complex task which has been an interesting area of operational research in the past. Much research has been carried out to find a solution to the production scheduling problems. We discover not only the human factor which affects the production scheduling problems but also factors such as the setup time, cost, and due date, which typically add further complexity to the scheduling processes. As a matter of fact, manufacturing systems are increasingly becoming more complex. Consequently, conventional techniques are no longer sufficient to solve complicated scheduling problems. To better understand the problems of scheduling, research of the past decade have reviewed and a summary given Figure 2.

To analyse and categorise the production scheduling problems, the approaches used in the past research have been divided into four main research areas. The first area of research has the aim of building and modifying scheduling algorithms which is also referred to as the scheduling techniques. The second area of research concentrates on automation of the scheduling system by developing decision support systems for the scheduling task. The third research area intends to build a scheduling system which emphasizes the human factors. And, finally the fourth area of research has the aim to analyze the practical implementation of the scheduling techniques in a real-world case study.

2.1 Scheduling Techniques

Research in the area of *scheduling techniques* is perhaps the oldest type of investigation in scheduling history and the most comprehensive research work compared with the other three research areas. The concepts which have been applied to scheduling techniques in the last decade can be summarized as follows: Theoretically, job shop scheduling problems belong to a non-deterministic polynomial (NP) problem family, which practically means that it is not possible to solve an arbitrary instance in polynomial time unless P=NP. This implies that in the practice, there are $n!*m$ possibilities to schedule n number of jobs and m number of machines on a given shop floor. This makes the job shop scheduling system quite difficult to handle.

Noronha and Sarma (1991) carried out a survey on how to apply knowledge-based approaches to scheduling problems. They found that the initial planning and scheduling may take place over several months. It is also clear that re-planning and re-scheduling must be done in real-time to meet deadlines. As a result, the need to disrupt a schedule as early as possible becomes an important objective of re-scheduling. Furthermore Suresh and Chauduri (1993) divided dynamic scheduling approach into a conventional method, a knowledge-based approach and a distributed problem solving approach. They also concluded that conventional techniques are no longer adequate to handle the situations, and that knowledge-based scheduling systems and distributed problem solving approaches hold definite promises.

A knowledge-based simulation model for job shop scheduling was proposed by Abdallah (1995) which has the objective to provide the decision maker (the scheduler) with options to handle different situations on the shop floor. These situations may include increasing work in progress (WIP), machine idleness, unsatisfying due dates, machines breakdowns, unavailability of labors, and rejection of certain operations or materials. Koh and Zouza et al (1996) used a simulation-based model for scheduling in a job shop environment.

Dorn and Kerr et al (1995) proposed a reactive scheduling using fuzzy reasoning to

