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Productivity Improvement Using Heuristics Algorithm in Scheduling A Flow-Shop Manufacturing, (Case Of Altex)

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PRODUCTIVITY IMPROVEMENT USING HEURISTICS ALGORITHM IN SCHEDULING A FLOW-SHOP MANUFACTURING, (CASE OF ALTEX)

MASTERS THESIS

By

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Program: Masters of Science in Production Engineering and Management

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DECLARATION

I, the undersigned, declare that the thesis comprises my own work. The work has not submitted previously, in whole or in part, to qualify for any other academic award In compliance with internationally accepted practices; I acknowledged and refereed all materials used in this work.

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DEDICATION

I dedicate this thesis to my lovely family members, who ultimately inspired and supported me, each step of the way. My special dedication is for my wife, Yemarwuha M., and my child, Hasset T., who always brought cheerfulness and energized me to do my best.

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Tibebu Alene, January 2020

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LIST OF ABBREVIATIONS

1. ALTEX…………. Almeda Textile
2. CDS ……………… Campbell Dudek and Smith
3. EDD………………. Earliest Due date
4. FIFO………………… First in first out
5. GA………………… Genetic algorithm
6. LIFO…………… … Last in first out
7. MSS ………………. Manufacturing system scheduling
8. MILP………………. Mixed-integer linear programming
9. NEH………………. Nawaz Enscore Ham
10. PLC………………… Private limited company
11. STPT………………. Shortest total processing time
12. TMFR…....................Two machines fictitious rule
13. WIP………………...Work- in – process inventory

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ABSTRACT

In manufacturing industries, meeting the dynamically changing need of customers and delivery times is the key to stay at the apex of global or national competitions. Manufacturing system consists and integrates entities such as machines, jobs with different operations to be processed in the corresponding machine, input materials, human operators, and all the things that facilitate the production system of a manufacturing industry so that enabling the firm to generate good wealth and to cope the dynamically changing market demand. The problem under study is a textile garment manufacturing industry of a flow shop-manufacturing environment. Even, giving high priority to the first arrival jobs in such manufacturing industries seems fair to customers and jobs, however, it does not consider other customer and job characteristics such as production cost, idle time, make-span, and tardiness of jobs. In this flow shop type of scheduling problem, “n” jobs considered to process on “m” machines and preemption of jobs not allowed. In addition, it assumed that the machines could process only one job at a time. The study conducted with the main aim of productivity improvement by minimizing the idle time of machines to control criteria or parameters such as make-span, resource utilization, and production cost for the case company by finding the most optimal sequence of jobs under the study. To carry out the study and find the best and efficient sequence of jobs heuristics algorithms such as NEH, CDS, palmers and EDD rules in the flow shop-manufacturing used, and the NEH resulted in the best sequence of jobs. As verified by the GA except for its tediousness, the proposed heuristic algorithm has good computational efficiency. In addition, in the proposed sequence of jobs with a 3.6% utilization improvement, the productivity improved by 17.2% than the existing schedule.

Keywords: Flow shop Scheduling, Heuristics algorithm, Make-span, Idle time, Productivity.

CHAPTER ONE

1.1 Introduction

The manufacturing sector is the heart and soul of developing and developed countries as detailed by Rao, K. and Tesfahunegn, (2015). In such manufacturing industries, meeting the dynamically changing need of customers and delivery times is the key to stay at the apex of the global or national competition. However, it is difficult to forecast future demand fluctuation and ever-increasing global competition. Then these pressures are the most determinant factors, which oblige the firms to think critically on how to improve the production process performance to produce the product within a minimum cost and deliver at a reasonable period of time as elaborated by Guo et al., (2006).

On the other hand either to lead or keep on with the competition track, it is investigated that productivity maximization and reducing the production time play the major role as recent research findings show Ren et al., (2015). Also, this production time reduction leads to a reduction in the level of work in progress (WIP) inventory as discussed by Almström and Sundkvist, (2011). While dealing with productivity maximization techniques enhancing the performance of machines is crucial and this approach makes them available for production Lee et al., (2000).

However, challenged with productivity; the apparel industries for non-developed and developing countries are receiving high attention. Productivity, therefore, is the critical issue that must be taken into account for the success of these countries to achieve their goal in the sector as stated by Odhuno, (2017).

Today the textile and garment industries in Ethiopia are increasing. Since its establishment in 1939 at Dire Dawa, the number of textile manufacturing companies, up to 1991, was less than 20, latter in 2012 the sector increased to 80, then in 2013 up to 110 whereas, in 2018 it reached about 130 as it is reported by Khurana, (2018). Out of these 130 and the newly emerging textile and garment manufacturing companies, woven and knitted garment products are their major products for the sector respectively. Knitted garment products such as round neck & V-neck T-shirt, polo shirt, and pants are common and well-known major products for these garment industries.

However, it is believed there is an intensive and unprecedented international market competition which poses another challenge for the newly emerging Ethiopian textile and garment industries as it has been discussed by Kitaw and Matebu, (2010).

Therefore, continuously looking and developing the new production system, production tools, and techniques are crucial to go forward with the rapidly changing needs of customers and market fluctuation. In addition, these garment industries must maximize the line efficiency and productivity; reduce lead times, ensure the required product quality to stay with this highly competitive marketplace as discussed by Nabi et al., (2015).

Investing in Ethiopia in the textile and garment sector is more attractive. Because of minimum power/energy cost, raw materials, and minimum manpower cost; still delivery time, efficiency of factories which is as slow as 40% to 45% in production of the garment assembly units, and cycle time are the most challenges that drastically pulling the sector back in general as reported by Ndichu, (2019). However, the sector given high attention by the government of Ethiopia, challenged with low productivity and long production time. Almeda Textile PLC is one of these in the sector facing the problem.

As the annual actual production report of the company indicates for the last seven years, it was 74% in 2011/12 and 2012/13, 60% in 2014/15, 61% in 2015/16, and 72% in 2016/17 and 2017/18 years. However, in 2013/14 the company achieved 100% planned production. The maximum production achievement was only 74%, for the recet periods. Compared to actual capacity of the operators and machines theier achievement 74% was not sasfactory, which can be characterized as low productivity.

Among many reasons for the low productivity, machine idle time, which encountered because of wrong scheduling rule used first come first served rule (FCFS), is the most prominent cause. Because this scheduling rule does not consider characteristics such as time required to complete the average number of jobs, machine idle time, and how to maximize facilities utilization. Hence, because of these reasons this study aim to find a new way of the production schedule for the case company in particular, and to Ethiopia in general to improve the productivity.

This study focused on the sewing section of the knitted garment products because, in garment manufacturing, sewing is the most critical task since the product to be produced has a number of operations as given by Chen et al., (2012). The study conducted by using heuristics algorithms for flow shop scheduling with make-span criteria that minimize; the machine idle time, work- in –process (WIP) inventory, resource wastage (machine and time), to enhance the production of the case company. This is because, heuristics algorithms are simply structured, fast, and robust scheduling approaches as attempted by Zobolas et al., (2009).

In addition, the proposed study emphasized, to minimize the total completion time of jobs, minimize the number of jobs that wait until the first job completes, minimize the idle time of the machines, improve the productivity of the company, and improve the man-machine resource utilization. In the study, heuristics algorithms such as Nawaz Enscore Ham (NEH), Campbell Dudek and Smith (CDS), palmers, and Earliest Due date (EDD) rule, are used to find the best sequence of jobs. Different solution methods applied for complex scheduling problems. Optimum solutions found using optimum methods; however, require longer time to derive the solution. On the other hand, do not provide optimum solutions, heuristic method is much faster and preferable for combinatorial (NP-complete or NP-hard) optimization problems Wang, (2005).

1.2 Background of the study

Productivity is not as it is a word rather; it is a very broad concept both in its operational content and in its aim. It is the issue of common understanding that supreme productivity implies a reduced cost of production, reduced the sales price of the goods, increased demand for the item, and helps the goods to compete effectively in the global market. Actually, the strength of a country, the success of the economy, the living standard, and the wealth of the nation are highly dependent on production and productivity.

With same input; increasing the output of goods and services or enhancing the productivity enables to reduce the cost of goods per each and every item so that to offer the good with a least selling price to the customer while generating good wealth as it is detailed by Roy, (2005). Also according to the author productivity defined as follows;

- Productivity is the ability to reduce waste associated with labor, machines, power, space, materials, capital and time.
- Alternatively, productivity might have defined as the human endeavor to have more outputs with minimum inputs of resources in such a way that the customer most importantly prefers the items produced.
- Productivity indicates a progressive mind set up and persistent motivation in discovering healthier, less expensive, faster, easier means of performing a job, producing goods and delivering services.

On the other hand, productivity is the efficient use of resources, labor, capital, land, materials, energy, and information in the production of goods. It is important to note that productivity improvement or the effective use of available resources is the only way for future development in the society. Productivity improvement results in direct increases in the standard of living under conditions of distribution of productivity gains according to Dezigncubicle, (2019). Researches proved that, developing a methodology that facilitates the use of lean manufacturing tools is an option that improves productivity Herron, (2006). In addition, it is noted that for any manufacturing industry to increase its long term competitive advantage, it has to find lean tools and techniques that enhance productivity Kulkarni et al., (2014).

1.2.1 Research gap

Here the gap of these researches in the literature is, they only focus on only one parameter or metrics such as make-span, tardiness, earliness minimization, and they did not consider other parameters associated with make-span i.e.

- ✓ Didn’t consider idle time i.e. minimized make-span leads reduced the idle time which intern improve productivity by increasing the output
- ✓ With the same machine and SMV machine efficiency increased because of the increased output however, they did not take into account.
- ✓ Some of the research papers only consider one parameter, such as tardiness, make-span. For example, research conducted by Nagano et al (2015).
- ✓ Previous scheduling research findings did not show the effect of minimizing one parameter on the other parameter; they concluded minimizing make-span reduced the idle time.

Therefore, the proposed study focuses on improving productivity by minimizing the idle time of machines, work-in-progress (WIP) inventory, number of tardy jobs, production cost, and combined in addition to the make-span criterion.

1.2.2 Preliminary analysis

In this research, the impact of the existing scheduling approach of the case company tested with the longest total processing time rule and Nawaz Enscore ham, then the existing schedule results in idle time of machines. In addition, a preliminary analysis is done, to show how the case company's actual production output is deviating the planned production volume.

Manufacturing industries know their production capacity and put their targeted production for a certain period may be per shift or per day. Depending upon their target, they measure whether their status is good or bad. Having this evidence from the very beginning the researcher analyzed and concluded that the actual production output of the case company was not as planned means that low productivity examined. Even the line balanced, the raw fabric was avail, and machine breakdown was insignificant still target daily production not achieved. The Engineering officers for the two shifts “A” and “B” posts the daily production target at the end of the shift hour, from this post, observed that impossible to achieve the targeted output. Here, the target is deviated means not able to produce as per the plan which means the line performance or productivity of the company is not in a good manner; in short, it can be concluded that the line output is deviating the targeted output means low productivity is challenging the company. Especially, machine idle time because of wrong scheduling investigated and claimed this might be the reason for low productivity. For this reason, related works of literature reviewed that improve the productivity of garment industries and concluded that work-study techniques, line balancing methods, lean manufacturing, total preventive maintenance practices, and others addressed in the literature review part are the most important means to alleviate the problem and the case company practicing these methods.

However, it is quite important to take into account that minimizing the idle time, minimizing WIP inventory, minimizing the production cost, and minimizing make-span are other issues that need attention and employed in the current competitive marketplace in addition to the above methods listed to improve the productivity of the manufacturing sector. Scheduling jobs in flow shop or mass-customized products manufacturing environments can bring a better productivity improvement than job shop manufacturing environment. Below is a column chart indicating how much deviation made in the actual production with that of the planned production.

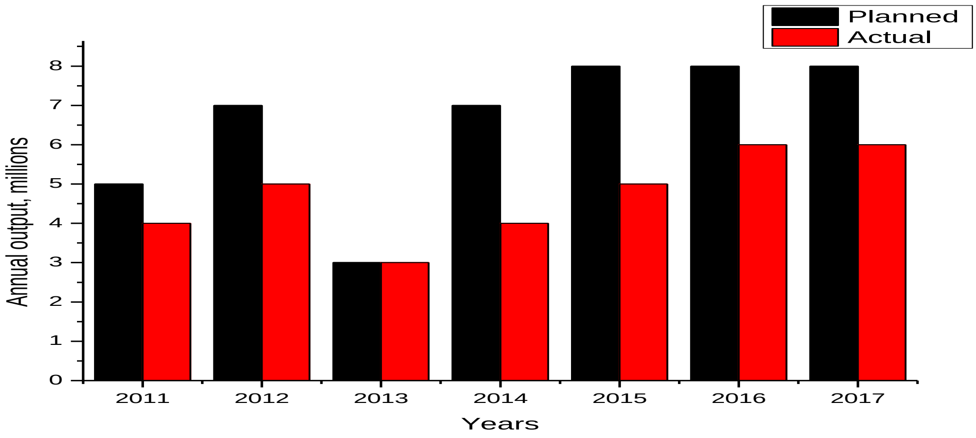

Figure1. 1 Knitted garment planned and actual production volume

As seen in the chart the actual production output is less than the planned production volume and this forces the manufacturer to find ways so that to over attack the problem of low productivity. This is what motivates the researcher to search a means so that enabling him to alleviate the problem the company faced.

1.3 Statement of the problem

Recent research findings indicate that for any garment industry good productivity is a must to sustain and to be profitable in the global marketplace as it is elaborated by Jadhav et al., (2017). However, this is the reality, especially in Ethiopia most garment industries are challenged with low productivity and long production lead times as discussed by Kitaw et al., (2010). Hence, as explained by these authors, to over attack the challenge previously line balancing and work-study techniques employed. In addition, in their study simulation, methods used to identify and enhance the performance of the garment industry. Nevertheless, no research had done in this area to improve the productivity of the garment industry by scheduling the jobs using heuristics algorithms.

Almeda Textile private limited company is one of the oldest textile manufacturers since 1996. It is one of the biggest mass-customized garment products producing companies in Ethiopia, which is located in the Tigray region in Adwa city. However, the company has a long history in local and export-oriented knitted textile products it is not possible for the company to produce more than 62.7% of the average planned production for the last six years. This shows the company's actual production devates the planned production by 37.3%.

Long lead-time, machine idle time, and customer dissatisfaction are important issues that the company has to resolve to stay with the competitive marketplace and satisfy customers. In addition, the company has to focus on new manufacturing technologies such as production scheduling since the existing scheduling rule didn't contribute to minimizing the total completion time for jobs, reducing the idle time of the machine, and reducing the production cost by increasing the number of output. While looking productivity of the case company from the very beginning it sets production target; after the product is produced the performance of the shop or the department with the scheduled job has been measured and found the performance of the garment department in the knitted garment section deviates the targeted production by 37.3%. Therefore, machine idle time is the principal cause for this performance inefficiency of the line or low productivity of the knitted garment section.

The case company's scheduling approach is based on a ''first come first served (FCFS)'' rule which is a dispatching priority rule. This rule used to process the jobs according to their order of arrival. However, its main attention is minimizing, job completion time and customer waiting time. On the other hand, according to Azila-Nadiah et al., (2012) the first come first served scheduling rule does not consider other characteristics such as total cost, the required time to complete average number of jobs, work- in process (WIP) inventory, how to maximize facilities utilization, and machine idle time. This shows the FCFS rule is unreliable and unaccountable in justifying productivity since it does not concede any other customer or job characteristics. In addition, the FCFS rule resulted in a larger idle time of machines as the pre-test of the proposed study identified.

In general, the inefficiency of the existing scheduling rule of the case company and its associated idle time of machines are the root causes of the problem question. Hence, with this and the very active research area of scheduling problems nature of hardness motivates to develop the problem statement of the proposed study to mitigate this challenge of the company.

1.4 Objective of the study

1.3.1 Main objective

The main objective of this study is to improve the productivity of the case company by reducing the idle time of machines, using heuristics scheduling algorithm.

1.3.2 Specific objective

The following are the specific objectives that the study expected to deliver.

- To find the minimum make-span relative to the idle time of the machine
- To propose the optimal sequence of jobs accordingly
- To examine the effects of heuristics algorithms on parameters such as make-span, production cost, and idle time.
- To find a schedule that can increase resource utilization and reduce the production costs
- To propose an optimal scheduling algorithm that can minimize the idle times of the machines that may increase productivity

1.5 Scope of the study

This study mainly focused on productivity improvement using selected heuristics algorithms in the knitting sewing section of the garment department of Almeda Textile PLC, which is a flow shop-manufacturing environment. Its main attention was to provide a near to optimal schedule for the selected garment industry. For the data analysis purposes only selected, heuristics algorithms Nawaz Enscore Ham (NEH), Campbell Dudek and Smith (CDS), palmer, and Earliest Due Date (EDD), are used. In addition, the data collected and analyzed in this study was limited to Almeda Textile private limited company, in the knitting section of the garment department where polo shirt has produced.

1.6 Significance of the study

The study provided the best schedule out of the alternatives for the identified products that might increase the productivity to the case company. The proposed schedule minimized the make-span to a certain extent, minimize the idle time of machines, reduce work in progress inventory (WIP), and increase productivity by increasing the availability of the machine for production. In addition, the algorithm developed for this study farther projected on how other similar companies, in the textile industry, can apply and benefit its advantages. Finally, other researchers would use the result of the proposed study as a reference for further studies.

