New method of scheduling to enhance the reliability and efficiency of the high tech and sensitive industries

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New Method of Scheduling to Enhance the Reliability and Efficiency of the High Tech and Sensitive Industries

By

Seyedehfarzaneh Nojabaei

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Doctor of Philosophy Degree in Engineering

The University of Toledo
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Scheduling includes clarifying plan and priority of the jobs that should be performed in a predetermined operation. It means that within an organization, scheduling pertains to establish the time of performing particular resources in the system. Scheduling is directly related to the use of equipment, facilities, and human activities. Thus, appropriate scheduling makes efficient use of the capacity. Efficiency and reliability are becoming the main pivotal aspects in all high tech and sensitive industries. Scheduling plays a crucial role in sustaining it. Different scheduling methods including classical scheduling, genetic algorithm, neural network, fuzzy logic, and so on. Based on reviewed literatures scheduling mostly deal with priority rules without considering the system states. An appropriate scheduling leads to significant enhancement of certainty in system. There is no method of scheduling in which “All Resource priorities, Time Action (duration), and Time Stamp” of processes have simultaneously
been considered. The new method of scheduling can enhance the efficiency and reliability of high tech and sensitive industries via considering aforementioned aspects. In the vast majority of sensitive and high tech systems the only criterion for allocating jobs to appropriate machines is to apply FIFO policy. Therefore, the main reason of failing to provide for fairness in distributed systems is considering only the criterion of time stamp as an input. Based on this criterion, the queue of jobs should be formed. Then, those jobs are allocated to the machines. In this dissertation, the all resources criteria of each job are being simultaneously considered. In this new scheduling method, the jobs should be positioned in temporary queue and sorting via developing bubble sort in MATLAB software (distributed computing tool box). Accordingly, all input factors including all inputs even managerial and environmental influential factors, time action (duration) and time stamp are considered for every process. CCR is a place in which the schedulers (computers) are located. Hence, the function of this section plays an important role in this dissertation. The main specifications of CCR are listed as: Control room is generally defined by its design, use and location. Control rooms allow people to control a system from a remote or centralized location. Central control station rooms are separated from the remainder of the building.

To evaluate the proposed method, there is a mathematical proof in order to show the enhancement of reliability also introduces two case study to evaluate the data. Eventually, it is proved that the rate of increase in efficiency and reliability by applying the proposed scheduling method is remarkable.
I dedicate this dissertation to my father and mother who my love to them is never ending and I am nothing without them
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CHAPTER ONE

INTRODUCTION

1.1 Introduction and problem state

Scheduling includes clarifying plan and priority of the jobs that should be performed in a predetermined operation. It means that within an organization, scheduling pertains to establish the time of performing particular resources in the system. Scheduling is directly related to the use of equipment, facilities, and human activities. Thus, appropriate scheduling makes efficient use of the capacity.

Baker (1974) proposed that scheduling occurs in every organization without considering the nature of the organization activities. Manufacturers should plan production by developing schedule for labors, equipments, procurement, design, manufacturing, industrialization, maintenance, even after-sale services and etc. In this regard, numerous of scholars have made attempts to schedule via divergent methods including classical scheduling (Xian, 2010), genetic algorithm (Ercan, 2005), neural network artificial (Cheng-Fa and Feng-Cheng, 2003), fuzzy logic (Vinod and Sridharan, 2008) and so on.

Kapanoglu and Alikalfa (2011) proposed that scheduling is an indispensable task for manufacturing systems in today’s harsh competitive markets. Ever-soaring massive numbers of research efforts have investigated the solution to scheduling problems.
Pinedo (2008) described that scheduling problems cope with the allocation of the resources (material, labor, technology) to carry out a set of activities during a period of time.

Studies in manufacturing scheduling mostly deal with priority rules without any consideration of the system states, sometimes due to ease of use in the shop floor. In traditional manufacturing systems, scheduling is carried out by machine operators and shop supervisors (Kapanoglu and Alikalfa, 2011). Therefore, serious surveillance problems can occur as a result of complex, multi-attribute, or state-observing rules. Computer-integrated manufacturing (CIM) systems, on the other hand, do not face these sorts of challenges. A priority rule is used to determine which job from a queue is to be operated next. Numerous priority rules have been introduced in the literature. Davis and Lawrence (1987) compared the performance of often individual priority rules with a randomized combination of these rules and shows that the combined method provides far superior results, but requires substantially more computing time. No priority rule appears to be superior to all the others (Pierreval and Mebarki, 1997). Their efficiency depends on the performance criteria of interest and the operating conditions. Even though some researchers adopt simulation and determine the most favorable priority rule(s) for the operating conditions, production objectives, and current shop status (Mebarki et al., 1998).

Mebarki et al., (1998) developed a heuristic dispatching strategy called “shift from standard rules” (SFSR). The strategy proposed is based on a dynamic selection of certain predetermined priority rules. The method for the selection of priority rules
includes an optimization algorithm for the numerical thresholds obtained via simulation. Some researchers propose meta-heuristics such as genetic algorithm and more recently, artificial intelligence (AI) methods. Most AI approaches to the scheduling problem have been expert system approaches or heuristic search methods combined with expert knowledge (Alpar and Srikanth, 1989). Without an adequate learning mechanism, expert system approaches are perceived as unsuitable for scheduling problems (Manikas and Chang, 2009).

The priority rules, also called dispatching or scheduling rules, have been widely used to provide good and time-efficient solutions to job-scheduling problems for decades (Pinedo, 2008). Kapanoglu and Alikalfa (2011) proposed nine most preferred priority rules for tardiness, collected from the previous studies to investigate the contribution of state-dependent priority rules (Aydin and Öztemel, 2000) and (Li et al., 2007). Indeed, research on effective scheduling plays a crucial role in improving production efficiency, decreasing production costs and so on.

According to the definition of reliability, the reliability of production scheduling process refers to the probability of completing the prescribed functions on the prescribed conditions and during the regulated working time. Reliability is the probability that a system conducts a particular service during a specified period of time (Shaomin and Zuo, 2010). Reliability analysis banks on stochastic models of the frequency, interval and intensity of faults in hardware and software (Smith, 2001). Adamyan (2002) stated one of the most substantial concepts in manufacturing industries is to assess the reliability and safety with sequential failures. Ishikawa
defined each cause or reason for fault is a source of variation. Causes are commonly classified into chief categories to recognize these sources of variation. The categories typically include people, methods, machines, material, management and the environment in which faults can be classified. Adamyan (2002) held a view that not only the safety and reliability of systems are directly dependent on all failure states of system but also depend on the sequential occurrences of those failures. In order to quantify system security and the grave consequence of accidental failures, several researches have been carried out (Huafei et al., 2006) and (Sheyner et al., 2002).

The other important point to mention is that applying appropriate method of scheduling causes significant enhancement of fairness in job scheduling. Among all jobs, scheduling can also provide very good overall performance (Sabin et al., 2007). Furthermore, this scheduling can reduce the number of failures and increase fairness in job assigning. Fairness can be defined as a powerful abstraction that has led to utilitarian results in industrial manufacturing systems. Krallmann et al., (1999) demonstrated that the term fairness can be transformed into a specific selection of job weights.

As mentioned in Section (1.1), the controversy surrounding job scheduling is obviously nothing new. The vast majority of scholars focus on scheduling optimization (Savkin and Somlo, 2009). In this regard, the numerous researches in the field of job scheduling have been dedicated to the allocation of $m$ machines to $n$ jobs on the bedrock of scheduling with the best performance. In traditional manufacturing systems, scheduling is carried out by machine operators and shop supervisors. On the
other hand, computer-integrated manufacturing (CIM) systems do not encounter this kind of challenges. Kapanoglu and Alikalfa (2011) introduced an interval-based learning scheduling system for building state-dependent priority rules in CIM scheduling.

Weiming (2006) asserted that things rarely go as expected in a manufacturing environment. Certain resources become unavailable and additional resources are required. The others aspects to mention are power system failures, machine failures, operator absence, and unavailability of tools and materials. In this regard, weiming proposed real-time scheduling to restore the performance of manufacturing systems.

Sun et al., (2010) stated that scheduling maintenance activities can be determined either before the schedule of jobs or jointly with the schedule of jobs. Therefore, a more realistic scheduling model has been taken into account associated machine maintenance activities. Weiming (2006) indicated that in a real manufacturing system all manufacturing resources should be considered so as to schedule not just jobs and machines. For example, a classical job shop scheduling problem with $n$ jobs, $m$ machines, and $k$ operators could have $((n!)m)k$ possible solutions.

Wei and Qiaoyun (2009) stated that several operations can be simultaneously processed by one machine with different priorities, and jobs with higher priority may be processed earlier. Tian et al., (2009) proposed that a control point is not the timing of a job being processed, but the priority of that job. To model the problem, stochastic
programming has been applied by Fazlollahtabar and Zandieh (2010). Shukla et al., (2008) suggests that job scheduling problem can be viewed as an optimization problem, bounded by both sequence and resource constraints. In this dissertation, it is assumed that each job should be performed. Unfair judgment in job scheduling and ignoring the priority of jobs based on the criterion of how much the jobs are tense, can drastically lead into a reduction in the efficiency and reliability of the whole system.

Holmes (1995) and Cruz (1996) are the first to have hinted at the idea of First-In–First-Out (FIFO). This policy is being applied to a vast majority of manufacturing systems. Due to allocating jobs with FIFO policy and only based on considering the mere criterion of time stamp, the optimizations models have never been fair-oriented. This concept can be quite clarified by supposing that there are three jobs in a paint shop of car manufacturing company referring to a scheduler in a central control room. The first job is to close the ramp door; the second is to move one of the horizontal machine’s axis; and the third one is to take action on a message about temperature raise in the mixing room of paint shop. The last one can result in a fire in the mixing room if the immediate measures are not taken. FIFO policy demands those three jobs to be processed just based on time stamp, i.e. the time of receiving. However, both first and the second job are time consuming. Therefore, the shop floor might catch fire when the third job is being processed and activated. However, it is obvious that by considering priority aspect for sorting the jobs to process, the probability of catching fire will be reduced or even eliminated.
Unfortunately, as long as the only criterion of allocating jobs to appropriate machines is FIFO policy, it can result in reducing the efficiency and reliability of the systems in which faults occur. In this research, three criteria (priority, time action and time stamp) of each job are being simultaneously considered for job scheduling problem.

In accord with the literature on scheduling, the main problem can be stated; there is no method in which all the priority resource criteria, time stamp, and time action have simultaneously been considered. Therefore, a more realistic scheduling model should take account of the six effective criteria including machine, maintenance, process, environment, management, and material activities. In this relation, the present work focuses on decreasing the probability of crash in manufacturing systems. Besides, in terms of importance and tensing, the time stamp (time of arrival), the time action (duration time), the specific priority (the six above-mentioned criteria) of each job are considered.

1.2 Goals of the dissertate

As there is no method of scheduling in which all priority resource criteria, time stamp and time action has been considered the objectives of research are:

(1). To develop a scheduling method with considering priority aspect in manufacturing systems.

(2). To evaluate the performance of the proposed scheduling method and thus validate the proposed method of scheduling in Iran Khodro Company (IKCO) case study.
To the best of the author’s knowledge, there is no method of scheduling which considers priority, time action, and time stamp to enhance the efficiency and reliability of manufacturing systems. The proposed method for manufacturing systems is capable of providing perfect scope in which the efficiency and reliability of system are enhanced, based on reducing the amount of related faults.

1.3 Scope of Dissertation and Limitation

Each company or organization which produces goods can be referred to as a manufacturing system. Regarding the scope, it should be mentioned that the number of machines and jobs are finite. The close scrutinizing of this issue reveals the fact that manufacturing system is not necessarily capable of being efficient and reliable. According to the literature, in most cases detecting the failure is time-consuming. As elaborated in Section 1.2, developing a new method which considers priority, time action, and time stamp parameters will increase efficiency and reliability.

As mentioned before, besides time stamp, priority and time action should also be taken into account in job scheduling. This implies that each job should be considered in three dimensions. Undoubtedly, this issue should be determined at the time of system establishment. On the other hand, the manufacturing system, the safety of which is being threatened, is ostensibly on the verge of collapse. So some preventive actions should be taken to reduce faults. Given all these, this method of scheduling is worth applying to manufacturing systems.
The case study involves semi-robotic car manufacturing paint shop and includes manufacturing process, material handling, inspections, and so on. All these processes are controlled by CCR (Computer Control Room). The scope is limited to IKCO paint shop, situated in Iran, with the capability of producing 52 UPH (unite per hour) and the cycle time of 1.14 minutes. The vehicle brand processing in this paint shop is national branding of Iran vehicle, SAMAND. As to the limitation of this research, the process of jobs and durations of processing should be predetermined. Another limitation is that due to the lack of sufficient number of authorities, the scheduling method is run via simulation. Indeed, in this research, implementation is not accomplished.

1.4 Organization of Dissertation

As mentioned in the previous sections, the research is classified to prepare background for all aspects of job scheduling in terms of efficiency, reliability and the appropriate way of assigning jobs to machines. Priority, and time action, and time stamp of each job via distributed controlling system are accordingly taken into consideration. The research is organized in five chapters. The First Chapter provides a typical introduction on the background of the research. The problem statement, objectives, as well as scope and limitations are also clarified in this chapter.

Chapter Two reviews some of the applicable scheduling methods as well as manufacturing control system, distributed controlling system, job allocation classification, application of queuing systems in the centralized schedulers environment, and priority rules. It also provides an introduction on reliability.
Chapter Three describes the methodology employed in this research. In this regard, the
time stamp, time action and priority are normalized, and then the sorter methodology
is applied. To evaluate the proposed method of scheduling, a simulated model is
programmed in distributed computing system of MATLAB software. The evaluation
results show that the efficiency is enhanced through a decrease in faults (errors)
leading to a lower system crash. In addition, mathematical proof demonstrates that the
reliability is enhanced. The case study is included in the third part of the evaluation of
the proposed scheduling method. It demonstrates the application of the proposed
method and its enhancement of system efficiency and reliability.

Chapter Four shows the result based on simulated algorithm. Accordingly, the result
provides comparison between the common method on the ground of FIFO policy and
the proposed scheduling method. The research tools for the clarification and
enhancement of system efficiency and reliability are Minitab software and SPSS
software. Discussion on these results is provided in the final section of this chapter.

Chapter Five summarizes the main points dealt with in the present work. In accordance
with the findings, conclusion is drawn and recommendations for further research are
noted.
CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Based on the recent decade researches performed by numerous scholars, scheduling plays a crucial role in manufacturing systems (Buyya et al., 2002). As mentioned earlier, considering priority of jobs and their time action can sustain the system efficiency and reliability. This chapter provides background information about the topics and theory explained in this dissertation. Scheduling, manufacturing control systems, job allocation, application of queuing systems in the centralized schedulers environment, and reliability are accordingly discussed in this chapter.