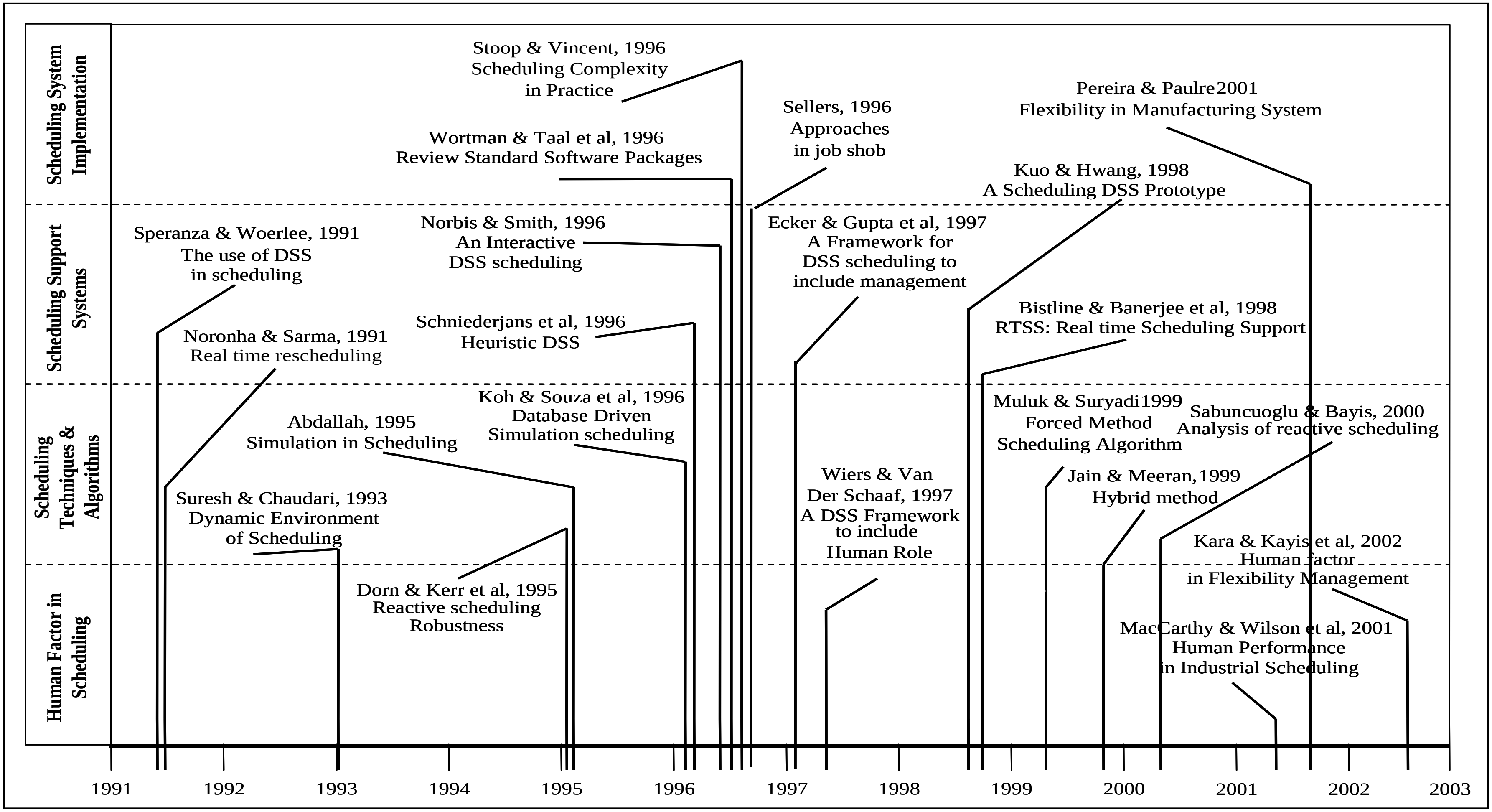

Figure 2 Scheduling Research between 1991 and 2003

improve the robustness of the steel making scheduling system. After their observation they concluded that a scheduling engineer has no motivation to optimize the scheduling because he knows that the uncertainty in the execution of his plan would make this impossible. However, they concluded, he does also know that some schedules are better than others.

In the specific domain of scheduling approaches, it is discovered that the heuristic methods are more preferable than exact methods (Sellers 1996). Therefore Muluk and Suryadi (1999) proposed a heuristic forced method in dealing with disturbances for rescheduling.

Jain and Meeran (1999) reviewed the deterministic scheduling work conducted in the past 40 years and concluded that many works were focusing on the creation of heuristics, rather than on the exact algorithms and complexity analysis. Although some attention has been paid to the complexity and the derivation of efficient algorithms, however, much of the focus has remained on the *elegant* heuristics. Current research is progressing in both directions and focusing on both aspects.

Sabuncuoglu and Bayis (2000) analyzed reactive scheduling problems in a job shop environment. They observed that reactive scheduling and controls are also important for the successful implementation of scheduling system; more research is needed in online versus offline scheduling to investigate new schedule techniques together with considerations of the partial scheduling.

From these results, we obtain that research on scheduling techniques which focuses on algorithms modification tends to become more complex in nature. Furthermore there is tendency to develop heuristic methods for real time scheduling to anticipate the dynamics of scheduling environment.

2.2 Decision Support System for Scheduling (DSS)

The aim of research in this area (scheduling support system) is to automate the scheduling process. In the late 1970’s the definition of scheduling support system was an interactive computer-based systems which helped decision makers utilising data bases and models for solving scheduling problems. It is believed that the use of DSS in solving scheduling problems will be effective because of its interactivity and the ability to analyze and synthesize a complex situation. In the past, numerous decision support systems have been proposed, However Esperanza and Woerlee (1991) states that most of research in this area focussed only on the characteristics of an application.

In the past 10 years, some works on scheduling support system emphasized the implementation problems of the system. Most results showed that some scheduling techniques embedded in a decision support system do not perform well due to some factors including the methodology, the human errors and the environment. Therefore Schniederjans and Carpenter (1996) proposed a heuristic DSS for scheduling which generates an optimal schedule in comparison with those generated by an analytic DSS without violating any necessary or sufficient mathematical conditions of the analytical methodology. Norbis and Smith (1996) proposed a dynamic heuristic DSS for the resource constraint scheduling problems. Ecker and Gupta et al (1997) suggested that there was a need to include a problem management tool as an integral component of the decision support systems when modeling for scheduling. This would allow capturing and resolving the conflicts caused by various constraints in the scheduling problems.