CHAPTER TWO

2.1 Literature review

The manufacturing system consists of and integrates entities such as machines, jobs with different operations to process in different machines, input materials, human operators, that facilitate the production system to generate good wealth and make firms competitor as it is detailed by Garg, (2013). It depicts that scheduling is important tool to minimize the maximum completion time for a job, increase the efficiency of a line, improve the productivity, to reduce or eliminate resource wastage, to minimize or eliminate the idle times of machines in the production line, reduce the production cost and time as it is reported by Jain, (2016) .

Scheduling improves productivity though not achieved simply. So far, some researchers showed that by applying different sequencing and scheduling algorithms, they found an optimal sequence for jobs to minimize the total completion time or make-span as detailed by Maroto, (2005). In addition, the concept of manufacturing scheduling concerned with the right allocation of jobs to the right machine over time as elaborated by Ritt, (2016) and Potts, (2005). Later on, a study conducted by Cappadonna et al., (2013) about flow shop scheduling with limited human resources for make-span minimization. With their numerical experiment proved that both numbers of machines and workers employed in any production system play the major role in minimizing the make-span.

While dealing scheduling, priority dispatching rules do not provide optimal results as well as better to be used in job shop scheduling problems, as recommended by Koruca and Aydemir, (2014). Also, a recent study carried out by Jayswal, (2018) about flow shop scheduling concluded that genetic algorithm (GA) performs better than two machines fictitious rule (TMFR) and shortest total processing time(STPT) rule though, TMFR minimizes the make-span, while the STPT rule minimizes the average flow time of a job.

In today's competitive market, environment effective scheduling and sequencing play a major role in the manufacturing industries to boost production. Therefore, scheduling has become a necessity for any manufacturing industry to stay in this competitive marketplace. By scheduling, it is possible to minimize the total completion time for a job, the number of tardy jobs, the idle time for a machine, and the work- in - process (WIP) inventory. Once the idle time of a machine minimized to a certain extent, the whole machines become available for production. With this machine availability, the productivity of the manufacturing industry increased.

In one or another way, today the manufacturing sector is facing a challenge due to globalization according to the works of Muthiah, (2006). Hence in the competitive global market environment manufacturers have to improve their productivity so as to have sustainable manufacturing practice as elaborated by Yasmin, (2018).

In the competitive market, a good production plan leads to increased output. The garment manufacturing industry is one that competes in the market and has a high volume of production with respect to the demand. To keep on with the delivery date and improve the productivity of the manufacturing industry to have a satisfied customer, scheduling has a major impact. That is why the area attracts many researchers starting from the past decades. According to the definitions of some scholars, scheduling is an allocation of operations of “n” jobs with the corresponding “m” machines.

However, flow shop scheduling is a challenging task many scholars put their suggestion and today the area attracts many researchers as clarified by Liu et al., (2017)and Vázquez-Rodríguez, (2010). In addition, the research indicated that make-span minimization is very important in that it optimizes the scarce resources, costs associated with the production, to meet the delivery times for the customer’s demand.

According to Dhiangra, (2013) scheduling algorithms for minimization of make-span were developed by; Johnson [1954] for two machines and “n” jobs. Palmer [1965] slope order of sequencing a job on a machine based on processing time. Campbell, Dudek, and Smith (CDS) [1970] extension of Johnson’s rule, and Nawaz, Enscore Ham (NEH) [1983] based on the assumption of jobs with higher total processing time in all the machines is given higher priority than jobs with lower total processing time in all the machines.

A comprehensive study on job shop scheduling using heuristics algorithms by Sridhar, (2015) was conducted with the aim of minimizing the total completion time of a flow shop scheduling problem. Their study used palmers, NEH, CDS, heuristics algorithms to minimize the make-span. The algorithm with a sequence of jobs that provides the minimum make-span time selected as the best sequence for the study. At the same year, another study which focused on tardiness issues were done by Nagano et al., (2015) on the scheduling of flow shop problem with the main objective to minimize the total tardiness. In the second study, researchers proposed different NEH heuristics for several tie-breaking mechanisms to solve the permutation flow shop problem while in the first paper the researchers' attention was to find the best algorithm that can minimize the make-span though this paper did not show the reverse effect that is reducing the idle time even could minimize the make-span. In addition, according to the second study, very loose due dates lead to trivial problems whereas closed due dates induced a flexible permutation flow shop problem. The NEH algorithm used in this research is an insertion of a new job, which has minimum processing time.

Framinan, (2015) carried out a study with the main objective to minimize the total flow time. In this paper, to achieve their objective the researchers used constructive heuristics of large numbers which are equals to 35 heuristics. They also conducted a comprehensive evaluation of available heuristics for the problem under study and other related problems. Finally, they proposed a constructive heuristics that combines partial sequences in a parallel manner using a beam search approach.

A recent research with the issue of make-span criterion to improve productivity was conducted by Wolde et al., (2018). According to the first study make-span minimization is directly dependent on the number of machines and workers allocated for the system, and In order to achieve the goal Genetic algorithm (GA) and mixed-integer linear programming (MILP) are employed to find the best sequence of jobs while in the second paper make-span criterion in flow shop scheduling was used to improve the productivity. Using the result of the second research the researcher deduced that, it is possible to reduce machine idle time, reduce work-in-progress inventory or holding cost, and boost the production of the manufacturing industries.

So far, Also, it had been seen that in most research papers, their attention while they conduct a research in scheduling of flow shop and job shop working environments is minimizing the total completion time of the last job or make-span as investigated by Guimaraes et al., (2016), Fernandez-Viagas et al., (2018), and Yang, (2011). In the first research which is conducted by Fernandez-Viagas and Framinan, (2015) the researchers developed the upper bound so that to minimize the total completion time while second researchers Benavides and Ritt, (2016) compared the known - permutation scheduling with permutation schedules to minimize the make-span.

2.2 Productivity improvement for competitive advantage

Today not only manufacturing industries but also service provider companies are seeking productivity as a result of market competition. To be productive companies have to focus on the issues proper utilization of resources, waste minimization, maintenance practice, and operator’s training, and effective scheduling. This is because today’s market is fluctuating tremendously due to the diverse customer wants; therefore, companies need to improve their productivity. With this issue research proved that effective maintenance practice will affect the productivity and profitability of any manufacturing practice as it has been elaborated by Alsyouf, (2007).

On the other hand, researcher’s in a similar fashion of productivity ascertains that productivity restructuring and growth is a must for a country’s economic development as well as to have citizens with better living standards as it is proved by Üngör, (2017), Sun, (2016), and Szirmai, (2000). On the other way, some researchers concluded that growth in technological progress, labor, and capital productivity are crucial for the economic growth of a country as it is detailed by Alani, (2012). However, previously it has been stated that countries that use high technological activity are better at enjoying a higher rate of productivity growth than other countries with low technological practices Fagerberg, (2000).

According to Moslehi and Khorasanian, (2013), flow shop problem is the most well-known and extensively used and researched scheduling problem. Such a problem be described there are sets of “m” machines at which a set of “n” jobs are to be processed. These sets of ‘n’ jobs have a number of “m” operations with a processing time on each set of “m” machines. These jobs are to be processed in a sequential and uninterrupted manner on each machine, meaning that there is no preemption of jobs and the machines can process only one job at a time as it is given by Chakraborty, (2007).

Also as it is described earlier developing an optimal schedule in a manufacturing environment so as to minimize the make-span is another means to improve productivity at the same time it is described as a crucial tool Sung et al., (2002). Another study conducted within a comparative analysis on the issue of labor productivity in the middle income and non-middle income countries concluded that raising the labor productivity will affect the level of income generation with these two groups of middle income and non-middle income Yılmaz, (2016).

Recent research carried out on efficiency and productivity improvement suggested that work measurement is crucial to reduce processes as well as production time Shahare, (2018). Also, as it is noted managing the production time and designing a fixture is another means to improve productivity in industries as stated by Singh et al., (2012). Similarly, it is noted that line balancing using standard time technique is another means to improve the productivity of a manufacturing company Chansangar, (2014). However, the main aim of any production system is to minimize the total production time as much as possible and as reported it is true in an organization millions of dollars are wasted because of lack of awareness of productivity, for this reason, industrial engineering techniques are also, crucial as noted by Khatun, (2013) and Haque, (2009) respectively.

Most researchers in the area of productivity improvement assure that lean manufacturing tools and work-study methods are potential tools to improve the productivity of a manufacturing sector Kulkarni et al., (2014). In another way besides the above methods of productivity improvement approaches make-span minimization by formulating appropriate scheduling problems so that to optimize the order of jobs will minimize the total time required to complete the job and it is concluded that this will improve productivity Janiak et al., (2009).

Organizations have a direct impact on contributions to GDP growth. The textile industry is the main sector for both developing and developed countries economies, with its great contribution of wealth generation and employment opportunity; besides to this while we are focusing about the issue of increasing productivity, it is one way of increasing competitiveness of the firm in the global market as discussed by Slović et al., (2016). In addition, so far, it depicted that productivity is a need that all manufacturing industries have to focus to survive in the competitive marketplace. Especially, in the garment section improving the productivity and minimizing the standard minute value (SMV) of sewing line is the one which plays the major role and this can be achieved through line balancing by identifying the bottleneck operation as it is given by Rahman, (2016) and Rao, S.A., (2014). In addition, it is noted that applying in industry, work-study techniques will increase production capacity Chipambwa, (2018).

Similarly, in addition to line balancing, time study, and lean manufacturing; it was stated that applying proper supervision and avoiding bad habits of workers helps to increase labor productivity by changing their attitude Adnan, (2016).

In addition, a study on productivity improvement proved that today's global market competition brought a dramatic need by producers to think critically about productivity. This is in order to stay in this competitive market environment, with this issue it is concluded that by time study minimizing the waiting time and waste; increases the efficiency so as to increase the productivity as it is reported by Duran et al., (2015) and Islam et al., (2013).

2.3 Sequencing and scheduling

Sequencing is a prioritization technique on a series of jobs in a particular sequence. By sequencing different jobs (with different operations) and processing times on each machine it is possible to increase the productivity and meet the delivery dates (due date) by rescheduling the jobs using different heuristics algorithms in the manufacturing sector. For each job, the size, the processing time is known, and they are not identical, meaning that the processing time for each job is not the same for all the machines. Here the problem is to find the best and near to optimal schedule/ sequence for the jobs of the knitting section of the garment department of the case company.

In manufacturing, industries used different types of sequencing rules. Some of these are, FIFO (first in first out), LIFO (last in first out), shortest total processing time rule (STPT), and earliest due date (EDD) rules, priority basis and processing time rules, etc. in the basis of processing time, applying different sequencing rules we can reach different processing times. In case, the sequence, which provides minimum processing time, will be adapted for the case. The task of determining; when the start and completion time of operation with a precedence relationship is termed as scheduling. On the other hand, it is the main shop floor activity to be carried out in order to increase the productivity of any manufacturing industry as illustrated by Chandrasekaran, (2014). Scheduling mainly used to assign a particular time to complete a certain job. Here, the main objective of scheduling is to reach a position where the total processing time for a job to complete as minimum as possible. Because, working environments that increase the total completion time for a job, increase machine idle time, increase work- in progress inventory (WIP), besides decreases the productivity of the manufacturing industry, this obliges the firm to think critically and find new ways of rescheduling algorithms as an important issue to improve the productivity. While scheduling the jobs in the production line previously the company was simply using the first arrival job in the shop was get into the process without considering the above characteristics simply to complete the first arrival job. Therefore, in order to overcome such a type of scheduling problem and to obtain an optimal or near to optimal and most economical flow shop sequence of jobs effective scheduling algorithm is required.

2.4 Types of scheduling

Scheduling in the manufacturing sector is a very challenging task because of its NP-completeness nature. Previously a number of researches conducted in the area and continue in the future as Laha and Chakraborty, (2007)discussed in their research about flow shop scheduling problems nature of preemption. Therefore, scheduling is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. There are three types of job scheduling approaches and each of them discussed here below:

2.4.1 Single machine scheduling

In this type of scheduling the order of jobs arranged in series in a particular or single machine. According to a single machine, scheduling "n" jobs be processed in a single machine for a low production volume environment.

These jobs arranged in ascending order of their processing time so that to achieve the best result or output. Jobs with minimum processing time will be set as the first job in the sequence processed on the single machine then the job with a higher processing time is at the end in the sequence at which the jobs arranged.

2.4.2 Flow shop scheduling

Inflow shop manufacturing environments, flow shop scheduling problem is a typical combinatorial optimization problem where each job has to visit each machine on the shop floor. The jobs processed in each machine follow the same sequence.

No preemption of jobs allowed that means once the job starts execution there is no chance to give priority for another job to execute, or interruption of the job and loading another job in the corresponding machine not allowed. The processing time for each job in each machine is different as well. As most of the flow shop problems are NP-hard it is challenging to reach in an optimal solution this is what makes it an attractive research area till now as it is highlighted in the introduction part of the proposed study.

At the same time, another researcher notes it as the number of machines is more than three the problem becomes NP-hard hence, this area attracts many researchers starting from the last six decades.

So because of its complexity as the size of the machines increases the area is an active research area with the main parameter of make-span criterion Baskar, (2016). For this reason, the heuristics algorithm is a better approach that gives practically accurate and suitable results as given by the author. Therefore, in such a case, the scheduler needs to arrange all the jobs in a particular order by using different combinations. This is to get the best and near to optimal sequence of jobs, that minimizes the total completion time and idle time of machines with the main aim to improve the productivity of any manufacturing industry.

2.4.3 Job shop scheduling

Another combinatorial optimization problem is a job shop scheduling problem. The only difference between single-machine scheduling and flow shop scheduling is that in such a case all the jobs to be processed may or may not visit all the machines on the shop floor. For the jobs to process, only selected machines used to complete the jobs. Each job has a different sequence of machines in the scheduling approach. In such cases, the sequence with a minimum total completion time (make-span) selected as the best sequence to adapt to the case.

2.5 Why scheduling as a means to improve productivity

Manufacturing job scheduling is a challenging task, though advantageous for profit maximization and customer satisfaction as described by Kayvanfar et al., (2014). Effective job scheduling minimizes the idle times of a machine, with this; the availability of a machine increases at the same time the efficiency and productivity of a line increased.

As a study signifies scheduling problems address the make-span minimization criterion to increase the shop floor productivity, besides to increase the rate of the delivery time of the finished product to the customers as reported by Udaiyakumar, (2014). In general, as discussed in the related literature review and the background sections of this study; effective scheduling could have brought an idle time reduction of machines, reducing production cost, reducing the holding cost or costs associated with inventory, and to keep or exceed the delivery time for the demand by minimizing the make-span and controlling the related parameters.

Generally, Customers prefer a high-quality product with a fast delivery which leads manufacturers' to focus on new methods of manufacturing as well as an improved manufacturing process as it has been investigated by Mezgebe et al., (2013). According to this study, the manufacturers have to improve the manufacturing process performance and they have to reduce unnecessary wastage associated with the production process. Unless otherwise, schedules not planned carefully, the result would be a bottleneck, which again results in waiting lines. Therefore, evaluating and taking actions especially, in mass customized products producing or flow shop manufacturing environments, proper job scheduling increases the efficiency of a machine in order to improve productivity. However, challenging to select the best schedule and scheduling algorithm, it is authenticated that scheduling can bring a revolutionary change in productivity as investigated by Chakma, (2015). Therefore, believed that scheduling is essential for the sustainability and growth of industries as well as the country's economy.

CHAPTER THREE

3.1 Research methodology

This section of the methodology section of the study conducted designed to accomplish the objective of the study. From the very beginning, the start of the work claimed to review related works of literature concerning productivity improvement methods, tools, systems, and algorithms. Also in the research heuristics algorithms used to minimize the make-span or total completion time of the job on the last machine. The scheduling aim was to reduce the idle time of machines to increase their availability, reduce the production cost, reduce the work in process (WIP) inventory, improve resource utilization, and increase the line efficiency as well as the productivity of the case company.

Since the main objective of the research is to increase the productivity by minimizing the make-span, idle time, production cost, and increasing the resource utilization; different heuristics algorithms such as, NEH, Palmers, CDS, and EDD were used to carry out the comparative analysis and select the one that minimizes the above parameters most importantly. In addition, the performance of these heuristics algorithms validated using a genetic algorithm. As it has been proved by scholars, NEH is the best heuristics algorithm for NP-hard m- machines and n- jobs sequencing problems to minimize the make-span as discussed by Kamburowski, (2008) and Leisten, (2003). On the other hand, it is verified in the sensitivity analysis of flow shop scheduling heuristics algorithms NEH is the least biased and most effective scheduling algorithm in minimizing the make-span, later it is proven that CDS is the next best as it is clearly stated by Nawaz et al., (1983). According to those researchers for small static flow-shop problems (3-9 jobs and 4-20 machines) as well for large static problems (15-30 jobs with 4-20 machines), NEH and CDS are the best flow shop scheduling algorithms with their computational efficiency.

It had seen that there are optimal solution approaches for flow shop scheduling problems, however, it distinguished that these approaches require longer manipulation time and memory to keep track of the calculations, which is much expensive even for small-sized problems. Hence, the proposed tools for this study can bring a revolutionary change in productivity as noted before in the literature review part of this work so far. Again, as discussed so far, the selected tools used for this study are the least biased and most effective solution approaches as well can provide near to optimal solutions. Therefore, because of these reasons the proposed study employed heuristics algorithms that can offer near to optimal solutions for flow shop scheduling problems. After the analysis was carried out using the four heuristics algorithms a Mehta heuristics algorithm called genetic algorithm employed to validate the performance of the proposed heuristics algorithms.

The available data suitable for the study gathered from two classes of data sources.

3.2 Data collection

For the proposed study, both primary and secondary data sources are used. Actual observation and interview used to assess the level of work-in-progress inventory, and the number of jobs waiting until the first job completed in the existing job sequence, and observed an idle time of machines and operators because of improper scheduling. Wrongly, scheduled jobs lead to longer waiting times of the first job until it arrived at the last machine. In addition, stopwatch used to record the proecessing time of jobs on each machine and documented separately.