A summary of theoretical background related to different scheduling methods is presented in section 2.2. Manufacturing controlling systems are defined, and the importance of distributed controlling system in improving manufacturing systems is reviewed in section 2.3. The next section (2.4.) is devoted to job allocation classification based on their characteristics, shortcomings and advantages. Section 2.5 discusses applying the queuing system, different methods of reforming the queuing systems, the concept of implementation of fairness, and priority rules. The reliability is reviewed in section 2.6.
2.2 Scheduling

Shin (2010) stated that scheduling consists of planning and prioritizing of jobs which necessitate being performed. As a decision-making problem, scheduling optimizes one or more scheduling criteria (Petrovic and Duenas, 2006). Based on a vast majority of research, not only does scheduling result in increasing efficiency and utilizing capacity properly but it also leads to a reduction of the time needed to accomplish the jobs. Besides, it is obvious that scheduling increases the profitability of an organization by considering the afore-mentioned factors. In today competitive world, efficient scheduling of resources such as machines, labors and raw material to process is one of the most important performance factors (Joshi et al., 2003). Due to divergent demands, single line production has been gradually replaced by multi-line production. In order to achieve this goal, the manufacturing lines may be geographically distributed in different locations (Sule, 2009). The off-line version of scheduling has been used, even though the released data must be known by scheduler in advance (Legrand et al., 2005).

Guo and Zhang (2010) asserted that scheduling is the process of assigning manufacturing resources and arranging time to the set of manufacturing processes in the process plan. Scheduling problem which is considered as NP-hard can be solved to a great extent by using heuristic methods (Fattahi et al., 2010). Finding an optimal solution without the use of an essentially enumerative algorithm is almost impossible. Furthermore, the computation time increases exponentially with the problem size. The problem becomes more complex in a number of circumstances such as unforeseen dynamic situations, simultaneous process planning and scheduling, or manufacturing
resources. Traditional approaches for solving scheduling problems encounter great difficulties. This mostly occur when they are applied in real situations because these methods use simplified theoretical models and are essentially centralized, i.e. all the computations are carried out in a central computing unit/center (Guo and Zhang, 2010).

To solve scheduling problems, a number of heuristic methods can be employed. Such methods include scheduling with Ant colony Optimization (Merkle and Middendorf, 2005), scheduling with genetic algorithm and Petri Net (Morandin et al., 2010), distributed scheduling with Genetic algorithm Chung (2009), and scheduling with a combination of Ant Colony and Genetic Algorithm (Rossi and Boschi, 2009), and so on.

In retrospect, scheduling is as ancient as human beings. Ghazizadeh and Pingzhi (2007) defined scheduling is the performance of defining priority or arranging activities in order to meet certain requirements, constrains, or objectives. The most substantial factor in this regard is time. Since time is still a restricting factor, we need to schedule activities so as to use a restricted resource in an optimum status (Kolisch, 1996).

Weiming (2006) believed that by booming industrial world wide little by little resources have become critical. The common thought is that machine, manpower and material (3M) are the most significant resources in industrial manufacturing environment. Ostensibly, scheduling those invaluable resources can lead the manufacturing systems towards flourishing and increasing efficiency, utilization,
productivity and the profitability of each industrial manufacturing system as an ultimate target (Sethi et al., 2001). Gupta (2006) indicated that scheduling concerns assigning restricted resources to jobs in predetermined times. It is obvious that such a decision making process aims at the optimization of one or more objectives. In general, timed planning is a generalization of the well-comprehended potential of scheduling for a donated set of timed jobs (Brucker et al., 1998).

Weiming (2006) noted that there are a set of jobs and a set of machines involved in job scheduling. Each machine is capable of handling one job at a time. Each job consists of a number of operations, each of which needs to be processed without any conflicted time period of a donated length for a given machine. In this regard, the ultimate goal is to recognize a schedule, i.e. an allocation of the operations to time intervals on the machines. It requires a minimum time length to make all jobs complete (Brucker, 1998). Rossi and Dini (2007) proposed that a fundamental production planning manner must be accomplished to sustain operation times. The problem has been recognized that $n$ different jobs must be scheduled on $m$ miscellany of machines. Each job engages in a set of operations conducted on machines based on a pre-specified request. Each operation is specified by the required machine and the fixed processing time (Tsujimura and Mitsukoshi, 1999) and (Ruiz-Torres and Centeno, 2008).

Weiming (2006) stated that scheduling is assigning operations to resources in a shorter temporal horizon and with respect to an appropriate criterion, e.g. the due date or priority. A number of heuristics, such as neighborhood search (Yuan et al., 2008) and simulated annealing (Shan et al., 2006) are proposed to generate resource assignment.
Also, scheduling can be described as the optimal location of resources over time. It best fits jobs in which these assignments must obey a set of obligations reflecting the temporal relationships between jobs and the capacity restriction of those sources (Yang et al., 2008).

The shop floor manager has to control the shop by spending a large amount of man-hour based on his experience and technical intuition. To solve this problem, Fujii (2008) proposed auction type scheduling, which plans the best processing schedule automatically. In this method, real-time scheduling decides processing work by applying auction, and concurrent executing simulation adjusts the scheduling parameter in order to adapt to the changing situation. As a result, the delivery delay and the setup time can be highly improved regarding a frequent situation change.

2.2.1 Traditional Scheduling

Vinod and Sridharan (2008) expressed that scheduling rules are widely accepted in industry. This is mainly due to the ease of implementation, satisfactory performance, low computation requirement, and flexibility to incorporate domain knowledge and expertise. The set includes Jackson’s rule, SmitLiu and Layland’s rate-monotonic rule (Pinedo, 2008). Even though, a number of questions still should be answered for classical job scheduling problem and the assumptions of these questions are as follows:

1. Each machine is capable of processing just one job at a time.
2. Each job is capable of being processed by just one machine at a time.
3. A set of $n$ multiple-operation part types is available for processing at time zero (each part type requires $m$ operations and each operation requires a different machine).

4. The process plans should be known in advance.

5. The $m$ divergent machines are continuously available (without any breakdowns and maintenance operations considered).

6. The individual operations are not pre-emptive.

7. The set-up times for the operations included in the processing times, are sequential and independent.

Abbedd. (2001) applied stopwatch timed automata under the circumstance in which some of the clocks might be frozen at certain states for job scheduling problem. Xian (2010) presented a state-of-the-art approach to solve classic scheduling problem in which timed planning is applied. In this regard, scheduling problem has been highly enhanced by utilizing a set of optimizations.

### 2.2.2 Scheduling Via Applying Genetic Algorithm

Yusof (2011) asserted that genetic algorithm (GA) is a powerful search technique based on natural biological evolution used to recognize an optimal or near-optimal solution. The idea of GA was first proposed by Holland in the early 1970s. Since then it has been widely used in solving optimization problem. Wen (2007) defined genetic algorithm as an adaptive method, which can be used to solve optimization scheduling problems. Saydam (2003) stated that GA is applied in order to recognize the initial solutions. The ability of GAs to handle complex constraints is further displayed by
permitting dual-resource constraints in a scheduling problem (Chaudhuri, 2009). Zegordi (2009) noted that GAs have been widely applied for parameter optimization, classification and learning in a variety of applications.

Saydam et al., (2003) mentioned that GAs address schedules as individuals in a population. Each schedule, or individual, is represented by a chromosome of genes and is characterized by its fitness value or objective functions. The procedure performs iteratively by addressing generations. New solutions or children emerge from parent solutions of the previous generation by two genetic operators; crossover and mutation. In this regard, offspring share features taken from their parents. Throughout this recombination or reproduction process in each generation, the fit test individuals live and the least fit die (Pinedo, 2008). Montoya-Torres et al.,(2010) stated that GA is a problem solving technique that uses the concepts of evolution and hereditary to produce good solutions to complex problems. Such problems typically have enormous search spaces and are therefore difficult to solve.

2.2.3 Scheduling Via Neural Network Algorithm

Chang (2005) viewed neural networks as a collection of communicating simple processing elements. These elements are a functional abstraction of the neurons in the central nervous system. Artificial neural networks (ANNs) can be put into local search based meta-heuristics category including simulated annealing, noisy methods, guided local search methods, iterated local search, tabu search, threshold accepting, and variable neighborhood search (Ghaziri and Osman, 2003). Much research literature addresses methods of minimizing performance measures such as make-span
Within the general scheduling domain, the make-span minimization provides a useful area for analysis. This is an important model in scheduling theory, and it is usually very difficult to find its optimal solution (Jain and Meeran, 2002).

As learning tools, neural networks are used to analyze the general relationship among variables that are difficult or impossible to relate to each other. This is conducted by learning, recalling and generalizing from training patterns as data (Shiue and Su, 2002). In other words, they are universal function approximates. Therefore, they are attractive for automatically learning the (nonlinear) functional relation between the input and output variables (Raaymakers and Weijters, 2003). Cao et al., (2007) argued that the advantage of neural network is to require a lot less computation than other modeling methods. In other words, the neural network computational speed permits fast solutions to problems not seen previously by the network (El-Bouri et al., 2000).

2.2.4 Scheduling Via Fuzzy Logic

As mentioned earlier, scheduling is the allocation of machines (e.g. resources) to jobs (e.g. tasks) in order to ensure the completion of these tasks in a reasonable amount of time. Vinod and Sridharan (2008) concentrated on improvement and analysis of scheduling rules by applying fuzzy logic. The discrete-event simulation model has flourished owing to its experimental orientation. In the simulation model, five scheduling rules are incorporated. Three scheduling rules using fuzzy logic algorithm have been developed and analyzed.
Petrovic and Duenas (2006) indicated that fuzzy sets theory has been successfully applied in treating different sources of uncertainty in scheduling problems. It is particularly applicable when intuition and judgment play an important role. Canbolat and Gundogar (2004) proposed a new fuzzy approach applying fuzzy logic to blend the priority rules. Subramaniam et al., (2000) presented a fuzzy schedule which utilizes the prevailing circumstances in the job shop to dynamically choose the most suitable dispatching rule from a set of rules. The three inputs used are relative work length (RWL), relative work remaining (RWR), and relative work remaining in next machine queue (RWN). The results indicate that fuzzy scheduler performs better than common dispatching rules.

2.3 Manufacturing Control Systems

Stephan and Sriraman (2005) stated that one of the fundamental wealth generators of the world economy for now and future is manufacturing industry. Based on a report developed by the European Commission (EC) in 2004 to create a vision of the manufacturing region for 2020, 26 millions of enterprises are estimated in the European Union (EU) by that time. About 10% refer to the manufacturing sector, and it will be about 22% of the EU National Gross Product. This data is strong proof that the manufacturing activity plays a pivotal role in the world of economy.

In the recent decades, the world has moving towards developing a global economy. Tsourveloudis (2010) asserted that the manufacturing industry moves away from the mass production paradigm towards the agile manufacturing. The life cycle of products becomes shorter while the need for a wide variety of them increases. According to
Stack and Downing (2005) market demands that merchandise offer higher quality at lower costs, have highly customized and short life cycles, and impose new essential items on manufacturing enterprises. On the basis of quality, response, agility and flexibility, substantial an enterprise substantially survive in the business. In this environment of worldwide marketing competition, companies can no longer be seen stand-alone. They are forced to reconsider the way they are organized in order to increase their competitiveness (Stephan and Vedaraman, 2005).

Emami-Mehrgani et al., (2011) discussed that industry strives to cut down on production costs and optimize profit through operating methods consistent with various legal requirements. This target can only be achieved through the application of controls governing all stages of production. The various resources must be essentially available throughout a manufacturing system to obtain the benefits flowing from reliable and efficient controls over output. Many researchers among them Kenne et al., (2003) and Charlot et al., (2007) have recently addressed optimal production control in flexible manufacturing systems. Despite these efforts, the severity and frequency of accidents remain unacceptably high during maintenance procedures.

Due to hierarchical and centralized control infrastructures production, the traditional manufacturing control systems are not designed to meet flexibility, robustness, responsiveness, re-configurability. Such centralized hierarchical organization can result in shutting down the whole system because of single failures at one point of the system hierarchy (Colombo et al., 2006).
The current challenge is to generate cooperative and reconfigurable manufacturing control systems that efficiently sustain small batches, product divergence, high quality and low costs. This is fulfilled by innovative aspects of adjustment, agility and modularization (Marík and Lazanský, 2007). Information and communication technologies, and in particular artificial intelligence techniques, have been applied for more than two decades. In this regard, distributed controlling systems seem to be appropriate to encounter these requirements (Bussmann and Schild, 2000). As long as properly designed and implemented, distributed controlling systems leads to significant performance that is flexible, reconfigurable, robust, adaptive and fully tolerant. It is obvious that those key parameters for manufacturing prosperity are really invaluable in such a harsh competitive global market (Luder et al., 2005).

Leit (2009) applied new methods to intelligent and distributed manufacturing control systems on the principle of emerging paradigms such as multi-job systems and holonic manufacturing systems (HMSs). He also surveys the applications of job-based manufacturing control systems including the real implementation in industry environment. The objective of his proposal is to concentrate on the manufacturing control applications.

In order to develop holonic manufacturing, applications can be addressed in (Farlane and Bussmann, 2000). Diltis et al., (1991) mentioned four fundamental sorts of control architectures: centralized, hierarchical, modified hierarchical and hierarchical. The centralized architecture is characterized by a single decision node in which all the planning and processing information functions are focused. This architecture proposes better control optimization, but there are a number of significant drawbacks including
the rate of tolerance to faults as well as the speed of response and expansibility particularly for large systems.

2.3.1 Traditional approach to manufacturing control problem

Lim and Zang (2003) expressed that the manufacturing control is associated with managing and controlling the jobs in the factory with the aim of performing the manufacturing plans. The manufacturing planning involves activities such as monitoring the progress of the product being processed, assembling, transferring and inspecting in the factory. At this level, algorithms are applied to determine the type of production, rate of production, and requirement duration for the production to be completed. The appropriate time and the proper way of utilizing the available sources can also be determined. Furthermore, the exact moment of job releasing to the factory, job routing, and job operation sequencing should be anticipated in advance (Baker, 1998). Based on its complication, particularly the high number of interactions between the diversity of components and the variety of functions performed, manufacturing control systems are traditionally accomplished applying centralized or hierarchical control concepts as illustrated in Figure 2.1:
Figure 2.1: Traditional Approach to Manufacturing Control Systems (Colombo, 1998)
The main components are planning, scheduling, execution (i.e. distributing, monitoring, diagnosis and error recovery), machines and tools control. All components operate in a determined temporal horizon. The components range from weeks or months at the strategic level to minute or seconds at the shop floor (Colombo et al., 2006).