The advances of the computer technology in the past few years made it possible to develop scheduling support systems for real time system applications. Kuo and Hwang (1998) proposed a prototype real-time scheduling support system that was based on a model of human behaviors in scheduling tasks. They made the observation that a scheduler used to apply simple dispatching rules (e.g. FCFS, LCFS, EDD and SPT) to real-time scheduling due to the unavailability of information about the current status in the scheduling process. They proposed the use of a heuristic method instead. Bistline and Banerjee et al (1998) proposed an interactive DSS to solve real-time scheduling problems that considered the values of a job and the customer. They emphasized that the primary objectives of a scheduling support system is the utilization of resources in order to improve profitability.

2.3 Human Factor in Scheduling

Human factor has become an essential part of research in scheduling due to the perception that an autonomous scheduling process is not able to guarantee the success of a scheduling system. The main problem according to Wiers and Van Der Schaaf (1997) is that regarding the implementation of scheduling information systems, there is too much emphasis on generating the schedules instead of an even consideration of all factors. For instance, in production scheduling humans are needed for solving ill-defined problems as they usually cannot be modeled.

MacCarthy and Wilson et al (2001) defined the human performance in industrial scheduling. Humans play a key role in planning and controlling scheduling systems and measuring the *good* schedules. Human planners and schedulers are crucial in scheduling systems as they operate in real-time. This is an area which provides considerable scope of fundamental work or research.

2.4 Scheduling Implementation

Wortman and Taal et al (1996)3 reviewed capacity planning techniques within the standardized software packages, and found that most applications created problems in their schedules. Sequencing techniques were often too difficult to follow due to the fact that a sequence changed significantly if something relatively small occurred. Stoop and Vincent (1996) reviewed the complexity of the job shop scheduling problems and discovered that there were only few successful implementations of scheduling techniques. Most of the existing successful implementations have only been realized in highly controlled production processes such as mass assembly and the (semi) process industry. The implementation of scheduling techniques or information systems is often a challenge for shop floor management and the scheduler(s). In many companies, scheduling is still a manual task due to the fact that some elements of scheduling are very difficult to automate (e.g. negotiating with suppliers about delivery dates). Pereira and Paulre (2001) proposed a flexibility approach model for manufacturing scheduling as they believed that some of the reasons why scheduling information systems failed in the past were related to the in-compatibility issues.

The overview of scheduling problems researched in the last ten years showed that there are various aspects which influence a scheduling system, and most importantly, the flexibility seems to be the most needed aspect of scheduling research. In the dynamic scheduling environment, the use of flexibility has been successfully applied to solve real problems on the shop floor. It has been acknowledged that failures of previous scheduling systems in the practice were due to incapability of scheduling to react in a dynamic environment.

As a result of this, it seems to be crucial to focus on the real-world problems of scheduling. We have to eliminate the root cause of the problem instead of optimizing an ill system. From this perspective, a description of the typical problems that occur in the job shop scheduling and the different approaches to solve these problems must be constructed first. This description will be used to develop a framework for a better scheduling system in the following section.

3. Analysis

Scheduling is a process of allocating available resources to perform some tasks on a period of time. As a decision making instrument, the purpose of scheduling is to establish schedules. As per this definition, production planning cannot be separated from production scheduling. Hence production scheduling is an essential aspect in manufacturing environment, especially in a job shop environment

From the literature survey and the manufacturing system hierarchy, we attain that various approaches of research have been explored by many authors. These approaches in scheduling can be examined as a whole union with 4 different layers (see figure 3). The core of the layer is the scheduling techniques. This is where actually the process of scheduling and sequencing commence. The second layer is the human factor who plays the most important role in the scheduling process. The next layer is the scheduling support system, which automates the scheduling process and the task of the human scheduler. The last layer is the implementation of the scheduling support system itself. This layer deals with the integration of the scheduling system into the manufacture system.

The gaps between the practical and theoretical aspects are accommodated by each layer. Most of the previous works in scheduling showed that research in each layer ignored the roles of works from other layers. Most researchers have focussed on the solution of the scheduling problems in their layer of interest only. What is needed is a focus on the whole by incorporating all other components.