In addition, the processing time of the selected product for the study in the corresponding machine collected and identified. The processing time for each job is different in each machine and at the same time, each job has its own number of operations. Also from the literature review, different heuristics algorithms manipulation techniques reviewed and understood, to avoid misunderstandings while carrying out the mathematical analysis.

Out of the products produced in the knitting section of the case company, round neck, V-neck, and polo shirts are the most frequently produced products. From these products, polo shirt with four different styles or models selected for the proposed study. Each of the four styles has 37 operations processed with five (5) different machines. The reason that polo shirt selected for the study is;

- ✓ The selected product is relatively highly demanded product hence, there is no production interruption throughout the year than that of the remaining products
- ✓ The number of operations of the selected product is more complicated than other products such as pant, round neck, and v- neck shirts
- ✓ Once again the machines required to produce the selected jobs are more than those required to produce the round neck and V-neck products

Therefore, because of these reasons, the proposed study selected these products to analyze and study if properly scheduled have an effect on reducing the machine idle time in order to increase the productivity of the company.

3.3 Data analysis tools or Algorithms

To design and develop the required schedule by considering make-span and other related parameters, data analysed using heuristics algorithms such as NEH, CDS, palmers, and EDD rules. Among these algorithms, the one that offered the minimum make-span selected as the best scheduling algorithm for the problem under study. In addition, for the data analysis purpose, two approaches considered.

1. When all jobs have equal importance to be scheduled: in this case, the analysis had done by ignoring the issue of the due date. This approached done by, NEH, Palmer's, and CDS rules.
2. When it is necessary to consider due date of orders. In this case, the analysis done by considering the due date of jobs i.e. all jobs arrived at a different time. According to their order of arrival, each job has due date then the analysis done based on the due date for each job. Hence, this approach used EDD rule.

3.3.1 Nawaz Enscore Ham (NEH) Algorithm

This insertion algorithm used to establish the final sequence by inserting an additional job in each partial sequence. The principle of this algorithm states that higher priority should give to a job that has maximum total processing time in all the machines than the job with minimum total processing time.

Steps for this algorithm followed represented by the following flow chart.

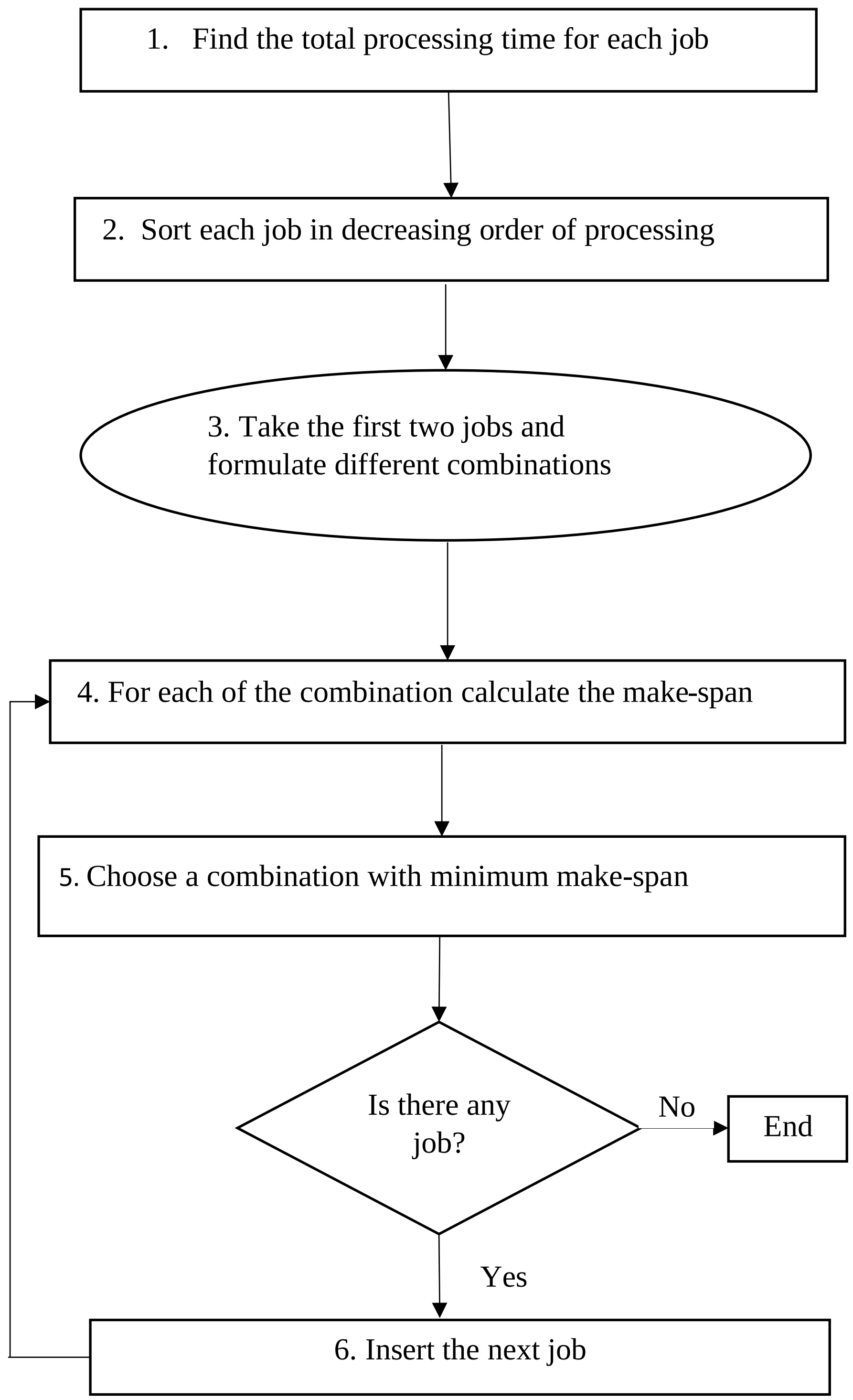

Figure3. 1 Flow chart showing steps followed in the NEH's algorithm

3.3.2 Campbell Dudek Smith (CDS) Algorithm

This is the second algorithm that the researcher employed. According to the CDS (Campbell Dudek and Smith) algorithm in order to obtain the most optimal sequence of job extension of Johnson's algorithm used as clearly described below.

For "n" jobs with "m" operations m = M1, M2, M3… (M_n) machines are required for each of the operations.

The chart below illustrates how the CDS algorithm works

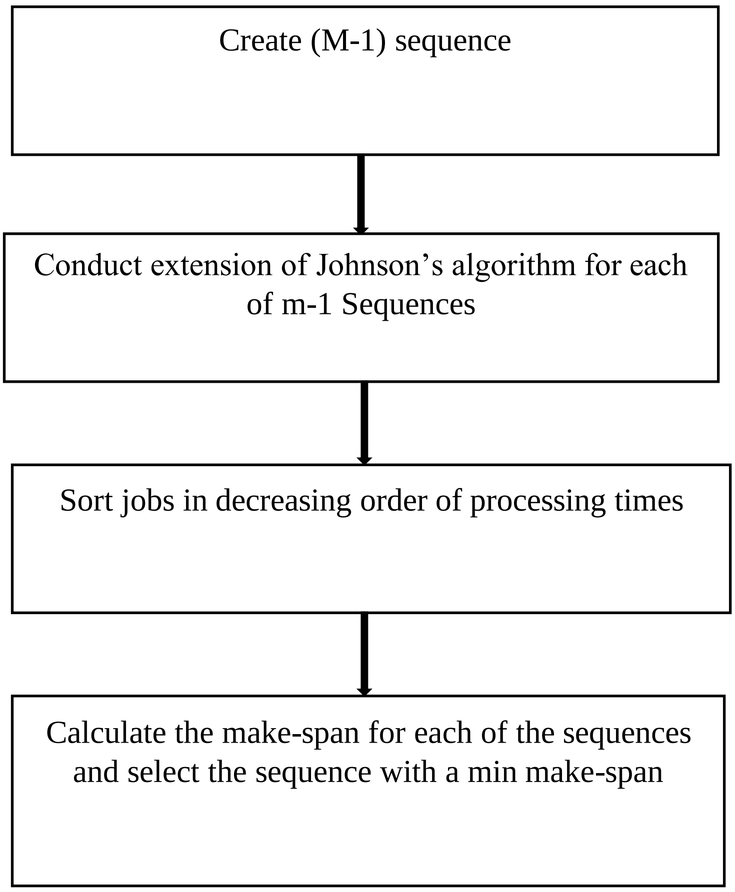

Figure3. 2 Flow chart showing how CDS algorithm works

3.3.3 Palmer's Algorithm

In this type of algorithm, the scheduler is required to offer weight to each machine and finds out a weighted sum for each job. Here below the flow chart shows how the algorithm optimization works.

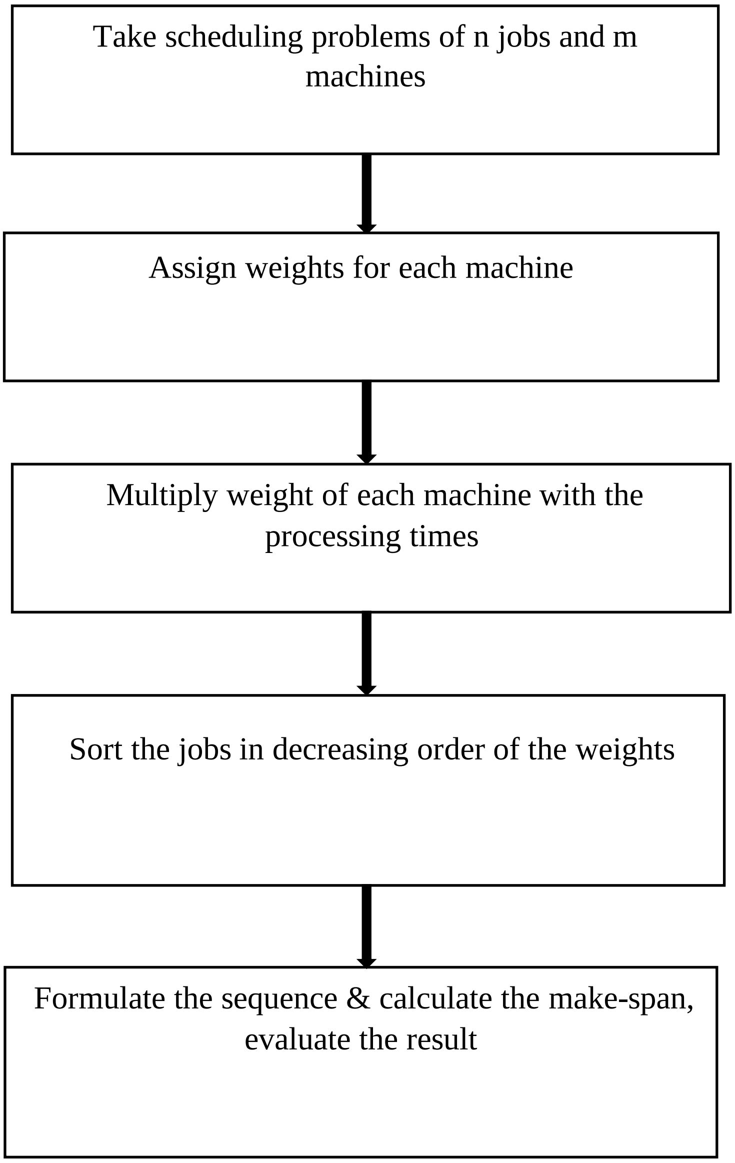

Figure3. 3 Flow diagram, which shows how the palmer's algorithm works

3.3.4 Earliest Due Date (EDD) Rule

The aim of EDD rule to reduce tardiness. EDD rule gives priority to the most imperative job or a job that requires quick decisions based on its delivery time or deadline. This is the last rule the thesis employed. According to this rule, jobs arranged in order of increasing their due dates. The main objective of this rule is to minimize the maximum job tardiness and maximum job lateness. The flow chart below illustrates how the scheduling rule can have achieved systematically.

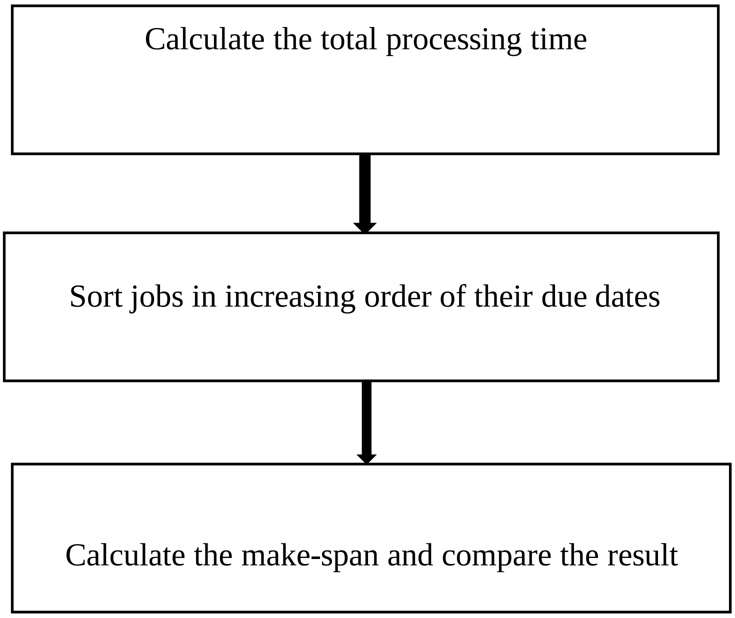

Figure3. 4 Flow chart representing how the EDD rule works

Using the above systematically, optimization approaches the researcher intended how the data analysis carried out using each optimization algorithm. For the data analysis the first assumption, i.e. all jobs have an equal chance for scheduling be analyzed using the first three heuristics Nawaz Enscore Ham (NEH), Campbell Dudek and Smith (CDS), and Palmer’s algorithms.

However, prior to formulate and code the machines, the layout of the machine for each of the required operations with the corresponding machines arranged in a sequential manner as given below. The following machine layout used only for style number 815 and this style number represented by J2, is key apparel with short sleeve. Therefore, for the described unique product prior to producing the first thing the machine layout has produced by the Industrial Engineer so that to avoid waiting for lines after the production has started. This machine layout has done first by taking into account the number of operations required for a unit product, then the layout given as follows.

Operation Name	M/C Type	W/station	W/station	M/C Type	Operation Name
Pocket Heming	CS	1	2	CS	Sleeve Heming
Sleeve Heming	CS	3	4	S.N.L.S	Box making
Box making	S.N.L.S	5	6	S.N.L.S	Sew placket
Box making	S.N.L.S	7	8	S.N.L.S	Sew placket
Box making	S.N.L.S	9	10	S.N.L.S	Sew placket
Pocket attach	S.N.L.S	11	12	S.N.L.S	Sew placket
Pocket attach	S.N.L.S	13	14	S.N.L.S	Pocket attach
Shoulder attach	4TH	15	16	S.N.L.S	Pocket attach
Rib tack	S.N.L.S	17	18	4TH	shoulder Attach
Rib Attach	4TH	19	20	S.N.L.S	Rib tack
Rib t/s 1/4	S.N.L.S	21	22	4TH	Rib Attach
Placket Top Stitch	S.N.L.S	23	24	S.N.L.S	Placket Top Stitch
Sleeve Attach	4TH	25	26	4TH	Sleeve Attach
Sleeve Attach	4TH	27	28	CS	Sleeve Top s/t
Sleeve Top s/t	CS	29	30	4TH	Side Seam
Side Seam	4TH	31	32	4TH	Side Seam
Label Attach	S.N.L.S	33	34	S.N.L.S	Label Attach
Bottom Heming	CS	35	36	BH	Button Hole
button Attach	BA	37			

Figure3. 5 machine layout for the polo shirt understudy

Where the above abbreviations of machines described as,

M/C= machine

CS= cover stitch machine

SNLS= Single needle lock stitch machine

4TH= Fourth threaded machine

BH= buttonhole machine

BA= Button attach machine

As can be seen in the above figure 3.5 the number of operations required to produce a unit product of polo shirt is 37. Based upon the number of operations the machines arranged in sequential order are also 37 machines, which equals the number of operations. As illustrated in the above figure3.5, it depicted the machine layout for the polo shirt. Therefore, the layout given in this figure properly works for the style numbers, 865,814, and 825, for a polo shirt, which means all the style numbers produced without any layout change.

For the data analysis purpose, different operations processed by the same machines are taken into the same group and these machines are considered as one machine. While doing this, the processing time for each operation in each machine added and compressed to five (5) machines. Each of the compressed machines described in the next part of the problem formulation.

3.4 Problem formulation

To conduct the proposed study, the available data arranged and expressed as follows. The proposed study conducted by selecting four (4) jobs of a polo shirt with different styles. In addition, these jobs supposed to process with five different stitching machines, installed in the sewing line knitting section of the garment department sequentially. Each job has its own processing time and operation in each machine. At the same time, the jobs have processed in the same order according to the sequential arrangement of these machines. The machine layout is constant unless otherwise the product changed, which means if the product/ article type changed with the change in the operations of the article different layout is required, however, for this case since the article, polo shirt is same once installed the layout served for each of the article types of the polo shirt given. The article style variation has not any effect on the layout since the operations are usually the same. Except for the number of operations variation, the machines used are the same hence; there might not be any machine layout change. In addition, it can be noted that for any flow shop manufacturing environments and shop floor activities the machine layout could not change since all the products produced would have the same rout of operations. In such manufacturing environments and job-shop production activities, the processing time for each job operation at each machine is different. Therefore, flow shop manufacturing environments are with the same rout of operations and need high attention in case of machine idle time reduction as well as productivity maximization. Below the identified product for the proposed study conducted and machines required to process these operations are given.