The performance of manufacturing plans is closely related to deviations of machine failures, operators’ shortage, rush orders, suppliers delay to provide parts, etc. In turn, this leads to the reduction of the productivity in manufacturing systems (Houseman, 2007). It is manifest that in such harsh circumstances, the system should react properly and quickly to the disturbance. Appropriate corrective measures should be taken to finish the production orders without any delay and minimize the influence of the disturbances. This can be done by revising the scheduling plans or performing appropriate maintenance (Xiaodong et al., 2001)

Leitão(2009) asserted that controlling machines or tools can be named as the lowest level of control hierarchy, initiation, cooperation and monitoring of the divergent machines systems. Traditional manufacturing control systems are not sufficient due to the point that those systems are not capable of efficiently supporting the current requirements. Manufacturing systems need to possess certain features such as flexibility, expansibility, agility and re-configurability. So, in order to fulfill the gap left by applying the centralized approaches, Leita˜o and Colombo (2006) presented a new class of intelligent and distributed manufacturing control systems.
2.3.2 Distributed Controlling Systems (DCSs)

Papazachos and Karatza (2010) pointed out that distributed systems have become very popular because of significant attributes such as cost-efficiency, scalability, performance and reliability. Rajaei et al., (2006) stipulated that several shared resources are interconnected in a distributed system via a communication network. Through a wide area connection, local resources can be grouped together so as to form a cluster connected to a grid network. Luder et al., (2005) considered a distributed system as a miscellany of independent entities which collaborate to overcome an obstacle that cannot be individually solved. Since the emerging of the universe, distributed systems have been in existence. This phenomenon, varying from a school of fish to a flock of birds, can be obviously seen in the whole ecosystem of microorganisms as a way of communication among mobile intelligent agents in our nature. Tzafestas (2001) proposed that the main reason of applying distributed computing systems (DCSs) as the utilitarian and widely advanced tool is the reliability of DCSs performance. This is mainly due to the widespread growth of both the internet and the global village. For computing systems, a distributed system has been characterized as follows:

First and foremost, jobs do not cease performing at the time of computer crashing. It means that the application software of DCS on operator stations provide the circumstances in which the operating personnel is capable of monitoring. Accordingly, real-time alters all sorts of parameters in the production process and ensure the reliability of system control (Xiong et al., 2008).
Secondly, an accumulation of computers not share common memory. Those computers are typically semi–autonomous, whereas they collaborate to address an obstacle collectively for computing system. To ensure economical interest reliable operating, quality assurance and reactivity are obviously substantial. These targets can be fulfilled via integrating control loop functions into each manufacturing level such as the design of the product or the maintenance of production and especially into the manufacturing process due to reacting at the earliest moment to defaults (Farid and McFarlane, 2006).

The distributed control system DCS is utilized worldwide to control the processes in the miscellany of fields around us. It is used in order to control hydraulic and thermal factories, power plants, airplanes, satellite systems and so on. This control system includes numerous controllers connected together by a fiber optic network. These controllers have the potential of communicating with each other by certain communication protocols to clarify what order from each one to perform. This communication process is applied to transmit data from one controller to other controllers with the aim of recognizing the appropriate action (Kshemkalyani and Singhal, 2008).

The integration of these functions even provides appropriate circumstances to probe for a global optimization of production quality. This integration necessitates a proper computer structure which is highly recommended to be distributed because the intelligence of the various functions is geographically distributed. This requires algorithms and efficient tools to apply and maintain databases, real time, distributed computer systems and communication networks (Couturier et al., 1992).
Tanenbaum and Steen (2007) suggested that distributed computing system is capable of meeting the requirements of different systems from weakly coupled to systems including wide area networks and brilliant couple systems like multiprocessor systems. As a unique coherent computer system, a group of independent computers emerge to system users. Zhou (1997) described a distributed computing system can characterize the group of autonomous process communicating in a communication network. This is conducted by processing aspects such as autonomy and heterogeneity while being devoid of common physical clock, shared memory, geographic separation.

In order to increase the global competitiveness and in reacting to fast altering customer demands, numerous enterprises are enthusiastic about possessing automated manufacturing systems (Shanmugham et al., 1995). Performing as an essential part of automated manufacturing system, control system must be based on standard usage and inherent sustenance of flexibility, interoperability and reconfiguration capability (Leitão et al., 2003).

Geliel (2009) declared that in DCS, job controlling is distributed among controllers, which communicate to each other via a network. Applying a distributed concept is a complicated obstacle. In this regards, Leita˜o and Colombo (2006) proposed a distributed concept divided into a number of small problems, all of whose tiny obstacles are capable of being mapped on an intelligent building block, i.e. control unit. Each control unit autonomously possesses its own purposes, knowledge, capabilities, skills and encapsulating intelligent performances. However, none of these has a global prospect of the system.
Leit (2009) demonstrated that there are many challenges in the automation technology area about distributing and convenient reconfiguration of systems. Since numerous industrial processes are of a complicated nature, it is hard to generate a dynamic model capable of defining the system behavior. The complication of industrial processes necessitates high level of control system. Indeed, the DCS emerges as the prominent control system in order to control complex types of processes, which are actually hard to control throughout system functions simultaneously. As an outcome, the vast majority of DCSs split the process into a number of control loops for each individual variable. On the other hand, in most circumstances the human operator is obliged to prepare for on line adjustment in order to control loop. This makes the process performance to a great extent rely on the operator knowledge and experience (Geliel and Khazendar, 2003).

Geliel and Khalil (2009) claimed that the control loops in DCSs suffer from numerous unanticipated disturbances. Hence, the human subjugations are not capable of fulfilling the required performance particularly whilst the operator does not have appropriate experience. Operator’s lack of experience leads to unacceptable performance and often causes failure and loss of production. As previously mentioned, the traditional systems often encounter malfunction. Therefore, distributing system should be applied even though application of distributed system results in the significant growth of complexity. It is necessary to optimize the required specifications along with sufficient tools which support distribution, reconfiguration, reusability and interoperability (Schainker et al., 2008).
Distributed control system (DCS) is recommended by Amro and Farlane (2006) for controlling jobs and decreasing complicated computation burden of control system. DCS becomes the most appropriate control system structure particularly for medium and large size of industrial processes. Controlling those systems necessitate sophisticated subjugations. Marcos (2004) stated that the complication of industrial processes demands high potential of control system. Accordingly, the DCS is as the most well-known control system for such kind of processes. Furthermore, it is so difficult to control the whole system variables simultaneously. DCS can separate the process into a number of control loops for each variable. As mentioned before, the human operator mostly requires providing online adjustment for control loop. This makes the process performance greatly rely on the operator background experience. It is obvious that the control loops in DCS suffer from numerous unpredicted faults. Therefore, the human subjugation is not capable of meeting the fundamental efficiency, particularly when the operator does not have adequate experience. Operator’s lack of experience may cause a reduction in efficiency and even may result in failure and reduction of production (Wade, 2004).

Nowadays, product intangible parameters have remarkably enhanced due to emerging software, built-in service capabilities, on line maintainability and so on (Colombo, 2001). On the other hand, controlling a sophisticated system is, as an outcome, a multidisciplinary task grounded in the erudition of manufacturing strategies, planning, and operations. It also relies on the integration of communication, information technology, and system control across the whole enterprise (Cruz-Cunha et al., 2007).
According to Ulieru (2007), due to centralization and large size, the requirements of huge investment, long lead times, and generation of harsh structures are always jeopardized. The physical machine levels are usually implemented utilizing large and typically expensive hardware platforms that support monolithic computer control applications (Colombo et al., 2006). Fanti et al., (1996) declared that in DCSs all modules can dynamically interact with each other in order to obtain local and global purposes. This scope can be restricted from the machine control level on the shop floor to the higher levels of factory management systems. The result is recognized as flexible production systems (FPS), which can enhance production flexibility by high productivity (Lauzon et al., 1996).

Schoop (2001) stated that reliability and the degree of flexibility in every manufacturing system is restricted to the reliability and flexibility of its mechatronic elements (workstations, storage, handling, transport systems and so on). It also depends to a great extent on the reliability and flexibility of the embedded control system. Shen et al., (2006) asserted that job-oriented software systems are becoming pivotal control software technologies in order to subjugate industrial manufacturing systems. Bohnenberger et al. (1999) declared that a multi-job oriented software platform can offer distributed intelligent control functions with communication, collaboration, and synchronization potential. Very recently, Demazeau (2010) introduced the architecture of an intelligent distributed control system (IDCS) based on a job collection presented. However, an extension of the distributed manufacturing system with different jobs is also discussed in the literature.
2.3.2.1 Distributed Control system Hardware

El-Sadek et al., (2004) noted that DCS is composed of a PC (process control), PC program and data base program. The PC program is applied to run the data base program for the requested functions. Kshemkalyani and Singhal (2008) suggested that the data can be shown on a visual basic graphic including the main program to describe system performance. The hardware consists of a sub-rack joined to the controller data base. The sub-racks have a reliable association with communication requests from the software. Colombo (2006) defined the distributed control system as the state-of-the-art technology for the control of system. It can be designed on the bedrock of either open or closed loop or both of them simultaneously. The system time delay should be minimized as much as possible in a closed loop control for sustaining stability of the system. The processing load of the controller should be optimized to maintain the controller away from overloading and execute the required function reliability by the developed DCS.

2.3.2.2 Synchronization

Lamport (1978) mentioned that clock synchronization does not need to be absolute. If two jobs do not interact, it is not necessary that their clocks be synchronized. This is based on the fact that the lack of synchronization would not be observable, and thus it could not cause problems. Moreover, Lamport (1978) demonstrated that it is not always pivotal that all jobs agree on exact time, but rather they agree on the order in which events happen. For a number of purposes, it is adequate that all machines agree on the same time. It is not substantial that this time matches the real time as announced on radio every hour. Hence, for a certain class of algorithms, internal consistency of
the clocks is a matter of debate. Whether clocks are particularly close to the real time or not is not important whatsoever.

For these algorithms, it is conventional to mention the clocks as logical clocks. As long as the additional constraint is present, the clocks may not be the same, but they must not emanate from the real time more than a certain amount. These clocks are called physical clocks (Lamport, 1978). To synchronize logical clocks, Lamport (1978) recognized a relation called “happens before.” The expression \( a \rightarrow b \) is read “a happens before b,” i.e. all processes agree on event a occurring first and followed by event b. Happens-before relation can be observed directly in two circumstances:

1. If a and b are events in the same process and a occurs before b, then \( a \rightarrow b \) is true.
2. If a is the event of a message being sent by one job, and b is the event of the message being received by another job; \( a \rightarrow b \) is also true. A message cannot be received before it is sent, or even at the same time it is sent. This is due to the point that it takes a finite amount of time to arrive.

Happens-before is a transitive relation; accordingly, if we have \( a \rightarrow b \) and \( b \rightarrow c \), then we have \( a \rightarrow c \). If two events, x and y, occur in different jobs which do not exchange messages (not even indirectly by third parties), then neither \( x \rightarrow y \) nor \( y \rightarrow x \) is true. These events are said to be concurrent, which simply means that nothing can be said (or need not to be said) about when they happen or which is first. What we need is a way of measuring time so that for every a, we can allocate a time value \( C(a) \) on which all jobs agree. These time values must have the property that if we have \( a \rightarrow b \), then we have \( C(a) < C(b) \). To state the conditions mentioned earlier, if a and b are two events during the same two jobs and a happens before b, then \( C(a) < C(b) \). Similarly,
if a is sending a message by one job and b is receiving that message by another job, then \( C(a) \) and \( C(b) \) must be allocated in such a way that everyone agrees on the values of \( C(a) \) and \( C(b) \) with \( C(a) < C(b) \). Plus, the clock time, \( C \), must always go forward (increasing) and never backward (decreasing).

Corrections of times can be made by adding a positive value, never by subtracting one. As a specimen, we can see Lamport’s algorithm application in Fig.2.2. There are three jobs running on different machines, each with its own clock and running at its own speed (Fig. 2.2.a). As it is illustrated, whilst the clock has ticked 6 times in job 0, it has ticked 8 times in job 1 and 10 times in job 2. Each clock runs at a constant rate, but the rates are different owing to differences in the crystals. Lamport’s algorithm corrects the clocks in Fig. 2.2(b).

![Figure 2.2: (a) Three Jobs, each with its Own Clock, (b) Lamport’s Concept Corrects the Clocks](image-url)
By considering the other addition, this algorithm meets the needs of global time. The addition is that between every two occurrences, the clock must tick at least once. If a job sends or receives two messages in quick succession, it must advance its clock by (at least) one tick between them (Lamport, 1990).

In most circumstances, an additional requirement is desirable: no two occurrences ever happen at exactly the same time. In order to obtain this goal, we can attach the number of jobs in which the occurrence happens to the low-order end of the time, separated by a decimal point. Hence, if events happen in job 1 and 2, both with time 60, the former becomes 60.1 and later one becomes 60.2. Applying this method help us to have a way to assign time to all events in a distributed system subject to the following conditions:

- If a events happens before b in the same jobs, \( C(a) < C(b) \).
- If a and b represent the sending and receiving of a message, \( C(a) < C(b) \).
- For all events a and b, \( C(a) \not< C(b) \).

This algorithm provides us with a way to achieve a total ordering of all events in the system. The vast majority of other distributed algorithms require such an ordering so as to avoid ambiguities. In different algorithms of distributed systems, a job necessarily adds a time (physically or mostly logically) to its message. The job writes current physical (clock) or logical (sequence number in counter) time in a special well defined format at the message. We call this additional current time Timestamp. Hence, we need to set priority and determine the time stamp for all the jobs to be performed in advance.
2.4 Process Assignment Classification

In retrospect, by concentrating on the examples of the system manipulated allocations, it can be demonstrated that allocation should be classified. Also, their characteristics, shortcomings and advantages should be negotiated.

2.4.1 Enforceable Job Allocation

Enforceable job allocation occurs as long as the allocation mechanism rules are assumed to be automatically enforced (Campbell, 1984). This characteristic is possible on the principle that all the resources in the whole system are subjugated by a unique scheduler. In most occasions, the protocol rules applied for the enforceable issue are commonly optimized to produce efficient allocations. In this regards, efficiency means to maximize utilizing resources and minimize the delays of system (Hu et al., 2006). A lot of techniques have been applied in order to optimize the use of resources, among which time-sharing techniques are remarkable (Chavez et al., 1997). This model is applicable to resources which sustain interruption and preemption. As a case in point, processors or networking equipment can be mentioned.

As early as 1960s, the processor time-sharing system has been innovated as compatible time sharing system (CTSS) by Griswold (1978). Scheduler is the time allocation algorithm of the processor among multiple processes. So, scheduler can be a particular process selected among the other processes so as to accomplish the following processor timeslot. The aim of scheduler should be clarified and implemented as the scheduling discipline by system designer. Some of the most applicable scheduling disciplines are weight fair queueing, earliest deadline first, shortest remaining time, and
round-robin. Indeed, all those police are the outcome of a goal function including fairness, deadline guarantee, waiting time minimization or utilization guarantee (Coles and Eeckhout, 2000).