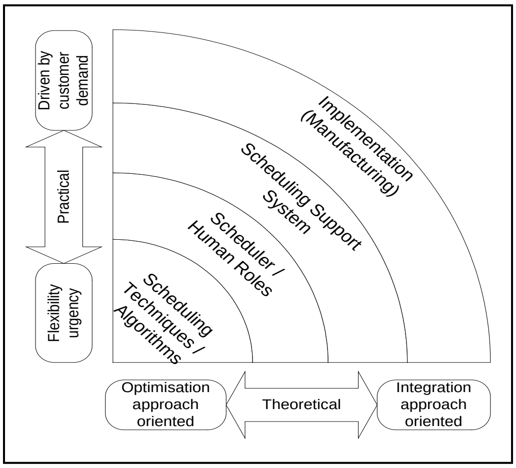

Figure 3 Scheduling Problem Analysis

Numerous scheduling techniques produced in the last 40 years built on optimum approaches. Scheduling models and mathematical models play the main role in this segment. Research conducted in this domain of scheduling produced results that were related to deterministic environment of scheduling system making sometimes the techniques impossible to apply to real-world problems. Although there have been some research works carried out in stochastic scheduling but it is still difficult to implement such a system due to the complexity of scheduling problems. And, due to this complexity, recent research has concentrated on the development of hybrid models instead of using a single technique. It has been also acknowledged that hybrid techniques are producing better result than the single techniques (Jain and Meeran 1999).

The framework in Figure 3 gives us a clear insight into the nature and behavior of job shop scheduling in a manufacturing system. The dilemma we are facing in the job shop floor scheduling system can be described as follow: If we select a narrow perspective, most problem solutions become optimization-oriented. On the other hand the nature of the problems in this perspective is dynamic and very difficult to optimize. If we use a wider perspective, the problem solutions become more customer-oriented, thus the nature of the problems in this perspective is long term, and it deals with the scheduling management such as planning and policies.

4. A Framework for developing a scheduling system

It is obvious that scheduling is not only a matter of optimization. Optimization is indeed required as one of its objectives. However in practice, optimization can often be not accomplished due to disturbances. Furthermore, scheduling is still a manual task in most companies due to the fact that some elements of scheduling are very hard to automate (e.g. negotiating with suppliers about delivery dates). Also, it is not always a good idea to rely on a human scheduler. When developing a sound scheduling system, ideally all the possible and realistic aspects of scheduling should be taken into consideration.

Therefore a framework proposed in this paper outlines the guidelines for development of a scheduling system in order to solve real world problems.