Knit garment of a polo shirt with different styles, where

J1= key apparel style no 865 (long sleeve),

J2= key apparel style no 815 (short sleeve),

J3= key apparel style no 814 (short sleeve) and,

J4= key apparel style 825 (short sleeve)

In addition, the machines required to process the above jobs given below with their detail expressions. Since this study mainly focused on the sewing line of the knitted garment section; activities such as pattern making, cutting, other finishing operations such as Ironing and packing did not have any effect for the sewing line productivity. Therefore, because of this reason, this study used the following jobs and machines in the rescheduling of jobs to carry out a comparative analysis with the existing and new scheduling heuristics algorithms. Hence, the above four jobs are processed with the following five machines and the processing time for each job on each machine is given in Table 3.1 below.

M1= cover stitch machine

M2= single needle lock stitch machine

M3= fourth thread machine

M4= Buttonhole machine

M5= Button attach machine

3.5 Performance justification of the company

In addition, to the annual production report revealed so far, in the introduction part during the data collection periods, the daily-targeted production versus actual output analyzed to show how much the productivity hindered in each day. Actual observations and hourly production target versus actual output in the sewing section of the knitted garment section imbalance shown, the main problem for low productivity found in the sewing line. This inability of meeting hourly production target leads to the daily production demand could not be achieved. Therefore, if it is not possible to meet the daily production target, this hampers the overall productivity of the sewing line as illustrated in figure 3.6 below.

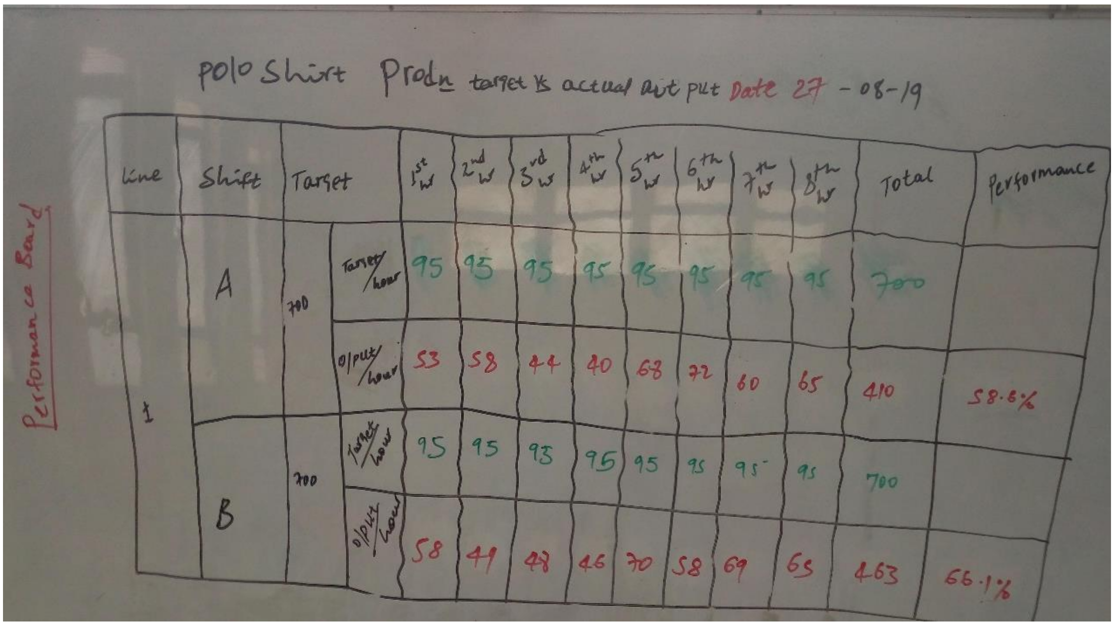

Figure3. 6 shift wise daily target vs. actual output of august 27, 2019

As the daily shift, wise production status of the case company given in figure 3.6 illustrated there was much difference within the targeted versus the actual production performance. Here it can be deduced that as the percentage performance of shift "A" indicates the sewing line was able to achieve about 58.4% while, shift "B" was able to meet 66.1% of the targeted production. Here we can conclude the sewing line daily production performance is much lower than its targeted production even all the resources, raw materials are available. In addition, the average daily performance of the company looks as follows.

$$\frac{P_A + P_B}{2}$$

Where,

P_A= Daily production performance of shift “A”

P_B= Daily Production performance of shift “B”

$$\frac{58.6 + 66.1}{2} = 62.4\%$$

This mathematical calculation shows the average daily production performance of the line for august 27, 2019 was 64.2%. This figure signifies the sewing line in this date expected to produce 1400 units of the polo shirt, however, able to produce only 873 units, which had a deviation of 527 units of the polo shirt, which in turn transferred to the next date. This inability of the line would lead to missing the in-time delivery of the company since it was not able to produce as per the daily production target.

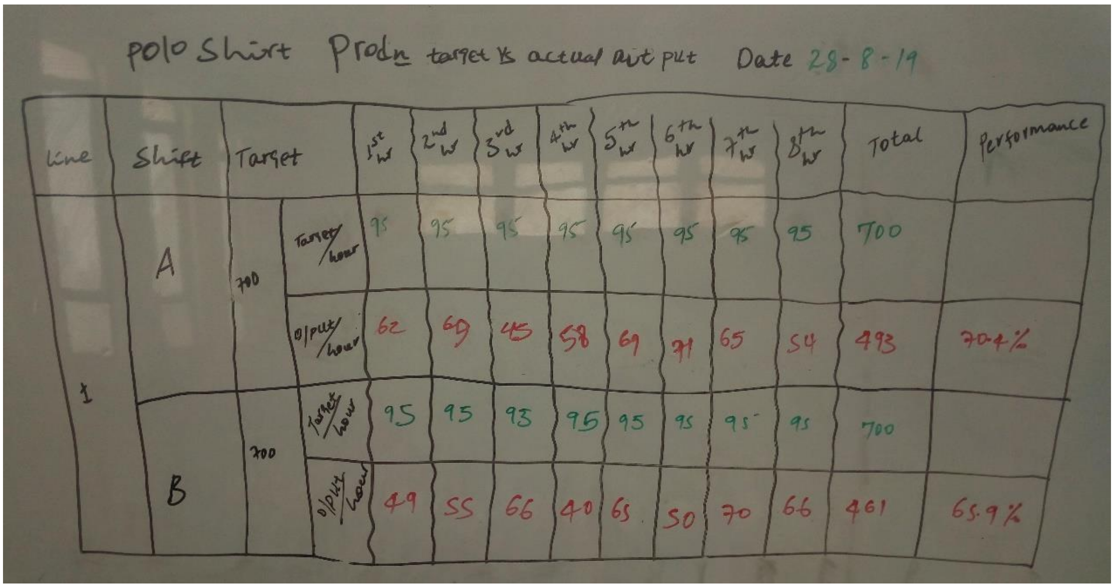

Figure3. 7 shift wise daily target vs. actual output of august 28, 2019

Once again, as illustrated in figure 3.7 the actual daily production performance of the date august 28, 2019 was only 954 units with a performance achievement of about 68%.

Figure3. 8 shift wise daily target vs. actual output of august 29, 2019

The above figure 3.8 depicts the average daily performance of the sewing line for both shifts “A” and “B” was 67.2%. This production performance achievement was lower than the performance achievement obtained in figure 3.7 by 0.8%. However, it was greater by 8.8% than the performance obtained earlier in figure 3.6.

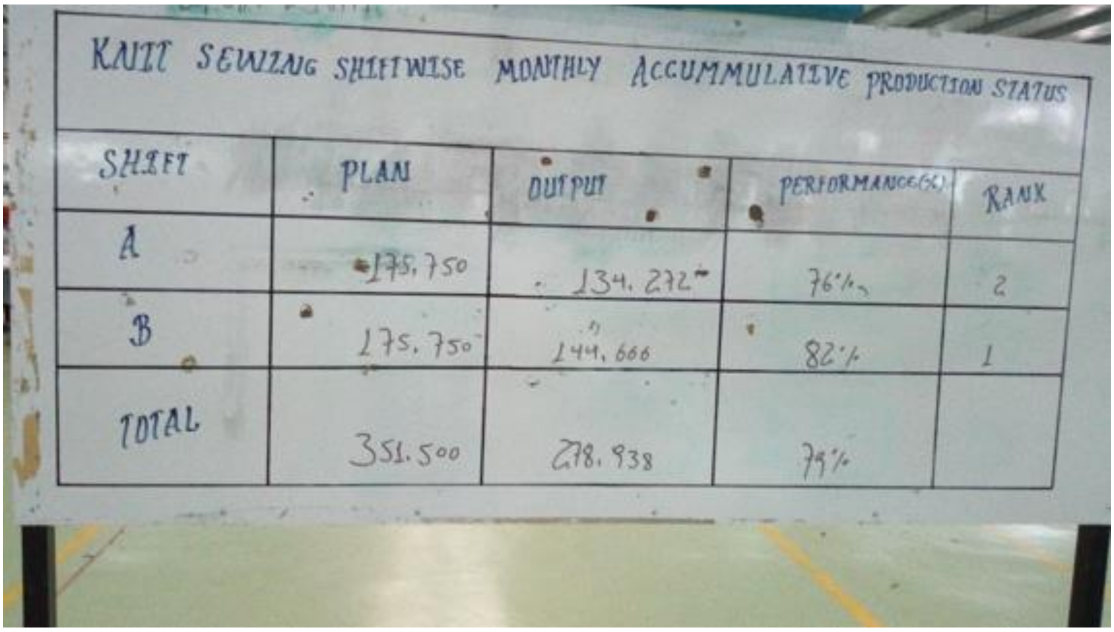

Figure3. 9 shift wise monthly august 2019 production status

This production performance obtained from the post by the Engineering officer of the case company.

As the average performance of the two shifts of “A” and “B” indicated, its maximum achievement was not more than 79% for the month of August 2019. Considering this actual production performance, a question raised to the production head of the knitted section of the garment department.

1) “What is the reason that most of the time the line produces below the targeted production?”

According to the response obtained from Mrs. **Tirhas** the production head of the section, the main reason for the low productivity of the line was un-shceduled(un-planned) or random product changeover. Even, the articles ordered did not have much delivery time variation the company produces some of them up to a week and the remaining for the next week by considering the status in producing the articles demanded. However, this course of action needs high management decisions concerning job scheduling by considering the impact of scheduling in machine idle time minimization and delivery time at the same time customer satisfaction.

2) "Have you ever faced any maintenance related machine breakdown?"

Yes of course. However, it does not have much effect on downtime since we have maintenance specialists assigned in each line. In addition, the down time beacuase of machine break down is almost negligible since actions taken as soon as a short stoppage happens with the help of red lights so that to alarm the maintenance personnel.

Figure3. 10 knit garment polo shirt input fabric

CHAPTER FOUR

4.4 Result and discussion

The data analysis first attempted using the existing, first come first served (FCFS) rule to show how mutch it deviates interms of productivity parameters such as machine idle time, make-span, and machine utilization or not. Table 4.1 given below illustrated the number of jobs of polo shirts and their associated operations with the corresponding machines and processing time. Then the result obtained using this scheduling rule for the proposed parameters compared in each of the proposed heuristics algorithms. The jobs listed in table 4.1 below indicated based on their order of arrival and the data used for the analysis and verification purposes.

Table4. 1 processing time of jobs

Jobs	M1	M2	M3	M4	M5
J1	7.65	2.07	3.2	8.28	0.72
J2	6.27	2.17	2.45	10.5	0.42
J3	5.96	2.07	2.33	9.99	0.4
J4	3.58	1.83	3.67	2.58	0.42

The data in the above table 4.1 obtained from the stopwatch record as explained in the methodology section of this study. In addition, the collected data checked with the existing processing time for the polo shirt on each of the styles of the articles used in the proposed study then finally, found and guaranteed on the data consistency. Then the standard minute values (SMV) for each of the operations of these four styles of polo shirt taken for this study. After the processing time for the 37 operations collected, the same machines used to process different operations grouped into one machine. Hence, a polo shirt with four styles is taken as four jobs with different operations and the machines used to process these operations are grouped into five machines as represented in the above table 4.1. The time to process each task of the jobs is determined after it had been recorded using the stopwatch and this added up to have the above concurrent data.

Firstly, based upon the operation breakdown the number of operations for study identified and SMV is calculated. In addition, the identified operations have recorded

5 times then the average observed time used so that to find the SMV for the required operation as well as to the unit product.

In the above data, the standard minute value (SMV) for each task determined as follows,

SMV = Basic time *(1+ Allowance)

Basic time= observed time * Performance rating

Observed time: The observed time here is the actual time required to stitch a garment, obtained by recording-using stopwatch.

Performance rating: it is a parameter of SMV, which related to machine and operators at what speed the operator can complete the task.

Allowance: the allowance used herein the SMV calculation taken from the case company and it was about 25%.

4.2 Result of the first come first served (FCFS) Rule

The following result depicted the make-span calculation using the existing scheduling approach of the case company. Because of the data analysis for first come, first served scheduling rule given below in table 4.2 depicted at machine three the maximum idle time was between job 1 and job 2. This means, job J1 completed at machine M3 with 12.92 minutes. Though it has to start processing job 3 as soon as it finished job J1 however, it is forced to wait until job 2 has to be completed at machine M2 that is machine M3 was idle up to 22.82 min until job J2 became free on machine M2.

Table4. 2 Result of make-span for the existing scheduling rule of FCFS

Jobs	M1(time)		M2 (time)		M3 (time)		M4 (time)		M5 (time)	
	start	finish	start	finish	start	finish	start	finish	start	finish
J1	0	7.65	7.65	9.72	9.72	12.92	12.92	21.2	21.2	21.92
J2	7.65	13.92	13.92	22.82	22.82	25.47	25.47	35.97	35.97	36.39
J3	13.92	19.88	22.82	26.32	26.32	28.65	35.97	45.96	45.96	46.36
J4	19.88	26.73	26.73	28.72	28.72	32.39	45.96	48.96	48.96	**49.38**
Idle time	0		4.2		16.4		4.27		26.22	

4.2.1 Make-span

The above table 4.2 depicted and analyzed that the existing scheduling approach of first come first served (FCFS) rule operated with a make-span value of **49.38 min.** in this case the first arrival job should be processed first and the last arrival job should get processed latter. However, so far in the problem statement authenticated that, the FCFS scheduling approaches only focused on minimizing job completion time and customer waiting time. Even it seems fair to the first arrival jobs however, it does not consider other customer and job characteristics such as average completion time of jobs, machine idle time, resource utilization, and production cost issues.

4.2.2 Idle time of FCFS scheduling rule

The idle time of a machine for the above operations calculated using the following formula,

TiT= $\sum_{i=1}^{5}(\text{idle time ofMi})$

Where,

TiT= Total idle time and

$M_{i\,=}$ idle time of each machine

Therefore, using the above formula and idle time values of each machine obtained in the above table 4.2 the total idle time of machines was,

Idle time of (M_1=0, M_2= 4.2 min, M_3= 16.4 min, M_4=4.27 min, M_5=26.22 min), then the total idle time of the sequence as per their order of arrival was,

Total Idle Time of the sequence= (0+4.2+16.4+4.27+26.22) min= **51.1 min.**

Here as observed at machine M1 there was not any machine idle time since it is the first available and ready machine for the first arrival job, whereas machine M2 had to wait up to a total of 4.2 min until machine M1 processes the first arrival jobs as per their sequence. Machine M3 was the third machine where the next larger idle time observed than M1 and M2. The fourth machine M4 was another machine that demonstrated a less idle time variation compared to machine M3 almost similar to machine M2. The last machine, M5 characterized by the machine where the largest idle time in the FCFS rule identified.

4.3 Result of Nawaz Enscore Ham (NEH) scheduling rule

According to NEH's algorithm, the analysis carried out in an iterative manner by inserting the new and near job in the sequence and the optimal answer could be the one that provides the minimum make-span. This form of the NEH insertion done for the whole iteration until all the combinations completed. At the end of the iteration, the sequence that contains all the jobs and the minimum make-span selected as the optimal sequence of jobs for the problem under study.

Using the input data given in the above table 4.1, the jobs processed in the corresponding machines considered and the make-span calculated using NEH's algorithm. This carried out after determining the total processing time for each job in each machine. In the NEH's heuristics algorithm step-wise iterations are used, to arrive the minimum make-span that might reduce the idle time of a machine, reduce the production cost, reduce the number of tardy jobs, and improve the resource (machine) utilization.

Table4. 3 Total processing time for each job

Jobs	**M1**	**M2**	**M3**	**M4**	**M5**	**Total Processing time**
J1	7.65	2.07	3.2	8.28	0.72	**21.92**
J2	6.27	2.17	2.45	10.5	0.42	**21.81**
J3	5.96	2.07	2.33	9.99	0.4	**20.75**
J4	3.58	1.83	3.67	2.58	0.42	**12.08**

Table 4.3 has shown the total time required to produce a unit product upon the given data calculation. The total time of the job has obtained by summing up all the corresponding time required for each operation at the specified machine, which simplified by using the following equation.

$$\mathrm{TT_i} = \sum_{\mathrm{j=1}}^{5} \mathrm{TM_{ij}}$$

Where

TT_i = represents the total time required to complete the i^{th} job, and

TM_{ij} = is the time required to process i^{th} job on machine j.

After the total time for each job has calculated, the NEH heuristics algorithm applied with the main objective of reducing the make-span and idle time of the machines. The following are systematic make-span calculation methods deployed in the NEH scheduling algorithm.