Sodan (2010) disclosed excellent solution in practice. The practical concept to increase time-sharing scheduling efficiency and reliability is the allocation of an algorithm defined in a way to assign priorities for each job. Eventually, it is ostensible that this kind of allocation enforces the system by setting the priorities devoted to every job. In this regards, the designer of mechanism is obliged to make decision about choosing the priorities. Deciding about this issue may change into a fairness hurdle in a large and complicated setting (Deitel, 1990). Employing queuing model to serve the request for resources is another possible solution in which the system is formed around queuing. The vast majority of services are complicated non-divisible requests with prolonged duration and large resource demands (Pingjuan et al., 2005). So, the delay is provoked by uninterruptible aspect of utilized resources. Simultaneously, the demand of completely defining the resources is essential for the application of queuing-oriented system in the vast majority of cases.

### 2.4.2 Cooperative Job Allocation

On the basis of fair sharing approach, classical resource allocation can be applied to reassign the machines to other jobs. Yet, in a setting which lacks an enforcer entity such as a centralized scheduler system, resource sharing can be implemented cooperatively by the designer. Accordingly, in this kind of system, it is better that the current resource holder donates their resource under the assumption that the
cooperative action will be much more efficient for the whole system (Brewka et al., 2006). As a specimen, older operating system schedulers versions (DOS, Netware) have some threading libraries which accomplish or advance real time in distributed systems (Mailler et al., 2003).

2.4.3 Non–Cooperative Allocation systems

Moreover, divergence from the well-behaved circumstances attains the allocation obstacle setting into the domain of non-cooperative allocation mechanism design (Zhu et al., 2004). This is a typical circumstance in which the attendances are concentrated on the maximum of utilizing the resources in order to detriment of the others. The most pivotal characteristic which is added to the attendance is selfishness. Indeed, this action occurs without an appropriate subjugation and control in that sector. In this case, it is obvious that the allocation problem will encounter the obstacle of the tragedy of commons (Hardin, 1968). Unlimited access to some resources leads those resources to overutilization.

Building the cooperative mechanism is the main issue capturing the attention of the designer (Wang et al., 2004). It means that all the components in each system have to be based on the policy of increasing the efficiency in the whole system. The system should also be in equilibrium, i.e. deviation from the outcome of allocation is not capable of increasing the unity of the system. Osborn and Rubinstein (1996) proposed the game theory in designing process fields such as participant strategy analysis.
One of the most essential points in allocation rules is selected by system designer. Accordingly, the allocation resources avoid the ultimate resource usage by associating the cost with utilization. As long as cost and value factors are proposed in the allocation process, those parameters fundamentally bring an economic-driven design and analysis. Economics have been utilized in computing in a number of regions (Ferguson et al., 1996). Resource utilizing involves distributed computational economies such as “P2P and Grid System” (Buuya et al., 2000), “Net Work Routing” (Link Sharing) (Feigenbaum et al., 2001) and so on. The prominent issue which constructs an economic-driven allocation market function is the price determining the system. Theory of Price is a really sophisticated science (Croson and Gächter, 2010), in particular in dynamic settings like system resource allocation.

2.5 Centralized Scheduler Environment Processing

Delbala (2005) stated that job assignment is one of the debating obstacles in manufacturing systems. It means that the appropriate way of allocating arriving or internally generated jobs among manufacturing processing machines plays crucial a role in increasing the performance of the system. Indeed, in order to provide the highest utilization of industrial manufacturing system capacity and increase the fairness of job assignments, DCSs can be applied (Chou and Abraham, 1982).

Kostin et al., (2000) asserted that one of the popular approaches to job assignment is applying a coordinator that takes care of the activities related to the distribution of jobs for execution among a set of processing machines. In this regards, it is necessary to reform a queue based on the specific criteria of each job. The next measure to be taken is assigning jobs from a reformed queue to selected machines (Bianco and Scicchitano,
2009). The response time for a multi-server queuing system is minimal if there is one common waiting queue of arriving jobs for all servers (Kermani and Kleinrock, 1979).

Bianco and Scicchitano (2009) demonstrated one possible solution to implement a common waiting queue of jobs in distributed multiple systems is by using a centralized scheduler. Such a scheduler maintains a common waiting queue and accepts all arriving jobs and sorting jobs in this queue if the time needed to schedule a job is negligibly small in comparison with the time required to process it. Then, this scheme is logically equivalent to a multi-server queuing system with one common queue, which has a well-known behavior (Zhang, 1991).

2.5.1 First in First out (FIFO) Strategy

Although scheduling algorithms have been studied for decades, almost all routers currently implement the First-In-First-Out protocol (FIFO). Accordingly, all arriving jobs are equally placed into a single queue and are then assigned (Blesa, 2005). To Cholvi et al., (2007) the reasons for the widespread adoption of FIFO as a scheduling algorithm are clear. Firstly, FIFO is easily implementable, which makes it very attractive for system designers. Secondly, FIFO is also very fast since the time required to make a scheduling decision is insignificant.

The common waiting queue can be formed on the basis of First-In-First-Out (FIFO) job queuing policy. This implies that the scheduler performs load-balancing and provides consistency of its copy of the common queue (Kostin et al., 2000). First-In-First-out (FIFO) is one of the simplest queuing policies used to provide best effort
services in packet-switched networks (Cholvi and Echag, 2007). One of the important features of FIFO's performance is stability, which is developed by Koukopoulos et al., (2003) as an adversarial queuing model. This model was developed as a robust model of queuing theory in network traffic, which replaces stochastic by worst-case. FIFO is by far the most widely used scheduling protocol. In traditional queuing theory, the source which generates network traffic is typically assumed to be stochastic. However, the growing complexity of network traffic makes it increasingly unrealistic to model traffic as, say, a Poisson stream (Bhattacharjee et al., 2005).

2.5.2 Last in First out (LIFO) Strategy (Stack)

Due to its speed, simple structure, and post-few grammar, Last-In-First-Out policy in distributed environments has been applied since early 1960s. These types of processors are characterized by a zero-address instruction set. Data are accessed from the top of one or more Last-In-First-Out (LIFO) stacks, rather than by register transfer (Doshi and Lipper, 1984). LIFO policy has attracted scholars’ attention because of real-time control and other applications where rapid context switching is important. Chaudhuri (2009) presented that LIFO is a family of replacement policies, members of which attach higher eviction priorities to the blocks residing closer to the top of the fill stack. Different members of the family use additional criteria to further refine this ranking. In this way, the volume of premature evictions from the upper part of the fill stack is minimized and capacity retention in the lower part of the fill stack is maximized.
2.5.3 Round Robin Scheduling Algorithms

Round Robin is also known as cyclic executive. This algorithm is one of the simplest scheduling algorithms for operating system processes, in which time slices are assigned to each process in equal portions and in circular order. Furthermore, all processes are performed without considering priority of each process. This scheduling is not only simple but also easy to execute. The name of the algorithm derives from the round-robin rule, where each person takes an equal share of something in turn. In computing, "round-robin" describes a method of choosing a resource for a job from a list of available ones. This algorithm is applicable of load-balancing jobs before distributing them to a number of machines. Besides, a classic method for scheduling jobs in a multi-job-based system is applying a round-robin scheduler (Ramos et al., 2003).

As the basic algorithm, the scheduler chooses a resource pointed to by a counter from a list. After that, the counter is incremented and, if the end is reached, there is a return to the beginning of the list. Round-robin selection has the potential of preventing starvation, as every resource will be eventually chosen by the scheduler. However, it may be unsuitable for some applications where affinity is desirable. Round-robin-based policies are popular for their low implementation complexity. To overcome weaknesses such as short-time unfairness and high latency several versions of round-robin policies have been recommended (Mamoun et al., 2008a). In round robin method, the jobs should be arranged in the ready queue in first come first served algorithms, and the machines operate the job from the queue based on time slice. If the time slice ends and the jobs are still manipulating on the machine, the scheduler will
forcibly pre-empt the performing job and hold it at the end of ready queue. Afterwards, the scheduler will devote the processor to the next task in the ready queue. The pre-empted task will make its way to the beginning of the ready list and will be performed by the processor from the point of interruption (Yaashuwanth and Ramesh, 2010).

Hongchao et al., (2008) showed that the time slice length is a critical issue in real time operating systems. The time slice must not be too small, which results in frequent context switches and should be slightly greater than average task computation time. When implemented in real time operating systems, round robin encountered two chief drawbacks; high rate of context switch and low throughput. These two problems of round robin architecture are interrelated. The proposed architecture focuses on the drawbacks of simple round robin algorithm that can be seen in the works of previous scholars such as (Chaskar and Madhow, 2003) and (Chaskar and Madhow, 1999). According to round robin algorithm, equal priority is given to all the tasks. Based on this drawback, round robin architecture is not suitable for real time operating systems.

### 2.5.4 Intelligent Time Slice for Round Robin in Real Time Operating Systems Scheduling

Intelligent time slicing is an algorithms introduced by Yaashuwanth and Rames (2010). It relies on three aspects including priority, average CPU burst, and context switch avoidance time, and it permits the user to devote priority to the system. As an assumption, average CPU burst is considered reasonable in the system. A dedicated small processor applied to reduce the burden of the chief processor is devoted to calculating the time slice. The calculated time slice is divergent and independent for each task. Accordingly, the tasks are fed into the ready queue and executed in the main
processor with their own time slices (Mamoun et al., 2008b). The proposed algorithm is capable of being implemented in real time operating systems based on greater reaction duration. Throughout this process, the users are capable of devoting priority to every individual task. The intelligent time slice is calculated by the dedicated small processor as illustrated in figure 2.3.

![Diagram of Intelligence Time slice Generation](image)

**Figure 2.3: Intelligence Time slice Generation (Yaashuwanth and Rames, 2010)**

Yaashuwanth and Rames (2010) applied the priority aspect of each task to intelligent time slice for round robin. Consequently, the system becomes more efficient and the waiting time of tasks in queue reduces to a great extent in comparison with simple round robin.

### 2.5.5 Priority Rules

The priority rules called dispatching or scheduling rules have been widely applied in order to provide appropriate and time-efficient solutions to job scheduling problems for years (Aydin and Öztemel, 2000). Waldau et al., (2010) stated the priority rule should be used on the shop floor and for the due date (scheduling decision) for incoming orders. Kapanoglu and Alikalfa (2011) showed that dependent priority rules were achieved by genetic algorithm based on machine learning. In their concept,
considering the fact that the adopted priority rule may turn out to be inefficient owing to any change in the operating circumstances, they address the following issues:

- which priority rule can yield better performance
- what changes in the operating conditions lead to adopting a new rule

When it comes to dealing with dynamic job environments, the practicality of the generated schedules should be considered. This excludes full-fledged computer integrated manufacturing systems where the demonstrated dependent priority rules can easily be implemented. Yildirim et al., (2006) expressed that jobs are scheduled in each work center (WC) on the ground of one of the following priority rules: first-come-first-served (FCFS), shortest processing time (SPT), or longest processing time (LPT).

Moser (1990) performed simulation experiment program in order to recognize the influence of scheduling and priority rule decisions on performance criteria. In this investigation, inputs for the simulation module were a number of machines at each work center (WC), the priority rule applied in scheduling, information on incoming orders, and the due date of each order. Hence, those inputs criteria resulted in the capability of measuring the system performance. Accordingly, alternative configurations were achieved via applying a number of machines and job priority rules at each WC.

Bhattacharyya and Koehler (1998) presented that the shop circumstances are directly related to the type of priority rules which should be selected. These circumstances are considered in terms of all the operating conditions including machine queue lengths, system and/or machine utilization, job-in-process, etc. QiMing et al., (2009) proposed scheduling algorithm and implemented the algorithm in process engine. Then, he set
priorities for each job before forming queue and scheduled service components according to the dynamically allocated priorities.

2.6 Reliability Systems

Sun et al., (2008) asserted that reliability plays a substantial role in the whole performance of each manufacturing system. Kim and Seong (2002) refers reliability on the basis of reliability elements. Distefano and Puliafito (2009) stated that there are several alternatives to represent and analyze system reliability. Some approaches are heuristic, some others are analytic (Markov models, Poisson processes, reward models, Petri nets (PN), etc.), and still some others are based on simulation (Monte Carlo, discrete event, etc.). Although they are all powerful reliability analysis methods, they can hardly be considered “user friendly,” i.e. it is often really hard to directly obtain a model from the specifications, especially in case of complex systems. This fact motivated the definition of specific reliability/availability modeling formalism known as reliability block diagrams (RBDs), fault trees (FTs) and reliability graphs (RGs) (Addel-Geliel, 2009).

Savsar (2000) emphasized the significance of reliability analysis of manufacturing systems in understanding and increasing the utilization and productivity of such systems. Wang et al., (2001) investigated the statistical distribution to characterize the reliability of a machining center. He concluded that the failure process best fits an exponential distribution. Chen et al. Zhu et al., (2011) suggested that dimensional quality and locator reliability are integrated in the assembly in the automotive industry. Nevertheless, the model used in the assembly process fails to be direct
applied to the machining process (Sun et al., 2008). On this basis, the two chief
categories of systems are series and parallel. The reliability is:

\[ R = 1 - P(E) \quad (\text{Eq. 2.1}) \]

\[ P(E) = \text{The Probability of Occurring Errors} \]

Serial and parallel system reliability is dealt with as follows:

### 2.6.1 Serial System Reliability

Figure 2.4 illustrates that in a series system if any of the units fails, then the system becomes inoperative.

Here the system reliability is achieved through the reliability of all components.

\[ R_s(t) = (R_1(t)) \times (R_2(t)) \times \cdots \times (R_n(t)) = \prod_{i=1}^{n} R_i(t) \quad (\text{Eq. 2.3}) \]

\( R_s(t) = \text{Series system reliability at time } t \)

\( n = \text{number of units in series} \)
\[ R_i(t) = \text{unit } i \text{ reliability at time } t, \text{ for } i = 1, 2, 3 \ldots n \]

For exponentially distributed times of failure (i.e. constant failure rate) of unit \( i \), the unit reliability is described by Dhillon (1999) and (Stapelberg, 2008).

\[ R_i(t) = e^{-\lambda it} \quad \text{(Eq. 2.4)} \]

Where \( R_i(t) \) is the \( i \)th unit reliability at time \( t \), and \( \lambda_i \) is the constant failure rate of unit \( i \).

By substituting equation 2.4 in equation 2.3, the below formula for reliability of series system emerges.

\[ R_s(t) = e^{-\sum_{i=1}^{m} \lambda_i t} \quad \text{(Eq. 2.5)} \]

For \( \lambda_i t \ll 1 \), equation 2.5 becomes

\[ R_s(t) \approx 1 - \sum_{i=1}^{m} \lambda_i t \quad \text{(Eq. 2.6)} \]

### 2.6.2 Parallel System Reliability

For parallel system reliability, as long as a ‘parallel’ component fails, the reliability of the overall system is reduced. However, the system remains completely or partially functional.