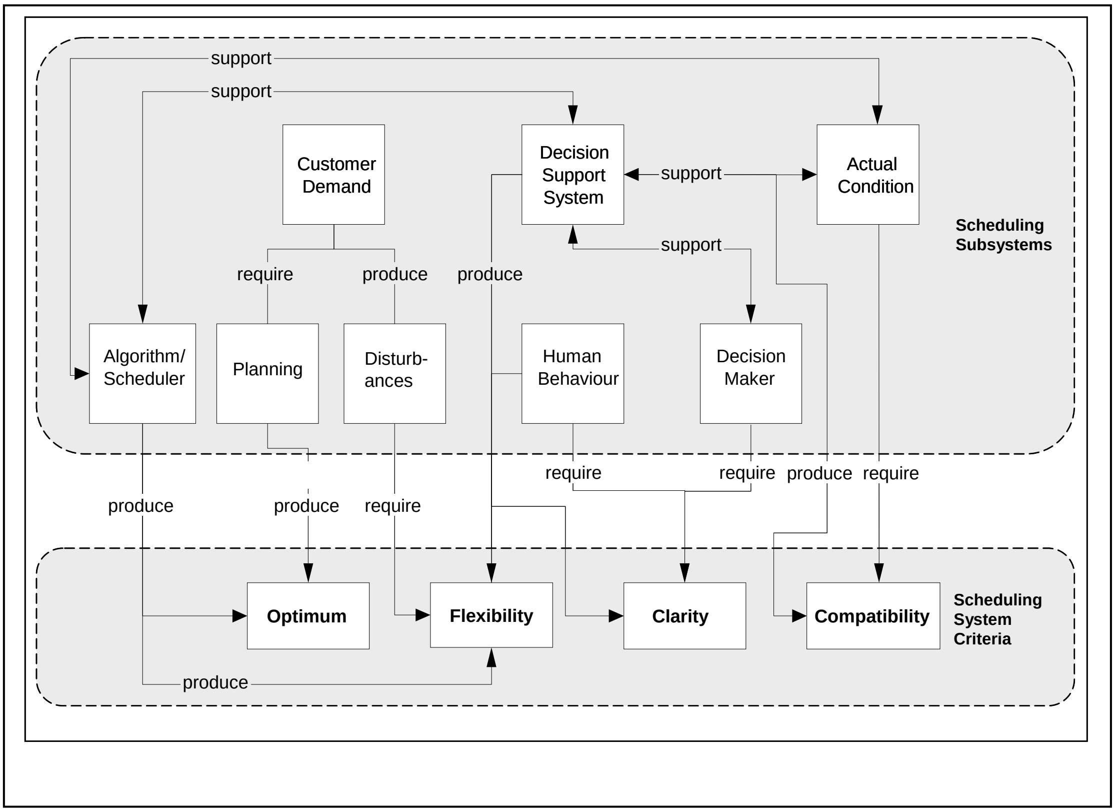

Figure 4 Scheduling Support System Framework

Figure 4 illustrates the process map of the proposed framework. This framework consists of the Scheduling Sub-Systems (Customer demand, Decision Support System, Actual condition, Algorithm Scheduler, Planning, Disturbances, Human behavior, and Decision maker) and the criterion for defining the requirements of the scheduling system (Optimum, Flexibility, Clarity, and Compatibility).The relationship between the framework elements has been illustrated with an arrow and take the form of *require*, *produce* or *support*. For instance, Customer demand subsystem may *produc*e disturbances which *require* some form of flexibility.

4.1 Optimisation

The optimization in the system is obtained from Planning and scheduling. The model should be able to optimize the system by balancing the disturbance. In such a case, the model does not only optimize a schedule within its technical parameter but it also has the ability to react to disturbances. Therefore optimization is not only subject to the creation of an optimized scheduling model. On the t be able to optimize the whole system. A good scheduling model should generate a schedule which minimizes the final state of the problem. A schedule may change constantly when a small problem occurs (Wortman and Taal et al

1996). Planning is proved to be the best tool to achieve optimization.

4.2 Flexibility

Kara and Kayis et al (2002) define flexibility as “the ability to respond effectively to the ever-changing and increasing needs of the customer”. In our model, the only subsystem which requires flexibility is the element customer demand. Customer demand on the other hand, generates disturbances in scheduling such as changes of job priorities, and new schedules for new product. Other disturbances such as the machine breakdown are considered as internal disturbances which can be usually controlled by staff. The decision support system and some form of scheduling rules usually add flexibility to the system by providing predictive information and reactive anticipation. The element Human behavior considers the fact that in a dynamic environment humans have the ability to adapt to the conditions and requirements (Wortman and Taal et al 1996). Human factor can also add flexibility to the system, so that the human-machine interactivity in a decision support system is preferred option to achieve flexibility for scheduling.

4.3 Clarity

The method in use must be transparent for the decision maker (human scheduler). Decision support system together with the decision maker creates clarity in the system. The system must be traceable for the human role regarding to what to produce, when to produce, where the bottleneck is, when a disturbance has occurred, what the resources are, and so on. The system should be able to notify the scheduler about the information required. Therefore the scheduler as the expert should be involved in the development of the system. Clarity in the system is also needed for generating flexibility in the system.

5. Conclusion

In this paper, a large number of approaches applied in the past ten years to solve scheduling problems have been discussed and analyzed. Each researcher’s work provides a different type of solutions to scheduling problems which seems to concentrate on a particular aspect o scheduling. More research is needed with a holistic view of the manufacturing system.

The observations made can be summarized as follows:

- The manufacturing environment is becoming more complex in its nature. A demand-driven supply chain means a customer-oriented approach to manufacturing system. This approach requires a robust scheduling system with the aim of satisfying customer demands.
- Most of the previous research seems to provide stand-alone solutions to scheduling problems. A holistic perspective of the manufacturing system needs to be taken into consideration for future research.
- A framework has been proposed with the aim of providing guidelines for the development of a scheduling system embedded in the demand-driven supply chain. This framework has been constructed by

taking into consideration of the complex nature of scheduling characteristics, the available methods, and variables which support the scheduling system.

- To create a robust schedule, the scheduling system must integrate both the flexibility and optimization. Lack of flexibility will usually generate nervousness to the schedule while lack of optimization will sacrifice the quality of the schedule.
- Finally, the framework proposed in this paper is only a beginning and provides some guidelines for further research in the development of scheduling systems in a job shop environment.

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