Step1. Find the total processing time. As calculated in the above table 4.3

Step2. Sort/ arrange the jobs in the decreasing order of processing times

Using the total processing time, obtained in table 4.3 the following sequence of jobs, formulated.

J1-J2-J3-J4

Step3. Consider J1 & J2 and taking in to account the first two jobs and forming two different combinations the possible sequence of jobs are **J1-J2** and **J2-J1**, by reversing their order

Table4. 4 Option one make-span for the partial sequence J1-J2

Jobs	**M1**	**M2**	**M3**	**M4**	**M5**
J1	5.96	8.03	10.36	20.35	20.75
J2	12.23	14.4	16.85	30.85	**31.27**

Here in option one in the above table 4.4, the initial make-span obtained using the partial sequence **J1-J2** is **31.27** min. this value compared with the make-span value, which was calculated using option two in table 4.5 below.

After taking in to account the results of the two partial sequences then the next iteration proceeded so that to find the minimum make-span.

Table4. 5 Option two make-span for the partial sequence J2-J1

Jobs	M1	M2	M3	M4	M5
J2	6.27	8.44	10.89	21.39	21.81
J1	13.92	15.99	19.19	29.67	**30.39**

As the partial sequence of the Nawaz Enscore Ham algorithm resulted in the two combinations provided two different make-span values for the case, then the sequence, which provided the minimum make-span, selected.

So sequence **J2-J1** with a make-span value of 30.39 min is chosen and the next job which is **J3** in the order of arrangements as given in step 2 is inserted so that to proceed with the analysis.

Step4. Take the next job i.e. J3

Now by using **J3,** we do have the following sequences i.e., **J2-J3-J1, J3-J2-J1**, and **J2-J1-J3** and we would have the following iterations that mean by squeezing **J-3** in three different places we obtained three partial sequences;

Table4. 6 Make-span for the partial sequence of J2-J3-J1

Jobs	M1	M2	M3	M4	M5
J2	6.27	8.44	10.89	21.39	21.81
J3	12.23	14.3	16.63	31.38	31.78
J1	19.88	21.95	25.15	39.66	**40.38**

Here in the above table 4.6, the main target was finding the total completion time or make-span with the given partial sequence of **J2-J3-J1** and found to be **40.38** minutes, which in turn compared with the result of the remaining two partial sequences. So now, let us proceed to the second partial sequence, which given in the above step 4, i.e. **J3-J2-J1** to find the make-span.

Table4. 7 Make-span for the partial sequence of J3-J2-J1

Jobs	M1	M2	M3	M4	M5
J3	5.96	8.03	10.36	20.35	20.75
J2	12.23	14.4	16.85	30.85	31.27
J1	19.88	21.95	25.15	39.13	**39.85**

Once again, the make-span calculation summary given in the above table 4.7 showed the minimum make-span value obtained using the partial sequence **J3-J2-J1** that is **39.85** min. However, this sequence results in a minimum make-span value compared to the result obtained in table 4.6 and it is impossible to insert the next job and find another combination to find the sequence with minimum total completion time. Therefore, it is mandatory to check whether the sequence **J2-J1-J3** can result in minimum total completion time for the last job or not since it is the last sequence obtained in the specified iteration.

Table4. 8 Make-span for the partial sequence of J2-J1-J3

Jobs	**M1**	**M2**	**M3**	**M4**	**M5**
J2	6.27	8.44	10.89	21.39	21.81
J1	13.92	15.99	19.19	29.67	30.39
J3	19.88	21.95	24.28	39.66	**40.06**

The result obtained in the summery of total completion time given in table 4.8 is still greater than the total completion time obtained in table 4.7. Therefore, out of the three combinations of the NEH's partial sequences a minimum make-span value obtained in the partial sequence **J3-J2-J1**, which results in a make-span value of **39.85** minutes. Hence, the sequence **J3-J2-J1** is chosen for the case and another combination of jobs is created and the solution process is continued by forming all the possible combinations in an iterative manner until all the sequences are evaluated and their make-span is checked turn by turn. Therefore, the process of iteration is continued using step 5 as a starting point and sequence **J3-J2-J1** as a partial initial sequence. since the jobs to be permutated are four, then four partial sequences of jobs are obtained. Therefore, based on the procedure the following four sequences of jobs formed to draw a conclusion using NEH's algorithm regarding the make-span.

Step5. Take the next job i.e. J4

Now J4 squeezed in four different ways i.e., **J3-J4-J2-J1**, **J4-J3-J2-J1**, **J3-J2-J4-J1**, and **J3-J2-J1-J4**, using these sequences let us find the make-span for each case turn by turn.

Table4. 9 Make-span for the partial sequence of J3-J4-J2-J1

Jobs	M1	M2	M3	M4	M5
J3	5.96	8.03	10.36	20.35	20.75
J4	9.54	11.37	15.04	22.93	23.35
J2	15.81	17.98	20.43	33.43	33.85
J1	23.46	25.53	28.73	41.71	**42.43**

After J4 squeezed in four different sequence locations, the partial sequence grouped in four different sequences. Out of these four partial sequences, the first sequence **J3-J4-J2-J1** resulted in a make-span value of **42.43** minutes which intern compared with the results of the other three partial sequences of the NEH heuristics algorithm. Likewise, the first partial sequence as given in the above table 4.9 another which is the second partial sequence that contains four jobs by squeezing J4 in the first position is discussed in Table 4.10 below and the make-span result obtained using the NEH's heuristics algorithm is given in the corresponding table.

Table4. 10 Make-span for the partial sequence of J4-J3-J2-J1

Jobs	M1	M2	M3	M4	M5
J4	3.58	5.41	9.08	11.66	12.08
J3	9.54	11.61	13.94	23.93	24.33
J2	15.81	17.98	20.43	34.43	34.85
J1	23.46	25.53	28.73	42.71	**43.43**

Once again as explained above, under table 4.9 the partial sequence **J3-J4-J2-J1** taken into account so that to draw a conclusion whether the make-span obtained using this partial sequence was greater or less than the result obtained in the partial sequence **J4-J3-J2-J1.**

As obtained from the result of the algorithm the make-span value **43.43** min, obtained using the second partial sequence was greater than the result obtained using the first partial sequence. Therefore, as discussed earlier the optimization process of NEH's algorithm continues until all the combinations with the four jobs are completed. Once again, let us proceed to the sequence **J3-J2-J4-J1** that is the third combination among the given alternative partial sequences.

Table4. 11 Make-span for the partial sequence of J3-J2-J4-J1

Jobs	M1	M2	M3	M4	M5
J3	5.96	8.03	10.36	20.35	20.75
J2	12.23	14.4	16.85	30.85	31.27
J4	15.81	17.64	21.31	33.43	33.85
J1	23.46	25.53	28.73	41.71	**42.43**

As the analytical result of make-span value for the third partial sequence, **J3-J2-J4-J1** indicated this sequence arrived at the same make-span value of **42.43** minutes likewise the result obtained in the first partial sequence **J3-J4-J2-J1.** Following this, the last but not the list partial sequence **J3-J2-J1-J4** is analyzed following the same procedure as the above three partial sequences. In addition, this analyzed and summarized in the tabular form, as given in table 4.12 below.

Table4. 12 Make-span for the partial sequence of J3-J2-J1-J4

Jobs	M1	M2	M3	M4	M5
J3	5.96	8.03	10.36	20.35	20.75
J2	12.23	14.4	16.85	30.85	31.27
J1	19.88	21.95	25.15	39.13	39.85
J4	23.46	25.29	28.96	41.71	**42.13**

As the analysis of the above iterations of make-span calculation values summarized in the above table 4.12 showed, the last iteration with a sequence of **J3-J2-J1-J4** in the corresponding table is the most optimal sequence to minimize the make-span than the above three iterated make-span values of the given combinations. However, when checking the idle time, the minimum idle time obtained from the third partial sequence of jobs **J3-J2-J4-J1.**

Therefore, as given in the above table 4.11 the optimal make-span value of the NEH'S algorithm obtained to be **42.43** minutes. As a concluding remark, the sequence **J3-J2-J4-J1** is an optimal sequence out of all the possible combinations obtained using NEH's heuristic scheduling approach.

In addition, as it is given step by step in the above calculations NEH used nine different iterations so that to arrive at the most optimal sequence of jobs in order to reduce the make-span and idle time of machines for the given flow shop scheduling problem.

The figure below depicted the make-span values obtained and summarized using the four jobs in four different combinations of jobs. Therefore, here observed that the first and third combinations with different sequence reached the same make-span values. However, the minimum idle time, which is the focus of this research, obtained in the third partial sequence of jobs. On the other hand, the second and fourth combinations gave different make-span values. The figure 4.11 below represented each sequence of jobs obtained using the NEH's algorithm with their corresponding values.

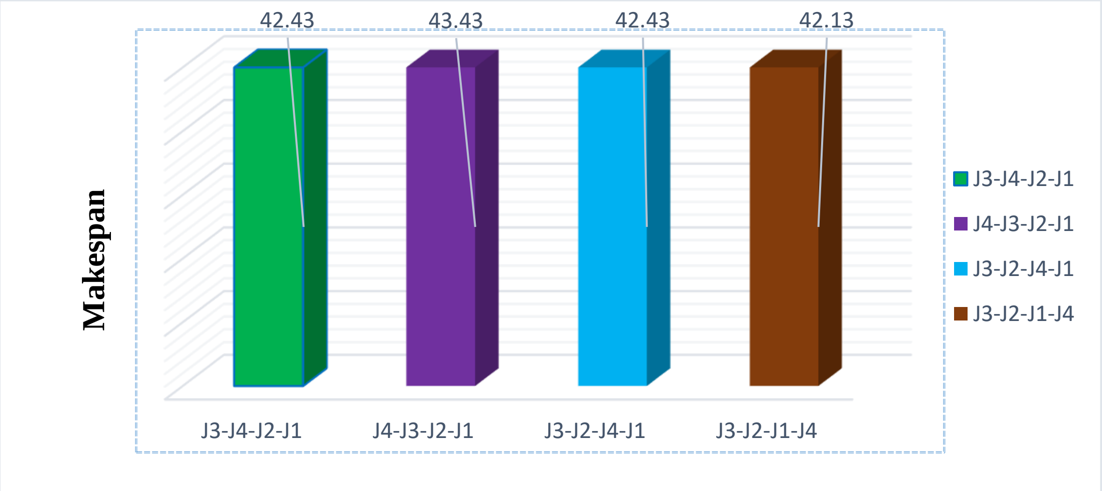

Figure4. 1 Make-span values of NEH heuristics algorithm in each of the four iterations

Taking into account the four partial sequences in the above figure 4.11 and selecting the partial sequence which had a make-span value of 42.43 minutes since it resulted a the minimum idle time than the other partial sequences. This is because, the aim is to minimize the idle time of machines. After the make-span optimized, using the NEH's heuristics algorithm the next most important point in the proposed study was to find the actual value of idle time of the machines using this scheduling approach as a proposed scheduling rule.

Previously using the first come first served rule (FCFS) the idle time was about 51.1 minutes. Using the idle time of the existing scheduling approach and finding the new idle time by the improved NEH scheduling method with the sequence of jobs a comparative analysis took into account and the percentage idle time improvement obtained using this new method or deviation discussed after the idle time of the new NEH's scheduling approach found.

Table4. 13 Idle time calculation of NEH's algorithm

Jobs	M1(time)		M2 (time)		M3 (time)		M4 (time)		M5 (time)	
	start	finish	start	finish	start	finish	start	finish	start	finish
J3	0	5.96	5.96	8.03	8.03	10.4	10.4	20.4	20.4	20.8
J2	5.96	12.2	12.2	14.4	14.4	15.5	20.4	30.9	30.9	31.3
J4	12.2	15.8	10.8	12.6	12.6	16.3	30.9	33.4	33.4	33.9
J1	15.8	**23.5**	23.5	**25.5**	25.5	**28.7**	33.4	**41.7**	41.7	**42.43**
Idle time	0		10.43		7.72		0		20.12	

As can be seen in the third iteration of sequences with four jobs iteration of a new and improved sequence of the Nawaz Enscore Ham algorithm with a sequence of **J3-J2-J4-J1** and make-span value of **42.43** min in the above table 4.13 the idle time of the sequence is calculated as follows;

Idle time of M1=0, M2=10.43, M3= 7.72, M4=0, and M5= 20.12

Total idle time= $\sum_{i=1}^{5}$(idle time ofMi)= 0+10.43+7.72+0+20.12= **38.27 min.**

As the above table 4.13 illustrated machines, M1 and M4 have zero idle times. As soon as the job arrived at the shop it gets processed by machine M1. Most of the time believed that, at machine M1 there is not forced idle time. In addition, at machine M4, it is the same, there is not forced idle time. However; there is uncontrollable (natural) idle time. Since there is, no mechanism of controlling the natural idle time, in the proposed study, the attention is only reducing the forced idle time of a machine. The analysis indicated that machine M4 started its operation after the job get processed by machine M3. Until the job completed on machine M3, machine M4 has to wait for 7.72 minutes, which is an controllable or natural idle time.

The target in this study is, either to eliminate or reduce the forced idle time that might happen because of wrong or inappropriate schedule. Hence, the idle time of machine M4 cannot be controlled. The last machine i.e. machine M5, in this case, has both natural idle time and forced idle time. The forced idle time obtained here for machine M5 is near to the natural idle time, which is 20.12 min.

Hence, it can be concluded that the new scheduling algorithm is better in reducing the forced idle time of the machine M5 than the existing scheduling rule and this comparative reduction of idle time for the last machine M5 is given below;

$$\%\text{ITR} = \frac{\text{Idle time of previous schedule on M5} - \text{Idle time of new schedule on M5}}{\text{Idle time of previous schedule on M5}} * 100$$

Where,

ITR= Idle Time Reduction, therefore the reduced idle time is;

% idle time reduction = $\frac{26.22 - 20.12}{26.22} * 100 = 23.3\%$

As the analytical result of the idle time depicted the new scheduling algorithm is capable of reducing the idle time of the machine M5 by 23.3% than the existing scheduling rule (FCFS) rule.

Using the final and optimal sequence obtained by NEH's heuristics algorithm the Gant chart constructed as follows, so that to show from which machines and between which jobs the idle time occurred.

NB: According to NEH's algorithm, the optimal sequence found to be **J3-J2-J1-J4** with a make-span value of **42.13 minutes** and an idle time of **40.29 min**. However, noted that the partial sequence **J3-J2-J4-J1** resulted in a reduced idle time of **38.27** minutes with a make-span value of **42.43** minutes. Therefore, here we can conclude that though the make-span is minimum in the first iteration from the given alternative of these two sequences of jobs the minimum idle time obtained in the third sequence of jobs. Therefore, it has adopted the previous sequence because of its reduced idle time. This is because of the 42.43-42.13=0.3-minute difference the idle time improvement goes to 40.29-38.27=2.02 minute.

On the other hand, by adopting the sequence **J3-J2-J4-J1** a 5% idle time is reduced than using the sequence **J3-J2-J1-J4** which can reduce the make-span (total completion time of the last job) in the sequence by 0.71% if it is selected for the situation. Therefore, taking into account the result obtained here the researcher prefers the sequence, which reduces the idle time by 5%. Because compared to the make-span variation the idle time variation is larger so the sequence which has to be adopted for the NEH's heuristics algorithm is **J3-J2-J4-J1** which results from a minimum idle time though a small variation in the make-span by 0.3 which is 0.71% maybe if it is adopted for the case.

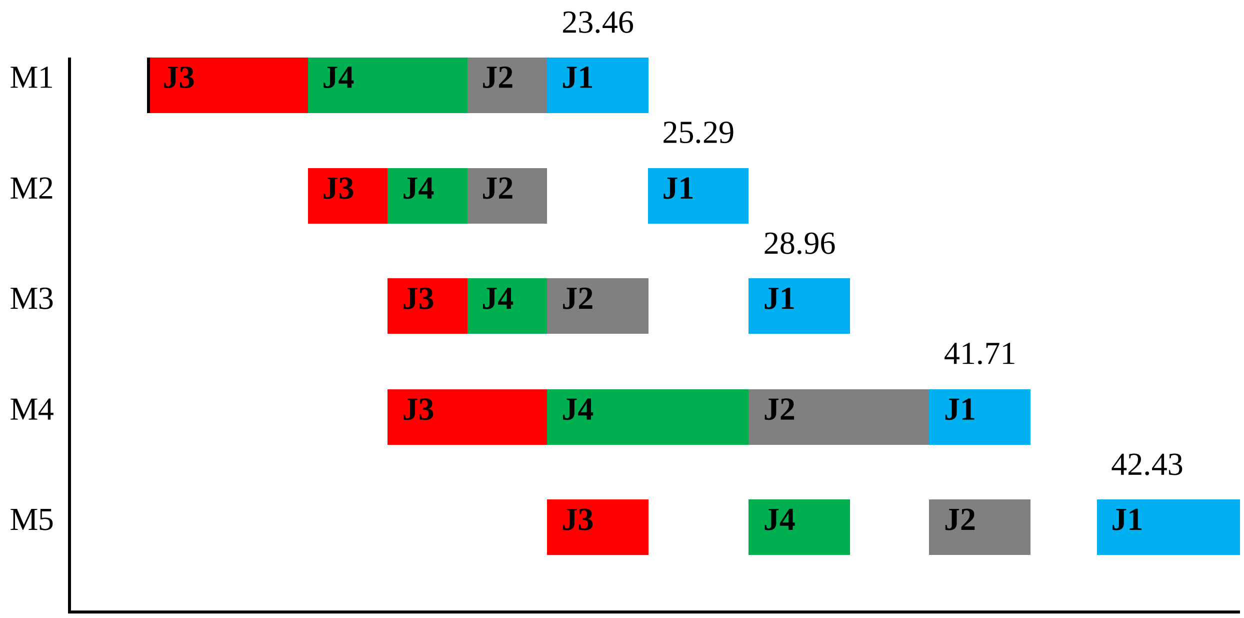

Figure4. 2 Gant chart for the sequence of jobs using NEH's algorithm

4.4 Result of Palmer's Algorithm

As discussed earlier in the methodology part of the proposed study this method deployed a weighted sum for each of these jobs. For the scheduling purpose, weights assigned to each of these machines and the weighted sum of each job calculated to find a solution. The following steps used for the case.