If any of the units fails, the system will continue to operate. Failure will only come when all of the modules fail.
Figure 2.5: Parallel System

Uniting reliability for time \( t \) dependent, the parallel system reliability is:

\[
R_p(t) = 1 - \prod_{i=1}^{n} F_i(t)
\]  
(Eq. 2.7)

Where

\( n \) = number of units in parallel

\( R_p(t) \) = parallel system reliability at \( t \)

\( F_i(t) = 1 - R_i(t) \) = time dependent failure probability of unit \( i \), for \( i = 1, 2, 3, \ldots, n \)

\( R_i(t) = \) time-dependent reliability of unit \( i \), for \( i = 1, 2, 3, \ldots, n \)

Based on the formula that \( F_i(t) = 1 - R_i(t) \), equation (2.7) becomes;

\[
\left( R_p(t) = 1 - \prod_{i=1}^{n} (1 - R_i(t)) \right)
\]  
(Eq. 2.8)

For constant failure rate or exponentially distributed times of failure for unit \( i \), by substituting equation (2.4) into equation (2.8), we get

\[
R_p(t) = 1 - \prod_{i=1}^{n} (1 - e^{-\lambda_i t})
\]  
(Eq. 2.9)
For identical units, Eq. 2.8 becomes

\[ R_p(t) = 1 - (1 - e^{-\lambda t})^n \]  
(Eq. 2.10)

Where \( \lambda \) is the unit constant rate, for \( \lambda t << 0.05 \), equation 2.10 yields;

\[ R_p(t) \approx 1 - \prod_{i=1}^{n} \lambda_i t^n \]  
(Eq. 2.11)

For identical units, equation (2.11) is simplified to;

\[ R_p(t) \approx 1 - (\lambda t)^n \]  
(Eq. 2.12)

### 2.6.3 Failure Mode and Effect Analysis (FMEA)

As a systematic process, failure mode and effect analysis (FMEA) is meant to analyze reliability. Not only does it improve operational performance of the production cycles but it also reduces their overall risk level. The task is performed in two ways; the system potential failures identified through the preliminary analysis are prevented and plant historical data are collected (Scipioni et al., 2002). The FMEA methodology was developed and implemented for the first time in 1949 by the United States Army. Owing to its characteristics of strength and validity, FMEA application field extended first to aerospace and automotive industry, then to general manufacturing in 1970s (Scipioni et al., 2002).

As a powerful and effective analytical tool, FMEA is widely employed in engineering project system design in order to examine possible failure modes and eliminate
potential failure (Xiao et al., 2011). In particular, it provides design engineers with quantitative or qualitative measures. Such measures are necessary to guide the implementation of corrective actions by focusing on the main failure modes and its impact on the products (Chen, 2007). As a standard practice in Japan, America, and European manufacturing companies, FMEA has been widely adopted by reliability practitioners (Chen, 2007) and (Zammori and Gabbrielli, 2011). Chen (2007) investigated a number of FMEA applications in various industries in Japan. He found that FMEA can be successfully manipulated in many industrial areas such as automobiles, electronics, consumer products, power plants, and telecommunications.

A vast range of information is collected based on process prediction and possible failure analysis by a technical panel. Such information is constructive to manufacturing process analysis and cumulating knowledge for improvement. Besides, collecting and organizing the knowledge obtained from FMEA is helpful in reusing and sharing FMEA knowledge, the basic resource for quality administration. During manufacturing process, apposite use of FMEA knowledge is a key promise of continuous improvement in manufacturing process (Xiuxu and Yuming, 2010). The characteristics of FMEA Knowledge in manufacturing process can be summarized as follows:
Thus, the benefit of FMEA is the continuous improvement of product quality and reliability, as a result of which less failure occurs (Stamatis, 2003)

**Figure 2.6: Steps for Performing FMEA**
2.6.4 Cause and Effect Diagram (CAED)

Cause-and-Effect diagram or fishbone is the diagram which shows the causes of a certain event proposed by Ishikawa (1985). Fishbone diagram is typically utilized for the quality defect prevention, product design and in order to recognize the capability of causing an overall effect. Each cause or reason for the fault is a source of variation. Causes are commonly classified into chief categories to recognize these sources of variation. The categories can typically be as follows:

- **People:** Anyone involved in the process in terms of manual processing, material handling and controlling.
- **Methods:** How the process is performed and particular performance requirements including policies, procedures, rules, regulations and laws.
- **Machines:** All equipment, such as computers, tools, etc. necessary to manipulate the job.
- **Materials:** Each sort of material applied in order to produce final product including raw materials, parts, etc.
- **Measurements:** Data generated from the process and applied to assess its quality.
- **Environment:** The circumstances, such as geographical location, temperature, humidity, time and culture in which the process operates.
- **Management:** Influential approach and strategy planning factor to prevent the cause for faults.
As mentioned, fishbone diagram illustrating parameters of equipment, process, people, method, machine, materials, measurement, environment and management, all influence the overall faults. As Figure 2.7 shows, smaller arrows connect the sub-causes to major causes. Ishikawa diagrams were presented by Kaoru Ishikawa (1985), who was the first one in quality management processes in the Kawasaki shipyards. In the process, he became one of the founding fathers of state-of-the-art management. As Tague (2005) mentioned, fishbone is one of the seven basic tools of quality control. It is popular as a fishbone diagram on the basis of its shape resembling the side view of a fish skeleton. Mazda Motors famously used an Ishikawa diagram in the development of Miata sports car. Paint shop number 2 in Iran Khodro Company can be another example. It applied this method after launching the paint shop with the aim of increasing the reliability of whole system (Based on quality documentation of IKCO).
2.7 Case Studies

Iran Khodro Company, also known as IKCO, is the leading Middle East automaker with its headquarters based in Tehran. IKCO is a public joint stock company with the objective of the creation and management of factories to manufacture various types of vehicles and parts as well as selling and exporting them. IKCO produces vehicles under 11 brand names. The Iranian-designed IKCO’s Samand has replaced the dated Paykan as Iran's "national car." It also features an Iranian designed hybrid dual-fuel engine in its Soren variant. The firm has a long-term relationship with European and Asian manufacturers including PSA Peugeot Citroen, manufacturing and assembling a number of models under license from these firms. In 2009, Peugeot 206, Peugeot Pars, Peugeot 405, Peugeot Roa, and Samand sedans were IKCO's export-bound cars sent to Azerbaijan, Iraq, Armenia, Uzbekistan, Turkmenistan, Syria, Russia and Belarus.

2.7.1 Plant Lay Out

Plant layout of the paint shop in IKCO is based on arranging the processes to paint the products, the body of cars. According to various types of layouts in manufacturing design, there is a product layout in this part of production line. In the production line of this company, production is based on producing cars in almost high volume in various types and options. Therefore, the production type of this company is a mass production.
The differences between capability of trim shop and paint shop can live up to scratch the export or the other internal consumers of SKD sites. Production will be devoted to maximum of SAMAND, 206, VAN, ROA producing. The Best Applicable Scenario: IKK IKCO.S IKCO.N

Figure 2.8: Lay Out of IKCO
2.7.2 Production Type

Table 2.1: Rate of Divergent Products

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>UPH</th>
<th>UPD</th>
<th>UPY</th>
</tr>
</thead>
<tbody>
<tr>
<td>206</td>
<td>35</td>
<td>753</td>
<td>199,500</td>
</tr>
<tr>
<td>SAMAND</td>
<td>52</td>
<td>1,118</td>
<td>296,400</td>
</tr>
<tr>
<td>PARS,405</td>
<td>48</td>
<td>1,032</td>
<td>273,600</td>
</tr>
<tr>
<td>ROA</td>
<td>20</td>
<td>430</td>
<td>114,000</td>
</tr>
<tr>
<td>L90</td>
<td>12</td>
<td>258</td>
<td>68,400</td>
</tr>
<tr>
<td>PICKUP</td>
<td>14</td>
<td>301</td>
<td>79,800</td>
</tr>
<tr>
<td>SUV</td>
<td>3</td>
<td>65</td>
<td>17,100</td>
</tr>
<tr>
<td>Rate of Production</td>
<td>184</td>
<td>3,956</td>
<td>1,048,800</td>
</tr>
</tbody>
</table>

Figure 2.9: Paint Shop Process Flow Diagram
2.7.3 Process

As shown Figure 3.9, different modules on first floor including pre-treatment (PT), electro deposition (ED), masking, sealer and PVC are considered.

In PT module, the body must be washed. So, this equipment is completely robotic based. The sensors should induce skid’s labels. After that, the robots spray the selected material. It has several sections including phosphate and rinse. Depending on the specification of the body, the robots select the appropriate material for the cleaning purpose.

In ED module, the body is subsided into the material pool slowly. After this, the contaminated body comes up from the pool. ED is electro deposition section. Via electrolyzing and creating positive and negative poles, electrons are released from vehicle body, and a strong layer of color covers the body. The body is transferred to the lift by roller bed. After lifting, the body goes across the ED oven in level 4 to make it dry. Afterwards, the hot body is moved to the lift and transferred to ED cooler in level 3; the hot body goes across the cooler.

Figure 2.10: Electro Deposition (IKCO’s Depicted Process)
Masking is used to cover the surface of booth components (e.g., robots, hoses) to protect them from a paint overspray build up. Two types of masking can be utilized; protective covers and chemical agents. Protective covers refer to a variety of shielding materials used to blanket or wrap booth components. The selection of protective covers depends on the component, the type of paint being applied and the anticipated amount of overspray. Protective covers include:

- Polyethylene (plastic) sheeting and masking cling film
- Plastic hose-wrappers
- Robot socks and covers
- Tar paper or roofing felt

Sealer is a popular type of sticky material to increase the protection of some part in the body like around the door, roof, bonnet and truck. The body transferred to the lift by roller bed. After lifting, the body goes across the sealer oven in level 5 by roller bed to make it dry. Then, the hot body is moved to the lift and transferred to sealer cooler in level 4; the hot body goes across the cooler. After sealer section, the monorail takes up the body, sends it to power and free handling system and transfers it to PVC section. PVC is a kind of sealer family (which is) from glues categories. The PVC is sprayed to under the vehicle body by robots. The robots are able to identify the amount of PVC that should be used under the body. The body is transferred to the lift by roller bed. After lifting, the body goes across the PVC oven in level 4 by roller bed to make it dry. Then, the hot body is moved to the lift and transferred to PVC cooler in level 3. The temperature of hot body reduces to the normal range by passing through this section.
The modules on the second floor of paint shop include primer, top coat and central control room (CCR). After PVC section, the scissor lift brings down the body from the power, releases the conveyer and leaves it on the roller bed which sends the body to primer section. In this section, the first paint layer is sprayed on the body. We must know that the robot recognizes the color according to the selected color in CCR where operator can command the robots to use the suitable color. The body is transferred to the lift by the roller bed. After lifting, the body goes across the primer oven in level 5 by the roller bed to make it dry. Then, the hot body is moved to lift and transferred to primer cooler in level 3; the hot body goes across the cooler.
After the primer section, the roller bed transfers the body and sends it to top coat section. In this section, the second paint layer is sprayed on the body. It may be mentioned again that the robot recognizes the color according to the selected color in CCR where operators can command the robots to use the suitable color. The body is transferred to the lift by the roller bed. After lifting, it goes across the top coat oven in level 5 by the roller bed to make it dry. Then, the hot body is moved to the lift and transferred to Top Coat Cooler in level 4. The hot body goes across the cooler, with the exception of Metallic colors for which the robots bin is changed.

As mentioned earlier, CCR is a place in which the schedulers (computers) are located. Hence, the function of this section plays an important role in this dissertation. The main specifications of CCR are listed as below:

Control room is generally defined by its design, use and location.

Control rooms allow people to control a system from a remote or centralized location.

Central control station rooms are separated from the remainder of the building.
Figure 2.13: Central Control Room (IKCO’s CCR)

Figure 2.12: Central Control Room Scheduler Computers (IKCO’s CCR)

The detail of CCR function is available in appendix B.1.
This section consists of some coolers to moderate the hot bodies. Due to reasons such as shortages of parts, this section also comprises buffer places to provide room to put the completed bodies. Layout of level 3 is available in appendix .B.1.

This section consists of ovens. Oxidizer is side equipment for oven in order to remove the oxidized weather inside the oven. Layout of level 4 is available in appendix .B.2.

2.8 Mathematical Formulation

This is a kind of discrete random variable distribution, and it can be applied in situation where one is enthusiastic about the occurrence of a number of events of the same type.
More specifically, the distribution is applied whilst the number of possible events is large, but the probability of occurrence over a given time interval is small. Two typical of such a situation are the waiting lines and the occurrence of defects. The distribution is named after Simeon Poisson (Heyde and Seneta, 2001), a French mathematician who expresses the probability density function known as Poisson Formulas:

\[ f(y) = \frac{\lambda^y e^{-\lambda}}{y!}, \quad for \; y = 0, 1, 2, ..., n \]  

(Eq. 2.13)

\[ F(Y) = \sum_{i=0}^{y} \frac{\lambda^i e^{-\lambda}}{i!} \]  

(Eq. 2.14)

In order to analyze the dissertation results in chapter four, the following formulas are being applied:

1. Mean Definition

Let \( X_1 \; X_2 \; X_3 \; ... \; X_n \) be \( n \) observations of a random variable \( X \) in order to measure the average of \( X_1 \; X_2 \; X_3 \; ... \; X_n \). One of the most commonly used statistics is the Mean defined by the formula

\[ \text{Mean} = \frac{\text{Sum of } X \text{ values}}{N(\text{Number of values})} \]  

(Eq. 2.15)

2. Standard Deviation Definition:

Standard deviation is a statistical measure of spread or variability. The standard deviation is the root mean square (RMS) deviation of the values from their arithmetic mean.

\[ s = \sqrt{\frac{\sum(X-M)^2}{n-1}} \]  

(Eq. 2.16)
3. Variance Definition:

Variance is the square of the standard deviation. The measure of spreading degree among a set of values is variance. The exact description of variance is the measure of the tendency of individual values varying from the mean value.

\[ \text{V} = s^2 \]  

(Eq. 2.17)

4. Normality Test: Data has normal distribution if skewness test range is between -2 and +2 (George and Mallery, 2006).

2.9 Conclusion

Chapter two reviews the previous research on the divergent methods of scheduling and manufacturing control system. It is shown that the vast majority of scholars have performed a number of researches in order to increase the efficiency and reliability of systems. Thus, appropriate scheduling can be a perfect scope by which efficiency and reliability of systems can be enhanced. Efficiency and reliability of system directly depend on the method of scheduling which is chosen and applied to each system. In this chapter, definitions regarding job allocation are discussed. Then, the role of different queuing systems in the centralized scheduler environment is reviewed. Furthermore, priority rules to provide appropriate and time-efficient solutions have been mentioned. Eventually, reliability and scientific method of root cause analysis are dealt with.
3 CHAPTER THREE

METHODOLOGY

3.1 Introduction

As manufacturing processes become far more complicated, factories show more enthusiasm about improving their capability. A higher level of capability can enhance their capacity in terms of the number of jobs being processed through a number of machines and equipment. As a case in point, in a flow line, all jobs should be processed by the same set of machines in a linear style from the first to last job station. Just one machine conducts all the processing for each station. Clearly, due to the simple nature of industrial environment, subjugation of those manufacturing systems is much easier than multiple machines altering into flexible manufacturing systems at different stages. Even though, it is still required that jobs transfer from the first to the last stage in order (Kurz and Askin, 2003). Flexible manufacturing systems occur in many divergent environments including automobile manufacturing systems (Smith., 2003). Scheduling flexible flow lines in an automobile plant in which a number of multiple machines and jobs are manipulating should be efficient and appropriate (Piramuthu et al., 1994).