Step 1: Consider a job-scheduling problem for five machines and four jobs.

Step 2: Assign some specific weights to each machine and multiply each job processing time by the weight given and sum.

Step 3: Sort the jobs in the decreasing order of their weights.

Step 4: Formulate a sequence based on the sorting done in Step 3.

Step 5: Calculate the Make-span for the above sequence.

In this case, the same problem of the above 5 machines & 4 jobs considered that already used for NEH's calculation considered.

Steps1 & 2 Assign weights to each machines. The weights to be assigned must be symmetrical for odd machines. Then in this case assign, negative (-ve), zero(0), and positive (+ve). For even machines, only assign negative and positive, zero should be removed. Then for this problem -4, -2, 0, 2, and 4 are selected weights.

Weight (M1)= -4, weight (M2)= -2,weigt (M3)= 0, weight (M4)= +2, and weight (M5)= +4 and then find weights as given below.

Weight of **J1** = (-4*7.65) + (-2*2.07) + (0*3.2) + (2*8.28) + (4*0.72) = **-15.3**

Weight of **J2** = (-4*6.27) + (-2*2.17) + (0*2.45) + (2*10.5) + (4*0.42) = **-6.74**

Weight of **J3** = (-4*5.96) + (-2*8.56) + (0*2.33) + (2*9.99) + (4*0.4) = **-19.38**

Weight of **J4** = (-4*3.58) + (-2*1.83) + (0*3.67) + (2*2.58) + (4*0.42) = **-11.14**

Using this value now let us sort the jobs based up on the decreasing order of their weightage as show in tabular form below.

Table4. 14 Calculated weights

	M1	**M2**	**M3**	**M4**	**M5**	**Weight**
J1	7.65	2.07	3.2	8.28	0.72	**-15.3…** (3rd job)
J2	6.27	2.17	2.45	10.5	0.42	**-6.74** (1st job)
J3	5.96	8.56	2.33	9.99	0.4	-19.38 …(4th job)
J4	3.58	1.83	3.67	2.58	0.42	**-11.14**…(2nd job)
Weight	-4	-2	0	+2	+4	

Step3. Sort the jobs in decreasing order of their weight

Using the above table 4.14 and the weighted sum of jobs to the decreasing order using Palmer's heuristics algorithm the sequence became **J2-J4-J1-J3.**

Step4. Formulate the sequence

Using the above table 4.14 of palmer's weight calculation the following sequence **J2-J4-J1-J3** obtained in step 3 and the make-span calculated using the palmers approach and the summarized result of the make-span obtained using palmer's heuristics algorithm given in a tabular form.

Table4. 15 Make-span calculation-using palmers rule

	M1	**M2**	**M3**	**M4**	**M5**
J2	6.27	8.44	10.89	21.39	21.81
J4	9.85	13.31	18.99	25.65	26.07
J1	17.5	19.57	22.77	33.93	34.65
J3	23.46	32.02	34.35	44.34	**44.74**

Palmer's heuristics algorithm is one iteration approach. Using this iteration both the make-span and the idle time for the near to optimal sequence of the jobs has been calculated and the result obtained with the sequence in the above table 4.15 is discussed. Then as the result of the calculation given in table 4.15 revealed that the make-span obtained using the palmer's algorithm found **44.74 minutes.** The result of the make-span obtained is greater than the one obtained in the above NEH's heuristics algorithms. After the make-span is obtained using the described sequence with the scheduling rule then the idle time of the machines is calculated and summarized in a tabular form so that to carry out a comparative study with the previously obtained idle time using the NEH's flow shop scheduling algorithm as well with the existing scheduling approach of the case company. Finally, the researcher once again compared the result obtained by comparing the above two heuristics methods with the result found using the CDS flow shop scheduling heuristics algorithm. The idle time and make-span result obtained using each scheduling algorithm compared with the existing scheduling rule of the case company. At the end of each algorithm, the most determinant parameters such as idle time of machines and make-span or total completion time of the last job on the last machine had to be considered. For further investigation of productivity improvement by reducing the idle time of the machines and increasing the machine utilization besides reducing the production cost by increasing the output rate with the introduction of the newly scheduling algorithms.

Table4. 16 Idle time calculation using Palmers heuristics

Jobs	M1(time)		M2 (time)		M3 (time)		M4 (time)		M5 (time)	
	start	finish	start	finish	start	finish	start	finish	start	finish
J2	0	6.27	6.27	8.44	8.44	10.89	10.89	21.39	21.39	21.81
J4	6.27	9.85	9.85	11.68	11.68	15.35	21.39	23.97	23.97	24.39
J1	9.85	17.5	17.5	19.57	19.57	22.77	23.97	32.25	32.25	32.97
J3	17.5	**23.46**	23.46	**32.02**	32.02	**34.35**	34.35	**44.34**	44.34	**44.74**
Idle time	**0**		**11.12**		**14.26**		**2.15**		**21.39**	

As introduced earlier, the idle time has calculated just like that of the make-span for each of the heuristics algorithms in each proposed method of problem-solving. Following the same procedure, likewise used in NEH's algorithm again it is necessary to find the idle time of the machines. Using the sequence of palmer's heuristics algorithm, then to compare and contrast whether the algorithm is better or poor in minimizing the idle time of the case company relative to that of the NEH's heuristics algorithm. In addition, the existing scheduling rule of the case company which previously discussed. Therefore, the idle time calculation is given as follow;

Total idle time= $\sum_{i=1}^{5}(\text{idle time ofMi})$ and using these idle time values obtained in the above-summarized table 4.16

M1= 0, M2= 11.12, M3= 14.26, M4= 2.15, and M5= 21.39 then finally, the total idle time using the palmer's heuristics algorithm was calculated as follows;

Total idle time= $\sum_{i=1}^{5}(\text{idle time ofMi})$= 0+11.12+14.26+2.15+21.39= **48.92 minute.**

Even though, the make-span reduced, however, as seen from the result of the idle time calculation using the palmer's heuristics approach it is greater than the result of the idle time obtained using the NEH's heuristics approach. Therefore, it was noted that until a minimum idle time obtained by taking in to account the comparative study among the four approaches of heuristics the process is continued. Here, the figure below depicted the idle time of the machines between which jobs and machines the idle time has happened.

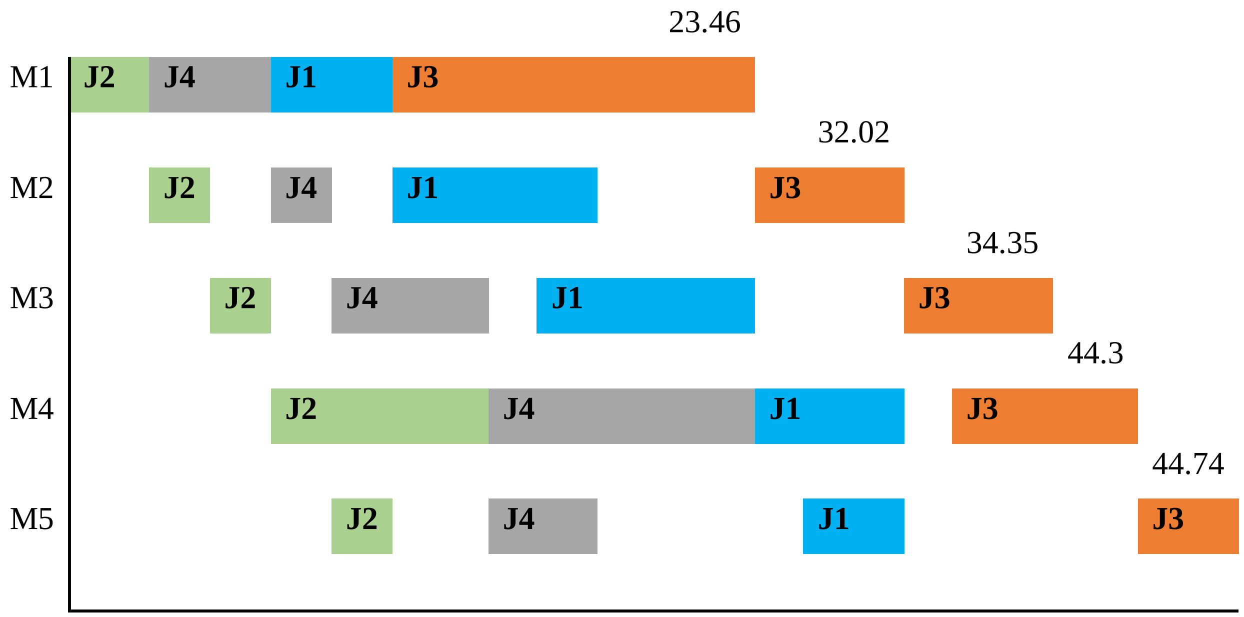

Figure4. 3 Gant chart for the Palmers heuristics algorithm

As can be seen from figure 4.3 the maximum idle time occurred in machine 5 and the next larger idle time found from machine 3, whereas from machine 2 there is also a comparable idle time.

However, from machine four the idle time occurred is much lower than the idle time occurred in the machines, five, three, and two respectively. At machine M1 as discussed, earlier the idle time recorded is zero (0). Therefore, at machine 1 except the natural idle time still, there is not any forced idle time as the results of the two heuristics algorithms of idle time calculation output reveals. Hence, for Palmer's heuristics algorithm, it is concluded that because of limited or one iteration step the required parameters both idle time and make-span were greater than NEH's heuristics algorithm.

4.5 Result of CDS (Campbell Dudek Smith) Algorithm:

Another optimization heuristics algorithm that the researcher deployed in the proposed study is the CDS algorithm. This rule used an extension of Johnson's algorithm in the iterations to arrive at a better and near to optimal solution. The iterative procedural solution of the algorithm given below in detail for each of the iterations of the extension of Johnson's scheduling of two machines and "n" job problems.

For m Machine: M1, M2, M3…... (Mm) & n Jobs;

Step1: create (M-1) Sequence. As shown in the table below this algorithm carried out,

S1	M1	M(m)
S2	M1+M2	M(m-1)+M(m)
S3	M1+M2+M3	M(m-2)+M(m-1)+M(m)
……	M1+M2 +M3 +…	………
……	M1+M2+M3+…	……….
S(m-1)	M1+M2+M3+…+M(m-1)	M2+M3+….+M(m)

Step2: Apply Extension of Johnson's Algorithm to each of the above (m-1) sequences.

Step3. Take the best possible Make-span out of them.

Step4. Evaluate (m-1) sequences based upon CDS.

Once again, considering the same problem of five machines & four Jobs as in palmers and NEH's algorithm the analysis of CDS has done as given below.

Table4. 17 Given data for the number of machines and jobs from table 4.1

	M1	**M2**	**M3**	**M4**	**M5**
J1	7.65	2.07	3.2	8.28	0.72
J2	6.27	2.17	2.45	10.5	0.42
J3	5.96	2.07	2.33	9.99	0.4
J4	3.58	1.83	3.67	2.58	0.42

Prior to proceeding to the make-span calculation, let us determine possible sequences created using the Campbell Dudek and Smith heuristics algorithm.

For that matter as just likewise that of the above two approaches of heuristics algorithms 5 machines and 4 jobs are used and the possible CDS sequences are determined by the formula (m-1) =5-1= 4 sequences which are considered as s_1, s_2, s_3, and s_4.

S1	M1	M5
S2	M1+M2	M4+M5
S3	M1+M2+M3	M3+M4+M5
S4	M1+M2+M3+M4	M2+M3+M4+M5

Taking in to account the first series s_1 with machines M_1 and M_5 as well 4 jobs the first iteration for the CDS heuristics algorithm is analyzed so as to find sequences of jobs so that to process them in an economical way of doing jobs.

Using this partial sequence of jobs the required make-span value is determined and considered maybe if it is the minimum acceptable make-span for the case analyzed for further study of the idle time and other parameters discussed earlier. Let us follow the table 4.18 below

Table4. 18 Sequence for S1

	M1	M5
J1	7.65	0.72
J2	6.27	0.42
J3	5.96	0.4
J4	3.58	0.42

So by using Jonson's rule for two machines and n jobs problem the following partial sequence for S1 obtained. In the determination of the sequence, the job with minimum processing time in the respective machines selected and placed either on the left or on the right side of the sequence.

For this case since **J3** has minimum processing time on machine M5 it is selected and has scheduled on the right side of the sequence and J4 was the next job with minimum processing time which is scheduled next to J3 on the left side. In cases of jobs with same processing time to avoid bias for jobs placement as I faced above in table 4.18 Jobs with equal processing time, which is 0.42 min on machine M5, next comparison went to the processing time on machine M1 and found that job J4 is a job with a least processing time compared to job J2. Therefore, that is why the researcher-selected job J4 placed next to J3 on the left side of the sequence. Then the next job **J2** is the job with minimum processing time assigned in the sequence next to J4. Following the same procedure, J1 is the last job with minimum processing time on machine M5 and placed next to job 2 on the left side of the sequence assignment. This sequence assignment clearly represented as given below.

J1	J2	J4	J3

= J1-J2-J4-J3

After the sequence is determined then what the researcher did was determining the make-span value using this partial sequence so that to comprehend maybe if it is the minimum make-span that can reduce the idle time of the machines that it was obtained in the previous scheduling algorithms.

Table4. 19 Make-span calculation for first sequence (s_1)

J/M	M1	M2	M3	M4	M5
J1	7.65	9.72	12.92	21.2	21.92
J2	13.92	16.09	18.54	31.7	32.12
J4	17.5	19.33	23	34.28	34.7
J3	23.46	25.53	27.86	44.27	**44.67**

Therefore, using the above table 4.19 the calculated value of the make-span was **44.67 minutes.** Thus, here we can understand that with the given input Johnson's two machines and four jobs flow shop scheduling problem with a sequence of **J1-J2-J4-J3** results a make-span value of **44.67 min.** Now let us proceed to the next sequence **S2** that given in Table 4.20 below,

Table4. 20-second series (s2)

	M1+M2	M4+M5
J1	9.72	9
J2	8.44	10.92
J3	8.03	10.39
J4	5.41	3

In order to determine the start of the job placement, it had focused on the second column since J4 has the least processing time on the last machine then placed on the right side of the sequence. The remaining jobs placed following the same procedure so that to place all the jobs in their proper position.

J3	J2	J1	J4

= J3-J2-J1-J4

Once again, likewise as done earlier proceed to find the make-span and this make-span calculation illustrated in the given table 4.21.

Table4. 21 make-span calculation for the second sequence (s2)

Jobs	M1	M2	M3	M4	M5
J3	5.96	8.03	10.36	20.35	20.75
J2	12.23	14.4	16.85	30.85	31.27
J1	19.88	21.95	25.15	39.13	39.85
J4	23.46	25.29	28.96	41.71	**42.13**

As the calculation value of make-span in the second iteration in the second sequence of CDS heuristics algorithm revealed both the make-span and the sequence are the same as the value obtained so far, using the NEH's heuristics algorithm in the last iteration. Therefore, using this approach the calculated make-span for the partial sequence is **42.13 minutes.** Hence, the remaining metric or idle time of the machines became the same as obtained by NEH's heuristics algorithm.

Since it is the second iteration in the CDS algorithm now let us proceed to the third iteration maybe if the minimum make-span and idle time value obtained and until the completion of all the iterations.

Table4. 22 third series (s3)

	M1+M2+M3	M3+M4+M5
J1	12.09	12.2
J2	10.89	13.37
J3	10.36	12.72
J4	**9.08**	6.67

Taking into account the methods used in the first and second iterations of the CDS heuristics algorithms the jobs are placed in their proper positions so that to formulate the sequence which enabled them to find the make-span. Fortunately, the third series reached the same sequence of jobs as the sequence obtained in series s_2 in the above table 4.21. Therefore, no need to calculate the make-span value to the sequence formulated now since there is not any difference in the sequence of the jobs, in addition, there is not any difference in the make-span value as well. This meant that the sequence of jobs and make-span value is the same 42.13 minutes as obtained in the second sequence of the jobs given under table4.21. The series 3 (S_3) resulted sequence of jobs looks like,

J3	**J2**	**J1**	**J4**	**=J3-J2-J1-J4**

Once again, now let us proceed to the fourth series (S_4) maybe if minimum make-span value found. Again now, proceed to find the fourth sequence. In this series, the researcher determined first the sequence following the same procedure likewise series 1, 2, and 3 respectively. Finally, the sequence, which provided the minimum make-span out of these four sequences of jobs, selected and compared for the required parameter idle time, which is the critical issue that needed attention.

Table4. 23 Fourth series (s4)

	M1+M2+M3+M4	M2+M3+M4+M5
J1	21.2	14.27
J2	21.39	15.54
J3	20.35	14.79
J4	11.66	8.5

For this series, J_4 is the job with the least processing time on the second machine M_2. So according to Johnson's rule for two machines and "n" jobs scheduling problems the job with the least processing time on either of the machines has selected and placed on the corresponding machine in the formation of the sequence for the jobs.