As mentioned, a number of utilitarian algorithms such as genetic algorithms, neural network, and fuzzy logic have been created and applied in order to obtain proper scheduling. On the other hand, because of the complexity of industrial manufacturing systems, the scheduling and controlling system should be much more efficient, reliable
and fault tolerant. The applicability of DCSs in coordinating and executing jobs has been displayed in the literature. DCSs are fundamentally applicable to fulfill the significant gap left by the centralized concepts. In this regard, Leita˜o and Colombo (2006) applied a distributed concept in manufacturing system.

Furthermore, in the vast majority of car manufacturing system the only criterion for allocating jobs to appropriate machines is to apply FIFO policy. Therefore, the main reason of failing to provide for fairness in distributed systems is considering only the criterion of time stamp as an input. Based on this criterion, the queue of jobs should be formed. Then, those jobs are allocated to the machines. Owing to an increase of manufacturing system efficiency and reliability in this dissertation, the three criteria of each job are being simultaneously considered. In this new scheduling method, the jobs should be positioned in temporary queue and sorting via developing bubble sort in MATLAB software (distributed computing tool box). Accordingly, three factors including priority, time action (duration) and time stamp are considered for each job.

To evaluate the proposed method, simulation is operated. The simulated algorithm shows that applying the proposed method of scheduling increases the efficiency of simulated scheduler by eliminating the faults caused by ignoring priority criteria and time action of jobs. Besides the mentioned simulated algorithm, there is a mathematical proof in order to show the enhancement of reliability. This chapter also introduces a case study to evaluate the data at the IKCO’s paint shop, the biggest car manufacturing company in Middle East. Eventually, it is proved that the rate of increase in efficiency and reliability by applying the proposed scheduling method is remarkable. The methodology of the dissertation is illustrated in Figure 3.1.
Figure 3.1: Flow Diagram of Dissertation
3.2 New Scheduling Method

As mentioned before, in majority of car manufacturing systems, the only criterion of allocating jobs to appropriate machines by schedulers of CCR (central control room) is FIFO policy. Accordingly, ignoring priority and time action of jobs for scheduling of those, is the major cause of failing to provide for fairness in distributed systems. In order to increase the efficiency and reliability of car manufacturing system, the three criteria (besides time stamp, priority and time action) for each job are simultaneously considered in this dissertation. The methodology involves normalizing the data and then sorting jobs via developing bubble sort in MATLAB distributed computing software. The study is performed on the basis of the criteria of priority, time action duration as well as time stamp. In order to evaluate the proposed method and optimize efficiency and reliability, a simulation is created. Then, mathematical proof is provided to show the increase in reliability. As mentioned, the scope of this dissertation is restricted to the evaluation of data in IKCO’s paint shop. As a case study, IKCO is used to evaluate the proposed method of scheduling. Eventually, as it can be observed in the result presented in chapter four, this evaluation concludes that the efficiency and reliability of the system are enhanced.

3.2.1 Assumptions

With the aim of increasing the efficiency and reliability, the afore-mentioned method can be applied to manufacturing systems. Once the safety of an automotive manufacturing system is jeopardized, based on consuming igniting substance and high temperature environment, it is obviously prone to collapse. Hence, some preventive
actions should be taken to increase fault tolerance. The assumptions of the methodology are as follows:

1. The schedulers are distributed.
2. Weight factors for each job are predetermined in terms of time stamp, action time and priority.
3. The number of machines and jobs are restricted and finite.
4. The only errors related to scheduling and priority of jobs is considered. the other errors caused by human faults are not included.
5. The system reliability includes series system and parallel system.
6. The finite queue of jobs is applicable to sorting module.

3.2.2 Normalize Method

Normalization refers to the division of multiple sets of data (in this dissertation data are vector’s elements) by a common variable in order to negate that variable effect on the data. Therefore, normalization makes the underlying characteristics of the data comparable. This allows data on different scales to be compared by bringing them to a common scale. In terms of the levels of measurement, these ratios only make sense for ratio measurements (where ratios of measurements are meaningful), not interval measurements (where only distances and not ratios are meaningful). Parametric normalization frequently uses pivotal quantities. Thus, the functions for whose sampling distribution do not depend on the parameters, and particularly ancillary statistics; pivotal quantities can be computed from observations, without determining parameters (Fischer, 2011).
3.2.3 Programmed Methodology

In this new algorithm of scheduling, the jobs should be arranged based on three criteria of priority, time action and time stamp. As discussed below, the new algorithm of sorting considers the three criteria to arrange the jobs and determine the queue of jobs. Figure 3.2 illustrates that time action, time stamp and priority of each job should be multiplied in a specific weight factor. The amount of weight factor for priority derives from the importance of the six criteria mentioned in section 1.2 for each job. As arranged, the weigh factor of the time action is changed in an opposite manner to the length of time. For instance, two jobs can be considered. The first one is loading new program on PLC, and the second one is summing up two integers with the same sequence but with different time durations received by CCR. The processing of the first job takes one second, and the other takes 1/1000 of second. Based on the queuing theory, it is not fair that the first job is processed by CCR because of being received just a little bit of time earlier than the second one. This implies that, the other must be delayed 1000 times of its time processing. So, by considering the condition of each job, the multiplied weight factor for that job can be changed.
The development of bubble sorter programming is available in appendix A.1.

To recapitulate, the total time of process will be reduced by applying this sorter. Applying this algorithm, the faults caused by ignoring priority and time action (besides time stamp) in scheduling jobs are eliminated. In turn, this algorithm results in a more efficient and reliable system of job allocation. In this regard, a coefficient of $K$ (Eq.3.1) is multiplied (*) in total faults of system. The multiplied amount showing the scope faults (error) is automatically removed from the system. Based on the fact that the amount of $K$ is between 0 and 1 ($0<K<1$), the system faults are reduced. On the other
hand, the performance of system obviously increases. This state is proved via Passion

distribution in Eq. 2.13 and Eq.2.14.

For example, five jobs arrived in the order described as follows:

Time Stamps: 1, 2, 3, 4, 5
And Time Actions: 2, 4, 1, 5, 3
And Priority: 3, 5, 2, 1, 4

In different circumstances, the weight factors of the mentioned parameters (T_s, T_a, P_r)
are changed in order to obtain the best status. In manufacturing systems, priority plays
a more indispensable role. On the other hand, the time action (durations) of jobs are
the determined items. Consequently, the weight factors can be defined as below:

\[ A = (0.3*T_s) + (0.5*T_a) + (0.2*P_r) \]

A: value of each job
T_s: time stamp
T_a: time actions
P_r: priority

Eventually, the job queue should be reformed based on the value of each job:

1.9, 3.6, 1.8, 3.9, 3.8, 3.9, 3.8, 3.6, 1.9, 1.8

Job1, Job2, Job3, Job4, Job5, Job4, Job5, Job2, Job1, Job3

3.3 Evaluation

To evaluate of the afore-mentioned algorithm, simulation method for numerical test

case, mathematical proof and the case study of IKCO are employed. Figure 3.4 illustrates
that reforming jobs in new queues eliminates the faults of systems caused
by ignoring priority criteria aspects and time action of those jobs. P (E) is the
probability of errors occurring. Hence, P1 is the probability of occurring faults or
errors for the schedulers working based on FIFO policy. P2 is the probability of faults or errors occurring for schedulers based on the proposed algorithm.

Figure 3.3: The Flowchart of Existing Method Of Scheduling

Figure 3.4: The Flowchart of Proposed Method Of Scheduling
3.3.1 Simulation Method for Numerical Test Case

As mentioned in section 1.4, the first objective is obtained by using MATLAB distributed computing server (DCS) software. Independent MATLAB® operations are simultaneously coordinated and executed on a cluster of computers, speeding up execution of huge scheduling problem. In some occasions, the priority and importance of some tense jobs demand the distributed system wait for the moment when the tense job enters the line. This is due to the fact that ignoring to take immediate measures for those tense jobs can reduce the efficiency and reliability of the whole system. In this part, we simulate the algorithm with MATLAB distributed computing server. So, we first find a resource as a scheduler.
The programming of simulated algorithm in MATLAB distributed computing can be seen in appendix A.2.
The simulated algorithm is created with MATLAB distributed computing software. So, a resource should first be found as a scheduler. Then, three jobs should be created, and in third step tasks should be assigned to each job. Now, it is time to submit all the jobs (with their tasks) to scheduler. The jobs are both submitted based on common algorithm and the proposed one. In the proposed scheduling method, the jobs are sorted out with the developed bubble sorter (Appendix A.1) already created by applying the three criteria (time stamp, time action and priority). The queue is thus reformed, and the jobs are assigned from the reformed queue to the system. This simulation is performed several times and random function for failures (errors) in the simulated algorithm is created.

### 3.3.2 Mathematical Proof

To show the reliability enhancement by applying the proposed method of scheduling, in this section a mathematical proof is presented. Based on the simulated algorithm in section 3.3.1 and Eq.2.13 and Eq. 2.14 mentioned in chapter 2:

Where $\lambda$ is the distribution paramete.

Then, cumulative distribution function is

$$F(Y) = \frac{Y^\lambda e^{-\lambda}}{Y!}$$

$E_{\text{Scope}}$: The errors caused by ignoring priority aspects and time action of each job

$E_{\text{Non-scope}}$: The errors occurring because of other reasons (these errors are not related to ignoring priority and time action of job)

$$E_{\text{Total}} = E_{\text{Scope}} + E_{\text{Non-scope}}$$  \hspace{1cm} (Eq. 3.1)
1: \[ F (E_{\text{Total}}) = \frac{\lambda^{E_{\text{Total}}} e^{-\lambda}}{E_{\text{Total}}!} \] (Eq. 3.2)

2: \[ F (E_{\text{Scope}}) = \frac{\lambda^{E_{\text{Scope}}} e^{-\lambda}}{E_{\text{Scope}}!} \] (Eq. 3.3)

\[ K = \frac{\lambda^{E_{\text{Scope}}} e^{-\lambda}}{E_{\text{Scope}}!} \frac{\lambda^{E_{\text{Total}}} e^{-\lambda}}{E_{\text{Total}}!} \] (Eq. 3.4)

The \( e^{-\lambda} \) causes the equation becomes non-linear. In Eq.3.4, \( e^{-\lambda} \) is deleted from the whole fraction. As a result, \( k \) ranges between zero and one.

Probability and reliability relationship can be defined in the formula below:

\[ R = 1 - P (E) \] (Eq. 2.1)

Where \( R \) stands for system reliability and \( P (E) \) represents the number of events (errors) in time duration

\[ P (E) = P (E_{\text{Scope}}) + P (E_{\text{Non-scope}}) \] (Eq. 3.1)

\[ P (E_{\text{Scope}}) = k * P (E) \] (Eq. 3.5)

where \( 0 < k < 1 \)
By combining equations (Eq. 3.3) and (Eq. 3.4) mentioned above, \( P(E) \) can be calculated from the formula below:

\[
P(E) = \frac{P(E_{Non\text{-}scope})}{1 - k} = \frac{1}{1 - k} * E_{Non\text{-}scope}
\]  
(Eq. 3.6)

Or: \( k' = \frac{1}{1 - k} \)

Then: \( P(E) = k' * E_{Non\text{-}scope} \)  
(Eq. 3.7)

where \( k' > 1, k' = k + 1 \), and \( k \) (or \( k' \)) is system-dependent; it varies from system to another. Since systems are never error-free and encounter errors all the time, K is always greater than 0. Based on this justification, the \( P(E_{Non\text{-}scope}) \) is not equal to 0. Therefore, the value of \( k \) is always less than 1. So it is obvious that by applying the sorter methodology \( E_{scope} \) will be omitted, it means that the amount of \( P(E) \) based on the (Eq. 3.1) will be reduce and based on reliability formula (Eq. 2.1), it leads to increase of reliability.

### 3.3.3 Distributed Control Systems (DCSs)

A distributed control system (DCS) permits its users to process large, time-consuming workloads in a collaborative style. With the aim of achieving this target, each workload must be divided into smaller independent units called jobs. Afterwards, these jobs must be redistributed to proper computational elements where they are processed in parallel.
Creation of a DCS can be achieved for agents and jobs. So, intelligent approaches have been presented for the optimization of the assigned jobs into machines (Computers).

A multi-job system includes several autonomous jobs with their own strategies and characteristics. Jobs collaborate with one another in order to fulfill the targets of the system. Cooperating jobs create a job collection, and collections can be considered as elements that create manufacturing lines of job collections.

### 3.3.4 Assumptions in Case Study

The case study in this dissertation deals with the performance of paint shop semi-robotic in car manufacturing environment. Accordingly, all process including material handling, manufacturing process, and inspections are being controlled by CCR. The scope of the case study in this dissertation is restricted to IKCO paint shop situated in Iran and with a capability of producing 52 UPH and a cycle time of 1.14 minutes. The vehicle brand in this paint shop is Samand, the national brand in Iran. Therefore,
besides assumptions mentioned in section 3.3, there some other issues for the case study of IKCO assumed as follows:

1. The scope brand: Samand
2. The number of cars produced per hour: 52 UPH
3. The system: semi robotic

3.3.5 Cause and Effect Diagram (CAED)

In order to evaluate the data in IKCO, the applied tool is CAED. As mentioned in the previous chapter, this method is known as fishbone or Ishikawa diagram. CAED can be visually separated into two sections: the right-hand side and the left-hand side. The fish head clarifies the effect. Accordingly, all the causes are connected to the central fish vertebral column.

![Cause and Effect Diagram](image)

**Figure 3.7: Factors Contributing to Defect**

These causes are capable of providing applicable and useful checklist. Due to the past experiences, CAED diagram is an extremely fruitful method in order to recognize the
root cause problems. Then appropriate measures should be taken to prevent the occurrence of root cause problems. Causes can be emanated from brainstorming sessions. These groups can then be labeled as categories of the fishbone. They can typically be one of the traditional categories mentioned above, but there may be something unique to the application in a specific case. Causes can be traced back to root causes with the afore-mentioned technique.

Typical categories applied to IKCO data are:

- Equipment (technology, machines, tools)
- Method (process)
- Material (raw material, consumables and information.)
- Man power (worker, operator, mind power (brain work: suggestions, innovations, creative plans))
- Measurement (inspection, audit)
- Environment (temperature /humidity)
- Management (management scheduling)
- Maintenance (repair, renew)

To make normal distribution, the data has been observed in 36 working days of the automotive manufacturing system paint shop (Montgomery, 2007). The data are related to the rate of Samand production in paint shop of IKCO. As mentioned before, the capacity of production per hour in this paint shop (UPH) is 52. Due to the various reasons, the rate of production obviously declines at times. Some of those reasons are caused by ignoring priority and time action of jobs. By applying the proposed method of scheduling, such faults (errors) can be eliminated. This results in an increase of the car production rate. On the other hand, the main reasons of faults in different module of paint shop can be determined by fishbone diagram. By applying the proposed
method, as previously mentioned, the rate of faults in system reduce. Based on reliability formulations, the reliability of the whole paint shop is increased.

3.4 Conclusion

It should be mentioned that simulation is essential to evaluate the effect of priority and time action of jobs on scheduling. Accordingly, the evaluation of the proposed methodology presented in chapter three requires introducing the IKCO case study. Based on all ideas mentioned and the results of simulated algorithm, it can be concluded that this algorithm is capable of increasing the efficiency and reliability by reducing the amount of errors caused by ignoring the priority and time action of jobs. In chapter four, the result of simulation method for numerical test case is presented. The result of the case study, before and after applying the proposed method, are also analyzed and discussed.
CHAPTER FOUR

RESULTS AND DISCUSSION

1.1 Introduction

The proposed method of scheduling to increase the system efficiency and reliability are evaluated through numerical test case (simulation), mathematical proof and the case study of IKCO paint shop which was explained in Chapter Three. As mentioned, in the manufacturing system, some preventive actions should be taken to increase fault tolerance. Accordingly, paint shops in automotive manufacturing systems, are the bottleneck of the whole system due to its function in terms of applying ignitable chemical substances and high surrounding temperature. The CCR system in IKCO paint shop plays the role of job distributor to increase the efficiency and reliability of whole system via applying new method of scheduling.

Based on the previous chapters, in order to recognize tense jobs temporary job queues by considering job priority, time action and time stamp are formed. This provides appropriate circumstances in which the efficiency and reliability of productions soar. The obtained results clarifies that the probability of occurring faults (errors) is reduced by considering priority aspect and time action of jobs. In this regard, evaluating the proposed method of scheduling via numerical test case shows an increase in system
efficiency. Based on Section 3.3.2, mathematical proof demonstrates that system reliability is enhanced by applying the proposed method of scheduling. Eventually, the case study of IKCO’s paint shop also reveals that the proposed scheduling algorithm increases the efficiency and reliability of paint shop.

The main advantage of the proposed method of scheduling in manufacturing systems is reducing the rate of faults (errors) which are derived from ignoring priority and time action of jobs. Based on Figure 4.2, the efficiency of production significantly increases by considering the priority and time action of each job and eliminating the scope errors. The Figure 4.6 shows divergent errors in the system. It can be observed that the largest portion of faults (errors) is allocated to the process. The second and third largest parts are respectively devoted to equipment and management. The next step is the root cause analysis of each one of the failures up to two levels of problem solving. Thus, Figure.7 illustrates that ignoring the time action of each job may lead to a remarkable amount of faults (errors) in the method (process) section. Therefore, the proposed method of scheduling is capable of eliminating these sorts of errors. The next portion of faults (errors) is specified to equipment. In this section, the root cause analysis reveals that by ignoring priority of some maintenance activities the rate of errors in system is increased. This can be considered as one of the two critical sub-branches of equipment faults (errors). In this research, the proposed method of scheduling is indeed suggested as a way to eliminate such faults (error). As noted, the third proportion of faults (errors) belongs to management, which occurs by ignoring the priority of jobs. After developing the proposed method of scheduling, owing to its function, these kinds of faults (errors) can be omitted spontaneously.
The achieved results in the performance of the proposed method not only show the enhancement in efficiency but they also cause the improvement of the reliability to a great extent. Figure 4.9 shows the enhancement of reliability after developing the proposed scheduling method. The deep analysis of bonefish is performed to recognize the root causes for ignoring priority, time action, and time stamp as well as to evaluate each main operation in IKCO paint shop. The next measure which should be taken is categorizing those faults (errors) on the ground of CAED criteria including equipment, process, people, material, environment and management. Moreover, these criteria are broken down into two levels in order to thoroughly analyze faults (errors) and determine the causes they originated from. The Figure 4.6 illustrates the main factors causing reduction in the reliability of IKCO’s paint shop are process and maintenance which were derived from ignoring priority and time action of jobs. The Figure 4.8 shows that some of those root causes are derived from ignoring priority and time action of jobs such as scheduling priority of urgent maintenance. As noted, the proposed scheduling method simulated in Chapter Three is capable of removing these kinds of faults (errors). Indeed, the proposed method enhances the reliability of system by reducing the faults (errors) in system.

1.2 Result of Simulated Algorithm for New Method of Scheduling

As mentioned in Section 3.3.1, the simulated algorithm is created with MATLAB distributed computing software. So, a resource should first be found as a scheduler. Then, three jobs should be created, and in third step tasks should be assigned to each job. Now, it is time to submit all the jobs (with their tasks) to scheduler. The jobs are both submitted based on common algorithm and the proposed one. In the proposed
scheduling method, the jobs are sorted out with the developed bubble sorter (Appendix A.1) already created by applying the three criteria (time stamp, time action and priority). The queue is thus reformed, and the jobs are assigned from the reformed queue to the system. This simulation is performed several times and random function for faults (errors) in the simulated algorithm is created. Accordingly, it is revealed that the applied algorithm results in better performance in terms of reducing system faults (errors). Besides, it is obvious that it increases the efficiency of the system via fair judgment and temporary queue changing based on the proposed method. Figure 4.1 illustrates the applied method results in increasing efficiency in comparison with the common scheduling method. In Figure 4.1, it is illustrated that the time of crashing scheduler decreases by the application of the proposed method. As shown, the efficiency of optimized algorithm is obviously better than the common algorithm. Subsequently, the probability of crashing scheduler reduces showing the increase of system reliability as well. Thus, our system is reliable and fault occurs less than the normal status.
Figure 3.4: A comparison between the previous status and the status produced by the proposed algorithm

The figure 4.1 shows a comparison between efficiency of scheduler when applying existing method and proposed method are applied. In existing scheduling method from time 7 up to time 10 the scheduler system crashed but by applying the proposed method of scheduling the system did not crash.

1.3 Influence of New Method of Scheduling on the Efficiency of IKCO’ Paint Shop

Figure 4.2 illustrates a comparison on efficiency of production before and after considering proposed new scheduling method in this thesis. The planned capacity of paint shop is equal to 52 automobiles units per hour. The efficiency belong to the 36 were measured out of 52 and multiplied by 100. Considering priority and time action of each job, beside its time stamp, in turn, causes significant enhancement of efficiency over time. On the basis of Figure 4.2 all amounts of efficiencies are increased via considering the new scheduling method.
Figure 3.5: Comparison of Paint Shop’ Efficiency before and after Proposed Scheduling

Figure 4.3 shows the distribution of efficiency for the 36 surveyed days of the research a mean of 91.81% is calculated. According to Figure 4.3, the majority of frequencies occurred from 90% to 94% and the standard deviation of efficiency is measured by 0.85. The Figure 4.1 illustrates that by average, the efficiency occurred (-0.85, +0.85) percent from mean 91.81%. (Appendix D shows one working day data before and after applying proposed method of scheduling).
Figure 3.6: Histogram of Efficiency before Considering New Scheduling Method

Figure 4.4 represents the importance on efficiency while after considering new scheduling method of the research. This histogram shows that the mean of efficiency in comparison with the before status has been increased for 36 observations. The new mean efficiency is measured by 95.64% while it was calculated 91.81% before considering the new method of scheduling. Although, it is obvious that standard deviation appears to smaller in comparison with before status. Based on Figure 4.4 standard deviation has improved. It means that standard deviation reduced from 0.89 to 0.59. Therefore, according to all points which has been mentioned, it can be concluded that both mean and standard deviation are improved by employing proposed scheduling method.
Figure 3.7: Histogram of Efficiency after Considering the New Scheduling Method

Figure 4.5 compares the normal distribution of both efficiencies before and after employing the new scheduling method. Based on this histogram for 36 days as the samples the mean of efficiency soared from 91.81% to 95.64% and the standard deviation reduced from 0.85 to 0.59.

Table 3.1: Descriptive Statistics: Efficiency of System before and after New Scheduling Method
<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency Before</td>
<td>36</td>
<td>91.8%</td>
<td>0.85</td>
<td>90</td>
<td>94</td>
<td>0.11</td>
</tr>
<tr>
<td>Efficiency After</td>
<td>36</td>
<td>95.6%</td>
<td>0.59</td>
<td>94</td>
<td>97</td>
<td>-0.58</td>
</tr>
</tbody>
</table>

Figure 4.5 compares the normal distribution of both efficiencies before and after employing the new scheduling method. Based on this histogram for 36 days as the samples, the mean of efficiency soared from 91.81% to 95.64% and the standard deviation reduced from 0.85 to 0.59.

Figure 3.8: Comparison Efficiency of Paint Shop of IKCO before and after Considering New Method of Scheduling.

Forming temporary queue based on priority, time action and time stamp of jobs with the aim of recognizing tense jobs provide an appropriate circumstance in which efficiency of production is enhanced. The obtained results clarified that by considering
priority aspect and time action of jobs the probability of occurring errors has been reduced. As mentioned to evaluate of new method of scheduling numerical test case has shown that the efficiency of system increased. Based on section 3.2, mathematical proof shows that by employing proposed method the reliability of system is enhanced. Eventually, case study of IKCO paint shop demonstrates that proposed method of scheduling simultaneously increase efficiency and reliability of paint shop.

The main advantage of the new method of scheduling in manufacturing systems is reducing the rate of faults (errors) which are emanated from ignoring priority and time action of jobs, based on Figure 4.2 efficiency of production has been significantly increased by considering the priority and time action of each job in order to assignment of jobs to machines the notable rates of faults (errors) has been eliminated.

Descriptive statistics in Table 4.1 illustrates that the skewness of efficiency before applying proposed method of scheduling is 0.11 and after employing proposed method of scheduling is -0.58. As mention in section 2.6 data distribution is normal if value of skewness is between -2 to +2. On the other hand, Montgomery (2007) states in normal distribution population when the samples are more than 30 the distribution of samples is normal too (Appendix C.1 provide appropriate information which are done by SPSS to shows the distribution of the population is normal). To show that there is significant differences between efficiency before and after applying proposed method of scheduling pair sample t-test can be employed. In this regard, SPSS is a perfect tool to provide appropriate information for decision. Based on the SPSS report which is presented in Appendix C.2 the significant of paired sample significant is equal to zero. It shows that this amount is less than level of significant ($\alpha$).
\[ H_0 : \mu_1 = \mu_2 \]
\[ H_1 : \mu_1 \neq \mu_2 \]
Thus, based on the result of significant test, hypothesis of \( \mu_1 = \mu_2 \) fails to reject and \( H_1 \) is accepted. So there is remarkable increase in efficiency after employing proposed method of scheduling.

### 1.4 Influence of New Method of Scheduling on the Reliability of IKCO’s Paint Shop

As mentioned in previous chapters the new method of scheduling is capable of reducing the faults (errors) of systems. In scheduling of jobs considering priority and time action besides the time stamp, declines the rate of faults (errors). In this section root cause analysis of failures in IKCO paint shop is performed. It is obvious that some failures in IKCO paint shop are due to ignoring the priority of tense jobs to perform earlier or not considering the time action of jobs in scheduling of jobs. It means that the only criterion of scheduling is time stamp or FIFO policy via schedulers in CCR.

Root cause analysis clarifies the amount of faults (errors) which occur due ignoring priority of tense jobs or not engaging the time action of jobs. Therefore, it is clear that sorting jobs based on priority, time action and time stamp causes the faults (errors) which are derived from ignoring mentioned criteria are spontaneously eliminated.

Figure 4.6 shows errors within the system which derived from six sections including “Equipment” by ■, “Process” by ■, “People” by ■, “Material” by ■, “Environment” by ■ and “Management” by ■. Based on the pie chart portions, it is manifest that process cause has the highest probability of occurrence among the others sectors.
Afterwards, the next root cause is “Equipment” then the “Management” is more than the others. Therefore, by splitting faults (errors) to their root causes, the chief factors of occurring faults (errors) in IKCO Paint shop are appeared.

Figure 3.9: Divergent Root Causes in Reduction of Reliability in IKCO Paint Shop.