J2	J3	J1	J4

=J2-J3-J1-J4

Using this sequence of jobs now let us find the make-span and put the summarized result in table 4.24 below.

Table4. 24 Make-span calculations for the fourth sequence

	M1	**M2**	**M3**	**M4**	**M5**
J2	6.27	8.44	10.89	21.39	21.81
J3	12.23	14.3	16.63	31.38	31.78
J1	19.88	21.95	25.15	39.66	40.38
J4	23.46	25.29	28.96	42.24	**42.66**

Because of the make-span, calculation given in table 4.24 depicted it is higher compared relative to the result of make-span obtained in table 4.21. Hence, using this partial sequence of jobs the new make-span associated with the sequence **J2-J3-J1-J4** found to be **42.66** minutes.

Therefore, the make-span values obtained in the above four iterations using the Campbell Dudek and Smith heuristics algorithm each of them with their corresponding sequence represented graphically as given below.

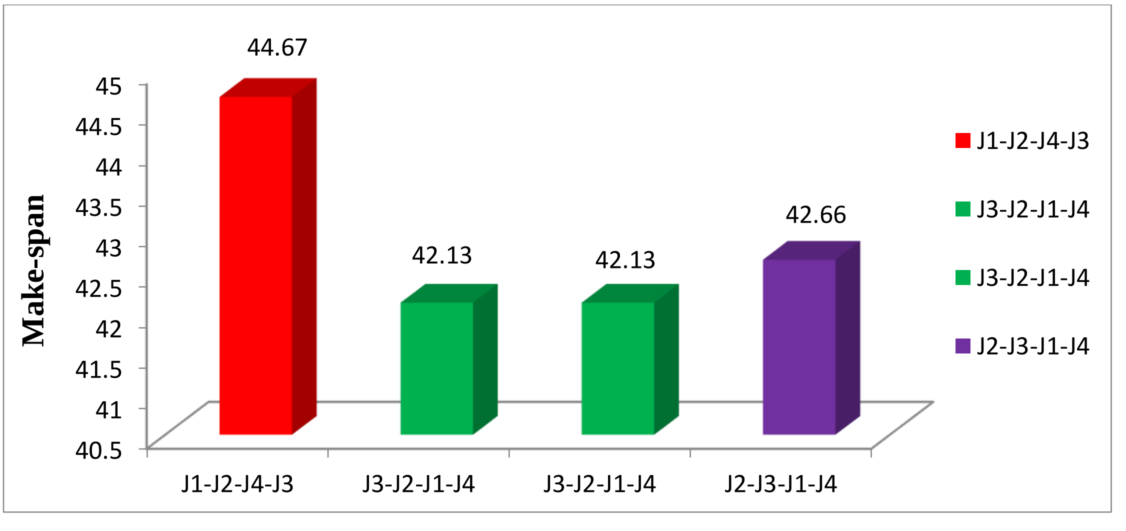

Figure4. 4 Iterated make-span values using CDS algorithm

As the chart indicated, the make-span values at the first (1^{st}) and fourth (4^{th}) iterations are higher compared to the second (2^{nd}) and third (3^{rd}) iterations. Slightly the fourth iteration provides better make-span than the first iteration.

On the other hand, the second and third iterations have an equal sequence of jobs that is **J3-J2-J1-J4** with a make-span value of **42.13 minutes.** In addition, the make-span value of the second and third iterations is the optimal make-span obtained using the CDS algorithm as obtained using the NEH's heuristics algorithm. Therefore, according to the CDS, scheduling algorithm, the sequence **J3-J2-J1-J4** is the optimal sequence of jobs with a minimum make-span value however, the sequence does not provide a reduced idle time.

Now using this optimal sequence of jobs let us calculate the idle time of jobs and compare the result of the idle time with the above two NEH's and palmer's heuristic algorithms. Among these three heuristics algorithms, the one which can provide the minimum idle time once again had to be compared with the result to be found using EDD rule.

Table4. 25 Idle time calculation using CDS heuristics algorithm

Jobs	M1(time)		M2 (time)		M3 (time)		M4 (time)		M5 (time)	
	start	finish	start	finish	start	finish	start	finish	start	finish
J3	0	5.96	5.96	8.03	8.03	10.36	10.36	20.35	20.35	20.75
J2	5.96	12.23	12.23	14.4	14.4	16.85	20.35	30.85	30.85	31.27
J1	12.23	19.88	19.88	21.95	21.95	25.15	30.85	39.13	39.13	39.85
J4	19.88	**23.46**	23.46	**25.29**	25.29	**28.96**	39.13	**41.71**	41.71	**42.13**
Idle time	0		11.19		9.28		0		19.82	

Fortunately, NEH and CDS arrived at the same sequence of jobs with similar make-span values of **42.13 minutes.** With this in mind, it is true also for idle time. This means since both NEH and CDS arrived at the same sequence of jobs then both of the make-span and the idle time of the machines is equal for the described sequence. Not only had this the idle time occurred at the same machine. On the other hand, the idle time occurred between the same jobs with the given sequence.

Total idle time= $\sum_{i=1}^{5}(\text{idle time ofMi})$= 0+11.19+9.28+0+19.82= **40.29 minute.** However, the idle time calculation result of the last iteration of the CDS heuristics algorithm reveals that it is lower than the result obtained in the above idle time **40.29**

min. since the idle time for the last iteration with the sequence, **J2-J3-J1-J4 is 39.86 minute.** Still, it is greater than the idle time obtained in NEH's heuristics algorithm with the sequence **J3-J2-J4-J1** that is **38.27 minutes.**

Therefore, as the analytical results of the two NEH and CDS heuristics algorithms indicated both of the algorithms arrived at the same sequence with identical make-span values of **42.13** minute, which is lower than that of the initial or existing scheduling rule of the case company and palmer's heuristics algorithm.

As pointed out and discussed earlier in the literature review parts the sequence, which provides a minimum make-span, can result in a reduced idle time, however, in this study, the idle time calculation result indicated that the previous studies' findings are wrongly concluded. Therefore, it does not mean that a schedule that provides a minimum make-span did not necessarily result in a reduced idle time of machines.

On the other hand, applying the same procedure likewise the above methods used in NEH CDS, and palmer's heuristics the existing scheduling approach of the case company resulted in a make-span value of **49.38 minutes** and an idle time of **53.1 minutes.** Compared to these three approaches of scheduling that is the existing and new scheduling approaches the new scheduling algorithms resulted in a minimum value for both the make-span and the idle time of machines. Because of the necessity to show, where and between which machines and jobs the idle time has occurred is most important to take action on the issue. The Gant chart below represents idle time with the sequence **J4-J2-J3-J1.**

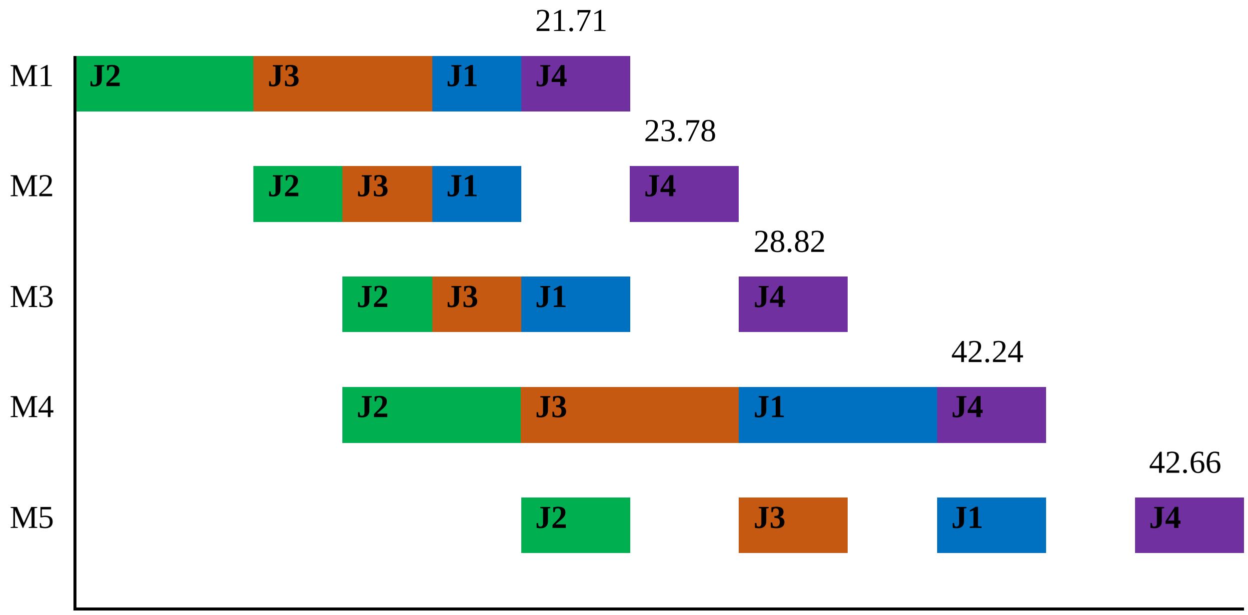

Figure4. 5 Gant chart for the idle time of the CDS heuristics algorithm

The above figure 4.5 shows the minimum idle time of the machines obtained using the CDS algorithm even it was not the optimal one for the make-span but reduces the idle time. Likewise, the above NEH's heuristics on machines M1and M5 only natural idle times have occurred. On machines M2, M3, and M5 the forced idle times are observed. Here what important is the focus of every researcher and business owner has to declined towards the reduction and elimination of such a forced idle time of machines which may happen because of wrong scheduling and other miss conceptions.

4.6 Result of Earliest due date (EDD) rule

This scheduling rule is the last scheduling rule, which employed in this thesis. According to the earliest due date, (EDD) rule as given in the methodology assumption in part two of this research jobs with the shorter delivery time has processed first than that of jobs with longer delivery time. Then as done in the above three heuristics algorithms jobs considered for, this case is similar. However, a little bit of the data used has a slight difference, which means that in addition to the above jobs used earlier, this data provided with a delivery time for each of the jobs or the required products and, this data is given below

Table4. 26 Data for the given jobs so that to apply EDD rule

Jobs	M1	M2	M3	M4	M5	Due date (days)
J1	7.65	2.07	3.2	8.28	0.72	35
J2	6.27	2.17	2.45	10.5	0.42	20
J3	5.96	2.07	2.33	9.99	04	38
J4	3.58	1.83	3.67	2.58	0.42	26

Now using this input data lets perform the analysis systematically

Step1. Calculate the total processing time for each of the jobs

This total processing time is previously from the very beginning of the existing scheduling rule of FCFS rule it was calculated hence, no need to find another total time since all the jobs and machines to be incorporated here are same likewise the above calculations.

Table4. 27 Total processing time for each job

Jobs	**M1**	**M2**	**M3**	**M4**	**M5**	**Processing time**	**Due date**
J1	7.65	2.07	3.2	8.28	0.72	**21.92**	35
J2	6.27	2.17	2.45	10.5	0.42	**21.81**	20
J3	5.96	2.07	2.33	9.99	0.4	**20.75**	38
J4	3.58	1.83	3.67	2.58	0.42	**12.08**	26

Using this total processing time and due date of each of the jobs sort them in increasing order of their due date as given below in the summarized table 4.28

Step2. Sort the jobs in increasing order of their due dates

Table4. 28 Sorted jobs with their increasing order of due date

Jobs	M1	M2	M3	M4	M5	Due Date
J2	6.27	2.17	2.45	10.5	0.42	20
J4	3.58	1.83	3.67	2.58	0.42	26
J1	7.65	2.07	3.2	8.28	0.72	35
J3	5.96	2.07	2.33	9.99	0.4	38

The sorted result provides a sequence of jobs that might help the researcher to find the make-span or the total completion time of the last job on the last machine and the minimum idle time that may occur if this sequence of jobs proposed for further execution. Accordingly, the sequence is **J2-J4-J1-J3**. Fortunately, EDD and palmer's heuristics algorithm provides a similar sequence of jobs. So not only the make-span value but also the idle time of the machines may be if the sequence is proposed to be practiced in the real world manufacturing environment is given in the summarized table 4.29 below within a similar fashion as discussed earlier in the palmer's heuristics algorithm.

Step3. Calculate the make-span and observe the result

Below table 4.29 indicates the calculated make-span value for the EDD rule as well as the idle time of machines.

Table4. 29 Make-span and idle time summery

Jobs	M1(time)		M2 (time)		M3 (time)		M4 (time)		M5 (time)	
	in	out	in	out	in	out	in	out	in	out
J2	0	6.27	6.27	8.44	8.44	10.89	10.89	21.39	21.39	21.81
J4	6.27	9.85	9.85	11.68	11.68	15.35	21.39	23.97	23.97	24.39
J1	9.85	17.5	17.5	19.57	19.57	22.77	23.97	32.25	32.25	32.97
J3	17.5	**23.46**	23.46	**32.02**	32.02	**34.35**	34.35	**44.34**	44.34	**44.74**
Idle time	**0**		**11.12**		**14.26**		**2.15**		**21.39**	

Since palmers and EDD scheduling heuristics algorithms arrived at the same sequence of jobs, hence the required parameter of make-span obtained using EDD rule is the same as likewise that of the make-span or the total completion time obtained using palmer's heuristics. Then as the result of the above table 4.29 given, the required make-span value using the earliest due date (EDD) rule is 44.74 minutes. Once again, the second, which is the most important metric in this research idle time, is the same as the result of the idle time obtained using palmer's heuristics. This idle time value of the given schedule is 48.92 minutes. So far, as observed in the palmer's heuristics algorithm the maximum idle time is at machine M5. The second and third largest idle time is at M3 & M2 respectively. At M4, the idle time is much smaller than even the idle time that occurred at M2. On the other hand, at machine M1 there is no forced idle time. The only idle time that occurred at machine M1 is natural idle time and this natural idle time is beyond the control of the scheduler. Therefore, here the researcher's intention is only on the forced idle time and its minimization by rescheduling the existing scheduling approach of the case company. This has done before in the analysis of NEH's and CDS heuristics scheduling algorithms. These algorithms provided a better make-span value than the palmers and EDD rule.

Not only this, these scheduling algorithms reduced the required parameters of this research i.e. idle time and make-span to a certain extent. Because of their importance in reducing both the idle time and make-span NEH, scheduling algorithms considered as the best flow shop-scheduling algorithm. In addition, CDS is the next best scheduling algorithm, which minimized the above parameters following NEH.

4.7 Result of Genetic Algorithm (GA)

As discussed earlier in the methodology part of this research, after the idle time of the machines and make-span (total completion time of the last job on the last machine) determined using the heuristics algorithms. By incorporating the collected data using FCFS, Palmers, NEH's, CDS, and EDD algorithms in the proposed study their solution performance capacity or effectiveness of the result has verified or validated using a genetic algorithm. In addition, to its usage in the performance measurement genetic algorithm is a heuristic search-scheduling algorithm. The collected data analyzed using a genetic algorithm in scheduling jobs in a flow shop-manufacturing environment. This search algorithm incorporated with the help of three fitness functions.

1. The first fitness function was taking make-span and idle time as the main parameter and determining the starting and finishing time of jobs in each machine so that to calculate both the make-span and the idle time of the machines;
2. The second fitness function was taking make-span as the main parameter; then determine both the make-span and idle time of the machines, in addition, to the start and finishing time of jobs in the corresponding machines.
3. The third fitness function was idle time; using this as the main parameter and to determine both the make-span and idle time, in addition, to the start and finishing time of the jobs in each machine.

Therefore, using these three fitness functions the GA determined both the above two parameters and the result was summarized in a tabular form as shown below in table 4.30 and each of the fitness functions has their own impact on the parameters to be determined in each case.

Table4. 30 result of GA

Jobs*Machines	**Fitness function**	**Result of Make-span(minute)**	**Result of Idle time(minute)**
4*5	Make-span +Idle time	42.64	38.18
	Make-span	42.13	39.75
	Idle time	44.67	37.74
8*10	Make-span +Idle time	139.5	40.5
	Make-span	126.9	72.9
	Idle time	139.5	40.5
10*15	Make-span +Idle time	164.7	172.8
	Make-span	148.5	382.5
	Idle time	164.7	172.8
15*20	Make-span +Idle time	263.7	281.7
	Make-span	230.4	630.9
	Idle time	272.7	271.8

As the result of the genetic algorithm summarized under the above table, 4.30 revealed taking in to account three fitness functions turn by turn make-span and idle time was calculated and the impact of each objective function on the idle time and make-span. This parameter in the objective functions is considered and the values of the make-span and idle time of the machines are calculated.

Considering, the first objective function that is make-span and idle time the required make-span found to be 42.64 minutes whereas, the idle time was 38.18 minutes. In addition, using make-span as the fitness function the result of the make-span and idle time of machines was 42.13 and 39.75 minutes respectively. For the third objective function that is idle time though, the make-span increased a bit the idle time reduced, to 37.74 minutes. In the literature review, parts discussed so far, if one can reduce the make-span possible to reduce the idle time. However, the result of the software in visual studio 2017 integrated with a genetic algorithm revealed taking the two parameters make-span and idle time at once and calculating the make-span and idle time could result in a better output or schedule than concluded so far. In addition, taking the idle time as the main parameter, and to control both the make-span and the idle time can provide a very good result than practiced so far, in researches and even the case companies scheduling rule.

Hence, it can be deduced that the GA solution for the make-span was almost the same likewise that of NEH'S and CDS heuristics algorithms. The only difference, that the GA and the previous heuristics algorithms, was minor variation in the idle time of machines. Using the GA, and CDS it was found to be 39.75 minutes with make-span as the main fitness function whereas, using the NEH heuristic algorithm it was determined to be 38.27 minutes with make-span as the main parameter. However, when the fitness function is idle time the idle time and make-span obtained using GA was 37.74 and 44.67 respectively. But, considering both make-span and idle time as the fitness function the idle time was 38.18 with a make-span value of 42.64 minutes. Here we can deduce that the result obtained using GA and the above scheduling heuristics algorithms are almost the same hence, the performance of these scheduling algorithms deployed in the proposed study has good performance in providing both the idle time of machines as well as make-span or total completion time of jobs.