Figure 4.7 shows that about 60% of faults are caused by “Process and Equipment”. It means that the most indispensable causes on this study are these two factors. The rest is about 40% which is emanated to “Material, Personnel and Environment”. The red line shows the accumulated faults from the most effective fault to the least one.
According to Figure 4.8 a root causes analysis is depicted which have been investigated two levels of problem solving. Based on Figure 4.8, not considering the time action of each job leads to the notable amount of failures in “Method (Process)” section. On the other hand breakdown and lack of on time maintenance are the two most critical sub-branch of “Machines (Equipment)” faults (errors) region. Moreover, the third influential factor of occurring faults (errors) in IKCO paint shop is scheduling priority which is caused by management.
Figure 3.11: Cause and Effect Diagram for Reduction of reliability in IKCO’ Paint Shop

Figure 4.9 depicts a comparison on reliability of IKCO Paint Shop before and after considering proposed new scheduling method in this research. On the principle of Figure 4.9, it is clear that the reliability for the 36 observed days in IKCO Paint Shop after considering the new method of scheduling significantly increased. Figure 4.9 compares both reliabilities before and after employing the new scheduling method.
As a specimen, in Table 4.2 data of one day among 36 sample days is presented. Table 4.2 provides information based on series and parallel system reliability. As mentioned in Section 2.6 the series system reliability is calculated by Equation 2.3 and the parallel system reliability is calculated via Equation 2.8. So, by considering IKCO paint shop process flow diagram Figure 3.7 it can be concluded that the reliability of IKCO Paint shop:

\[ R_{\text{Total}} = R_{\text{ED}} \times R_{\text{PT}} \times R_{\text{Sealer}} \times R_{\text{PVC}} \times R_{\text{Primer}} \times (1-(1-R_{\text{Top Coat}}) \times (1-R_{\text{Top Coat}})) \times R_{\text{Oven}} \times R_{\text{Cooler}} \]  

(Eq 4.1)

Based on the author root cause analysis;

1- 0.4 of “Equipment” failures (errors) are caused by ignoring priority
2- Whole percentage of “Management” failures (errors) are caused by not considering priority

3- 0.6 of “Process” failures (errors) are caused by not considering time action

Therefore, new status faults (errors) is calculated as below;

\[ \text{New status error} = 0.4 \times \text{error}_{\text{Equipment}} + 1 \times \text{error}_{\text{Management}} + 0.6 \times \text{error}_{\text{Process}} \]
<table>
<thead>
<tr>
<th>Row</th>
<th>Operation</th>
<th>Module</th>
<th>The Average of Reliability</th>
<th>Failure Cause Analysis</th>
<th>New Status</th>
<th>Updated Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PT</td>
<td>96%</td>
<td>4%</td>
<td>2%</td>
<td>0.008</td>
<td>97%</td>
</tr>
<tr>
<td>2</td>
<td>ED</td>
<td>95%</td>
<td>5%</td>
<td>3%</td>
<td>0.012</td>
<td>96%</td>
</tr>
<tr>
<td>3</td>
<td>Masking</td>
<td>95%</td>
<td>5%</td>
<td>2%</td>
<td>0.05</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>SEALER</td>
<td>95%</td>
<td>5%</td>
<td>3%</td>
<td>0.038</td>
<td>99%</td>
</tr>
<tr>
<td>5</td>
<td>PVC</td>
<td>95%</td>
<td>5%</td>
<td>2%</td>
<td>0.03</td>
<td>98%</td>
</tr>
<tr>
<td>6</td>
<td>Primer</td>
<td>95%</td>
<td>5%</td>
<td>3%</td>
<td>0.032</td>
<td>98%</td>
</tr>
<tr>
<td>7</td>
<td>Top coat</td>
<td>93%</td>
<td>7%</td>
<td>2%</td>
<td>0.062</td>
<td>99%</td>
</tr>
<tr>
<td>8</td>
<td>Oven</td>
<td>95%</td>
<td>5%</td>
<td>4%</td>
<td>0.016</td>
<td>97%</td>
</tr>
<tr>
<td>9</td>
<td>Cooler</td>
<td>97%</td>
<td>3%</td>
<td>3%</td>
<td>0.012</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>Daily</td>
<td>68.12</td>
<td>0.15</td>
<td>0.05</td>
<td>0.02</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Table 3.2: Data of the First Day Based on Series and Parallel System Reliability
Figure 4.10 shows the normal distribution of reliability for the 36 surveyed days of the research a mean of 71.81% is calculated. According to Figure 4.10, the majority of frequencies occurred from 60% to 90% and the standard deviation of reliability is measured by 8.019%. The Figure 4.10 illustrates that by average, the reliability occurred (-8.019, +8.019) percent from mean 71.81%.

![Histogram of Reliability before Considering the Proposed Method of Scheduling](image)

**Figure 3.13:** Histogram of Reliability before Considering the Proposed Method of Scheduling

Figure 4.11 represents the importance on reliability after considering proposed scheduling method. This histogram shows that the mean of reliability in comparison with the before status has been increased for 36 observations. The new mean reliability is measured by 83.47% while it was calculated 71.81% before considering the new method of scheduling. Although, it is obvious that standard deviation appears to smaller in comparison with before status. Based on Figure 4.11 standard deviation has
improved. It means that standard deviation reduced from 5.019 to 4.638. Therefore, according to all points which have been mentioned, it can be concluded that both mean and standard deviation improved by employing proposed scheduling method.

![Histogram of Reliability after Considering the Proposed Method of Scheduling](image)

**Figure 3.14: Histogram of Reliability after Considering the Proposed Method of Scheduling**

Figure 4.12 compares the normal distribution of both reliabilities before and after employing the new scheduling method. Based on this histogram for 36 days as the samples the mean of reliability soared from 71.81% to 83.47% and the standard deviation declined from 5.019% to 4.638%.
Figure 3.15: Histogram of Reliability before and after Proposed Method of Scheduling

Table 4.3 represents a brief description based on statistics of both reliability before and after considering new method of scheduling. Based on the Table 4.3 number of samples are supposed to be 36. The range of observation before is about (41.79-89.99) while after employing new method of scheduling this range is changed into (68-93). Table 4.3 illustrates that the mean of samples for before status is 71.81% and after considering the proposed method of scheduling this rate has been soared to 83.47%. It means that the overall rate of reliability is increased by applying proposed method of scheduling.

Forming temporary jobs queue based on the priority, time action and time stamp of jobs to recognize tense jobs provide a perfect condition in which efficiency of
production is increased. The obtained results clarified that via considering priority aspect and time action of jobs the probability of occurring errors has been reduced.

Table 3.3: Descriptive Statistics: Efficiency of System before and after New Scheduling Method

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability Before</td>
<td>36</td>
<td>71.81</td>
<td>8.02</td>
<td>41.79%</td>
<td>89.99%</td>
<td>-1.25</td>
</tr>
<tr>
<td>Reliability After</td>
<td>36</td>
<td>83.47</td>
<td>4.638</td>
<td>68%</td>
<td>93%</td>
<td>-1.01</td>
</tr>
</tbody>
</table>

Descriptive statistics in Table 4.3 illustrates that the skewness of reliability before applying proposed method of scheduling is -1.25 and after employing proposed method of scheduling is -1.01. As mention in section 2.6 data distribution is normal if value of skewness is between -2 to +2. Moreover, Montgomery (2007) states in normal distribution population when the samples are more than 30 the distribution of samples is normal too (Appendix C.3 provide appropriate information which is performed by SPSS to shows the distribution of the population is normal).

To show the significant differences between reliability before and after employing proposed method of scheduling pair sample t-test can be applied. In this regard, SPSS is a perfect tool to provide appropriate information for decision. Based on the SPSS report which is presented in Appendix C.4 the significant of paired sample significant is equal to zero. It shows that this amount is less than level of significant ($\alpha$).

$$H_0 : \mu_1 = \mu_2$$

$$H_1 : \mu_1 \neq \mu_2$$
Therefore, based on the result of significant test hypothesis of $\mu_1 = \mu_2$ fails to reject and $H_1$ is accepted. So there is remarkable enhancement in reliability after employing proposed method of scheduling.

1.5 Conclusion

Chapter Four shows result of numerical test case (simulation) and case study of IKCO’s Paint Shop. Based on numerical test case by applying new method of scheduling efficiency system is increased. The case study shows that efficiency of IKCO’s paint shop before and after considering the new method of scheduling in terms of the rate of production. In this regards, 36 working days of IKCO’s paint shop observed as the samples. The next step is measuring differences between the capacities of production line based on its UPH. The differences between before and after status is because of some errors in system but a part of those errors are because of not considering priority and time action of jobs. So it is obvious that by considering the new algorithm of scheduling the portion of errors which are derived by ignoring priority and time action of jobs are spontaneously eliminated.

To evaluate the new method of scheduling in order to enhance of reliability of IKCO’s Paint Shop, main operation stations of IKCO’s Pain shop including Pre Treatment (PT), Electro Deposition(ED), Masking, Sealer, PVC, Primer, Top Coat, Oven, Cooler have been evaluated. The errors of each operation station have been analyzed based on the six categories of bonefish diagram then whereby splitting those categories failures into more detail root causes the portion of causes which have been emanated.
due to not considering priority and time action of jobs have been eliminated. It is ostensible that by eliminating this portion of failure the reliability of IKCO’s pain shop has been enhanced.
CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Introduction

Chapter five briefly summarizes the thesis main objectives and reviews how these objectives are achieved. The concluding points and recommendations for future research are provided in this chapter.

5.2 Summary and Conclusion

As gained from the afore-mentioned review of literatures, priority occupies a central role in scheduling. Accordingly, the carried out research, the PR rule can outperform the FIFO rule in a way to obtain the same service level constraint for a range of parameters. Based on the study conducted intelligent time slice in round robin can be improved by including priority aspect. This improved intelligent system contributes to better scheduling.

In retrospect, the only criterion for allocating jobs to the machines in industrial manufacturing systems by centralized schedulers is FIFO policy. Thus, due to increasing the efficiency of manufacturing systems in this thesis, three criteria (time
stamp, time action and priority) of each job are simultaneously considered. As mentioned in section 1.2, As far as stated, in a manufacturing environment, things rarely go as expected. Certain resources become unavailable and additional resources are required. The others aspects to mention are power system failures, machine failures, operator absence, and unavailability of tools and materials. However, to the knowledge of the present author, there is no method of scheduling which considering all aspects of priority resources criteria, time stamp and time action simultaneously. In this research, a more realistic scheduling model takes account of the six effective criteria including machine, maintenance, process, environment, management and material activities. Hence, besides the time stamp (time of arrival) and the time action (duration time), the specific priority (the judgment is based on those six criteria mentioned above) of each job in terms of the amount of importance and tensing is considered to reduce the probability of crash in manufacturing systems.

As mentioned the first objective was obtained by using MATLAB distributed computing server (DCS) software, coordinating and executing independent MATLAB® operations simultaneously on a cluster of computers, and speeding up execution of huge scheduling problem. The methodology used in this thesis is the definition of job scheduler and positioning jobs in temporary queue and sorting via developing bubble sort in MATLAB distributed computing software. This is conducted on the basis of three factors of priority, time action (duration) and time stamp.

The second objective was achieved via cause and effect analysis method (CAEA). In this regard, bonefish diagram was applied in order to categorize the failures in the
miscellany of groups including material, equipment, people, maintenance, management and environment. Accordingly, based on the simulated scheduling algorithm, the faults of ignoring the priority and time action of jobs are spontaneously eliminated from the system. Minitab software is used to show the status of the system in terms of efficiency and reliability, both before and after applying the proposed algorithm.

In order to evaluate the proposed method and optimize efficiency and reliability, a numerical test case (simulation) is first created. Besides the simulation, there is a mathematical proof to show the increase in reliability. As mentioned, the scope of this research is restricted to the evaluation of data in IKCO paint shop. Thus, IKCO is used as a case study to evaluate the proposed method of scheduling. Eventually, by applying this evaluation, it can be concluded that efficiency and reliability of system are enhanced. It means that the objectives of thesis are achieved.

The results of numerical test case and case study can be seen in chapter four. The numerical test case shows system efficiency is increased by lessening the failures (errors) of the simulated scheduler when priority aspects and time action of jobs are considered along with the time stamp of jobs. The programming of simulated algorithm in MATLAB distributed computing can be seen in appendix A.2. To evaluate the proposed method in this simulation, the definition of job scheduler and tree jobs; afterwards, the jobs are submitted to schedulers based on the proposed method and the existing method of scheduling. After performing this simulation for several times and creating a random function for failures, as mentioned this algorithm results in more efficient system by reducing system faults which leads to the scheduler
crashing. The proposed method is capable of increasing the reliability of the system. Another important point to be mentioned is that the application of the proposed method can be more beneficial in failure prone manufacturing system. This implies that, by using this method, the rate of faults (errors) is declined. Therefore, in the failure prone manufacturing system, the proposed method of scheduling can perform such a preventive function of faults. To wrap up, it can be concluded that the objectives of this thesis are completely achieved.

5.3 Recommendation for Further Researches

Increasing the efficiency and reliability of manufacturing system is vital. The usefulness and applicability of the proposed method for failure prone manufacturing system seems to be of certain importance. Traffic or starvation of jobs can be the result of poor efficiency and low reliability of the system. In this regards, this section provides some recommendations for further researches in this area of science. Considering practical implementation of the proposed method of job scheduling and the comparison of the result with simulation results, three suggestions are made as follows:

1. Developing the proposed scheduling method for reducing jobs starvation and traffic for failure prone manufacturing systems
2. Using the proposed method of scheduling in order to increase the productivity of the system and compare the results with the previous status
3. Using the proposed method to reduce the delivery time of end items in manufacturing systems and decline the delays.
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APPENDIX A

The Programming of Developed Bubble Sort

A.1 Sorting Algorithm

%% PUTTING AN VECTOR OF NUMBERS IN AN ASCENDING ORDER?

% Abstract: This program shows you how to put a vector
% of numbers in an ascending order using the bubble sort method

clear all

Ts=[1 2 3 4 5];
Ta=[2 4 1 5 3];
Pr=[3 5 2 1 4];
A=(0.3*Ts)+(0.5*Ta)+(0.2*Pr)

%disp(A)

%% SOLUTION

% Number of entries, n
n=length(A);

% making (n-1) passes
for j=1:1:n-1
    % comparing each number with the next and swapping
    for i=1:1:n-1
        if A(i)>A(i+1);
            % temp is a variable where the numbers are kept
            % temporarily for the switch
            temp=A(i);
            A(i)=A(i+1);
            A(i+1)=temp;
        end
    end
end

%% OUTPUT
%disp('  ')
For 10 JOBS:
%disp ('OUTPUT')

%disp ('The ascending matrix is')
disp(A)
%% PUTTING AN VECTOR OF NUMBERS IN AN ASCENDING ORDER?

% Abstract: This program shows you how to put a vector
% of numbers in an ascending order using the bubble sort method

cle

clear all

%disp(‘This program shows the bubble sort method’)
%disp(‘to put a vector of numbers in an ‘)
%disp(‘ascending order’)
%disp(‘ ‘)

%% INPUTS
% The vector of numbers
%disp (‘INPUTS’)
%disp(‘Input the vector of numbers’)

%FUNCTION
Ts=[1 2 3 4 5 6 7 8 9 10 ];
Ta=[2 4 1 5 3 2 8 9 10 1 ];
Pr=[3 5 2 1 4 3 7 4 3 2 ];
A=(0.3*Ts)+(0.5*Ta)+(0.2*Pr)
%disp(A)

%% SOLUTION
% Number of entries, n
n=length(A);
% making (n-1) passes
for j=1:1:n-1
% comparing each number with the next and swapping
for i=1:1:n-1
    if A(i)>A(i+1);
        % temp is a variable where the numbers are kept
        % temporarily for the switch
        temp=A(i);
        A(i)=A(i+1);
        A(i+1)=temp;
    end
end

%%% OUTPUT
%disp('  
%disp('OUTPUT')
%disp ('The ascending matrix is')
disp(A)

A.2 The Programming of Simulated Algorithm via DCS
clc
close all
sched = findResource('scheduler', 'type', 'local')
j = createJob(sched)
createTask(j, @sum, 1, {[1 1]})
createTask(j, @sum, 1, {[2 2]})
createTask(j, @sum, 1, {[3 3]})

submit(j);

waitForState(j)

results = getAllOutputArguments(j)
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Title: Optimizing of Efficiency Supply Chain System via Development of Priority Oriented Scheduling Method (Conference Proceeding)