In addition, to its usage in performance validation if GA implemented in the flow shop manufacturing environment the algorithm has a good impact on reducing both the idle time and total completion time of the last job on the last machine (make-span). Then GA is better where preemption of jobs in a manufacturing environment not allowed, to process jobs so that to deliver the products in time to the end-users. As well as reduced production cost by increasing the output of the line and increasing the machine utilization with the workforce.

4.8 Validity of the proposed heuristics algorithms

The genetic algorithm (GA) deployed in this study was incorporated for two purposes. The first aim why the researcher used this software was to find a schedule that might reduce the idle time of machines. And another application of GA applied in this study was to validate whether the proposed heuristics algorithms deployed earlier in the data analysis purpose was capable in reducing the idle time of machines as well as minimizing the total completion time of jobs considered in this study by finding the near to optimal sequence of jobs. As incorporated by the GA, the existing data, which previously has analyzed by the above heuristics almost the same solution of the problems, was arrived using GA. Hence, the above iterative heuristics algorithms have shown their good performance in finding an optimal schedule of jobs by disproving the existing FCFS scheduling approach as a wrong way of job scheduling tool. In addition, the researcher understood and concluded that whatever any problem size except its complexity and time-consuming nature due to the NP-completeness of the problem with the increment in the size of the jobs and machines the proposed heuristics algorithms can solve and reduce both the idle time and make-span of jobs.

The GA was incorporated for different data values and using the previously fitness functions it calculated both the idle time of machines and make-span of jobs for any problem size. So far, as many scholars asserted that whenever, it is possible to minimize the make-span or total completion time of a job at the same time concluded possible to reduce the idle time. However, the researcher contradicted with the existing research finding. This was based on the comparative analysis of GA with three fitness functions reached that especially when idle time is our objective and the attention is to find both the idle time and make-span of jobs the result obtained was better which had previously obtained using the proposed heuristic algorithms. Even, by using idle time as the fitness function the GA calculated the idle time which is less than the result obtained by using both make-span and make-span + idle time as a fitness function. On the other hand, by taking into account make-span and idle time as a fitness function a comparable idle time and make-span were calculated still the idle time which is less than the result obtained by using the heuristics algorithms of NEH, CDS, EDD, and Palmer's approach except for a small variation with the make-span. Therefore, the researcher believed for any manufacturing especially, for those of which company produces mass-customized products idle time should be the principal or basic parameter than make-span that has to be minimized to improve the productivity of the corresponding company.

The GA was incorporated with different sized problems might be if the above fitness function usages have different outcomes either in minimizing the make-span time or reducing the idle time of the machine. For eight jobs by 10 machines problem, observed that when the fitness function is make-span + idle time and idle time; the idle time calculated in both cases was the same with a make-span and idle time 139.5 and 40.5 minutes respectively. Whereas, when the fitness function is minimizing the make-span so that to reduce the idle time as previous research finding proposed the idle time increased to 72.9 minutes even it can reduce the make-span up to 126.9 minutes. Here we need to take care while we use a scheduling algorithm and fitness functions to control some parameters of a study especially studies that require the same parameters to be controlled. Once again, the validity test checked up another problem which is 10 jobs by 15 machines and the solution arrived the same result of make-span and idle time when the fitness functions or the objective functions are make-span+ idle time and idle time then their make-span and idle time were 164.7 and 172.8 minutes respectively. In another way, when the objective function is make-span and to find the other parameters especially the idle time, which is the most important parameter that needs high attention, found doubled about 382.5 minutes, however, the make-span was minimized to 148.5 minutes. In addition, a problem with 15 jobs by 20 machines was tested taking the objective functions make-span + idle time later idle time; then make-span resulted in 263.7, and 272.7 minutes and the idle time ranged from 281.7 to 271.7 minutes whereas when the objective function was make-span the idle time was increased to 630.9 minutes. Therefore, from these results, the researcher concluded idle time is the best parameter that most importantly reduces even the make-span than the make-span can reduce the idle time and minimize the make-span.

4.9 Comparison between existing and proposed scheduling algorithms

After the analysis has been conducted the researcher carried out comparison between the existing scheduling approach FCFS rule of the case company and the newly proposed scheduling algorithms of NEH, Palmer's, CDS, EDD, and finally the GA which is used to validate the performance of the proposed heuristics algorithms in the rescheduling process of the selected jobs in the study. Summarized result of the comparison given for the make-span and the idle time one by one.

4.9.1 Make-span comparison

Out of the alternatives obtained in the iterative process of the data analysis; only alternatives, which provide the minimum make-span value, have taken for the comparison in each scheduling algorithms. As the analysis result revealed the minimum make-span obtained by using NEH and CDS scheduling algorithms with the same sequence of jobs. In addition, the make-span value obtained using EDD and Palmer's scheduling approaches was the same since both of the scheduling algorithms reached the same sequence of jobs. In short, the results for these scheduling algorithms and that of the GA values given in figure 4.6 below.

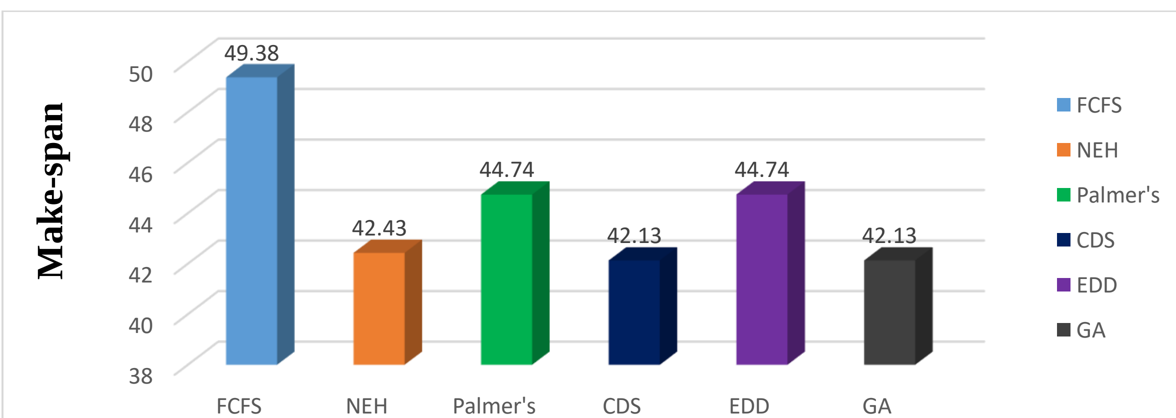

Figure4. 6 Result of make-span values using different scheduling rules

4.9.2 Idle time comparison

Likewise, the make-span comparison of the existing schedule and newly scheduled jobs has done. Idle time, which is the main parameter in the proposed study, carried out for the same fashion and this result of the idle time illustrated in figure 4.7 below.

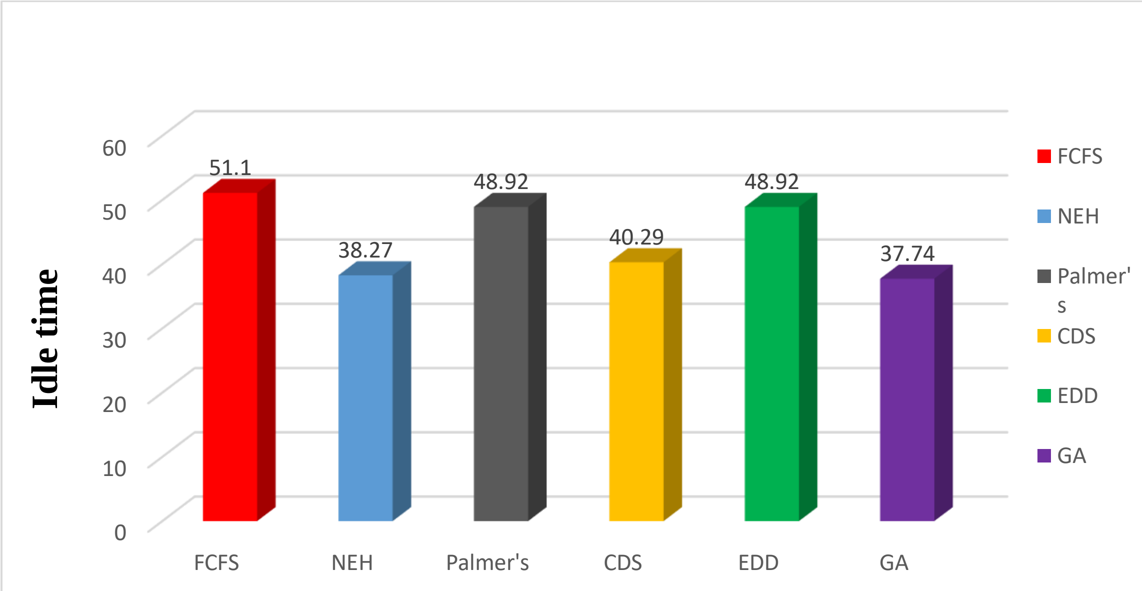

Figure4. 7 Result of idle time with different scheduling algorithms

From the very beginning of the methodology and data analysis process, the researcher deployed four different scheduling heuristics algorithms. Nawaz Enscore Ham's heuristics scheduling algorithm, which resulted in a minimum idle time, was the best scheduling algorithm out of the four and even the existing scheduling algorithm of the case company and the proposed study that can be minimized the idle time of machines better than the other scheduling algorithms. This research mainly focused on reducing the idle time of machines and improving the productivity of the case company knitting section of the garment department taking in to account the polo shirt as the product studied. The performance of these scheduling heuristics algorithms has been verified by the GA and it is observed that both the result of make-span and idle time obtained was almost the same. Particularly, the comparative results of the above figure 4.17 indicated that the Genetic Algorithm obtained the most preferable reduced idle time with an idle time of 37.74 minutes. This idle time was a bit less than the idle time obtained using NEH, which is 38.27

minutes. Therefore, here we can deduce that heuristics algorithms have good capacity in idle time reduction as the above analysis result revealed.

4.10 Discussions on resource utilization

Resource utilization defined as how intensively scarce resources utilized in a company. In the production process of goods, different resources of the companies utilized. Out of the many resources, which used in the production process of polo shirt machines, labor, and time are the most important parameters, which given high attention in the proposed study within the case company of Almeda Textile PLC. As it had seen earlier, about 13.36 minutes wasted because of wrong scheduling because of the idleness of the machines. Therefore, if the newly proposed scheduling algorithm adopted for the case it is possible to produce one average unit product of a polo shirt every 13.36 minutes. On the other hand, the time required to stitch a key apparel style 825 (short sleeve) which is represented by J4 is 12.08 minutes**,** however, if properly scheduled the above 13.36 minute can produce more than one extra key apparel style 825. Hence, in the present study can conclude if the jobs are properly scheduled it is possible to produce one more polo shirt of the described style every 12.08 minute and the remaining 0.28 minutes can produce about 7 button attach operations since the time required for button attach is about 0.4 minutes as given in the processing time data from table 4.1. Therefore, it could be incorporated in such a way the time that previously was considered as the main resource in the case company might be properly utilized though it needs an effective management decision.

4.9.1 Machine utilization

As defined above about resource utilization machine utilization is a measure of how intensively utilize the stitching machines that the company has. This machine utilization had calculated for each of the existing and the proposed or optimized schedules.

$$\text{Machine Utilization} = \frac{\text{Machine running time}}{\text{total available time in sequence}} * 100$$

4.91a. existing sequence utilization

In order to determine the utilization of machines in the existing schedule, the mathematical calculation used the Gant chart constructed earlier in the idle time and make-span determination phase. Then by using that chart the utilization of each machine is calculated one by one and finally, the average utilization of each of the five machines was determined so that to take into account a comparative investigation with the revised schedule using the proposed scheduling algorithms. Here below given the calculated values for each of the five machines using the existing schedule of jobs.

$$Um1 = \frac{M1runningtime}{totalavailabletime} * 100$$

Where Um1= utilization of machine M1;

M1= Machine 1

$$Um1 = \frac{26.73}{26.73} * 100 = 100\%$$ This means the machine one fully utilized.

$$Um2 = \frac{24.52}{28.72} * 100 = 86\%$$

$$Um3 = \frac{15.99}{32.39} * 100 = 49.4\%$$

$$Um4 = \frac{44.69}{48.96} * 100 = 91\%$$

$$Um5 = \frac{23.16}{49.38} * 100 = 47\%$$ This shows the idle time of the machine forbids the utilization.

Now let us calculate the average machine utilization for the five machines as given below

$$Averageutilization = \frac{Um1 + Um2 + Um3 + Um4 + Um5}{Numberofmachines}$$

$$Averageutilization = \frac{100 + 86 + 49 + 91 + 47}{5} = 74.6\%$$

From this analysis, we can understand the average machine utilization for the case company with the existing schedule is about 74.6%.

4.10.1b new proposed sequence utilization

Applying the same procedure as used above to determine the utilization of the existing schedule below given the utilization of the new proposed schedule.

$$Um1 = \frac{23.46}{23.46} * 100 = 100\%$$

$$Um2 = \frac{15.55}{25.53} * 100 = 61\%$$

$$Um3 = \frac{21.13}{27.86} * 100 = 76\%$$

$$Um4 = \frac{44.03}{44.03} * 100 = 100\%$$

$$Um5 = \frac{22.92}{42.64} * 100 = 54\%$$

$$Averageutilization = \frac{100 + 61 + 76 + 100 + 54}{5} = 78.2\%$$

As we can saw from the calculated results of the average machine utilization of the machines in the existing schedule and new proposed schedule the average machine utilization of the new or proposed schedule is more than that of the existing schedule. This shows job scheduling in a flow shop manufacturing environment' can bring about a good resource utilization improvement. Numerically this machine utilization improved from 74.6% to 78.2% by the rescheduling of jobs. Hence, as we have seen from the result we can conclude effective job scheduling can bring resource utilization improvement in manufacturing companies. Especially, this is very important in mass-customized products producing manufacturing environment.

From the above mathematical analysis, the utilization of machine M3 changed from 49% to 76% because of scheduling. Once again, the utilization of machine M4 changed from 91 to 100% at the same time the utilization of machine M5 changed from 47% to 54%. This shows where the critical point that machine utilization should take into account. This individual machine utilization improvement brought a cumulative machine utilization improvement for the case company, which increases machine availability for production so that to increase the productivity of the section without any addition of raw materials, machine, manpower/operator, and without layout change of machines. Therefore, the percentage utilization change of the new proposed sequence schedule of jobs is about 3.6%.

4.11 production cost and productivity analysis

4.11.1 Production cost analysis

In order to carry out the production cost estimation of the existing scheduling and the new proposed schedule of the case company first identified all costs most importantly associated with the sewing line. As addressed by the researcher, the costs associated with this sewing line are; labor/operator cost, power cost, and machine depreciation costs are the most, which took into account the study. The following formula is given how the cost analysis was carried out.

$$\text{Production cost per unit} = \frac{\text{Total production cost incurred in a day}}{\text{Total garments produced}}$$

In order to determine the production cost per unit fist, it has attempted to determine the total sewing cost and the number of garment outputs with the existing and the new sequence of jobs.

4.11.2a. Output determination:

Taking the new proposed sequence of jobs **J2-J1-J4-J3** obtained by GA with a make-span value of 42.64 minutes and 38.18-minute idle time of machines respectively and with 16 hr. daily working hours per two shifts of a day. The average processing time for a one-piece polo shirt was about 19.4 minutes. In addition, an operator can produce four units of polo shirt every 76.56 minutes that is 76.56/19.4= 4pcs. Therefore, each of the 37 operators could produce about 148 pieces of polo shirt every 76.56 minutes. In a day where the company works for two shifts, there are (960minute/76.56 minute) = 12.54 intervals. However, it is possible to produce about 148 pieces every 76.56 minutes. Therefore, 12.54*148=about 1855.92 pieces of a polo shirt. In general, with the existing schedule, it was possible to produce about **1855.92** pieces of a polo shirt.

However, the researcher arrived that the existing schedule of jobs was not much important since its idle time of machines is higher than the proposed schedule. Hence, if the proposed schedule adopted, the 13.36-minute idle time, which wasted every 76.56 minutes because of the wrong sequence of jobs, would be a productive hour. Then with this productive hour, an additional 13.36*12.54=167.53 minutes would be available. As discussed so far, the average processing time for one piece is 19.4 minutes, and then an operator would produce 167.53/19.4=8.64 pieces of a polo shirt. Hence, the 37 operators could produce additional, 8.64*37=319.5 pieces if the new sequence of jobs adopted.

Generally, if the new sequence of jobs or schedules adopted, 1855.92+319.5=**2175.4** pieces produced every day.

4.11.2b. sewing cost determination

To determine the total sewing cost of the line with the given layout, all the costs associated with operator salary, power cost, and machine depreciation cost considered.

$$\text{TSC} = \sum \text{operator salary} + \text{power cost} + \text{machine depreciation cost}$$

Where TSC= total sewing cost

- ✓ **Operator salary**: the operator salary is 1427 birr for 26 working days per month. Then, divide this to 26 and multiplying by 37 operators **2030.7** birrs/day.
- ✓ **Machine depreciation cost**: in order to determine the machine depreciation cost the machine cost for the five (5) machine types used so far, in the data analysis considered. This cost which obtained from Google (alibaba.com) the average dollar exchange rate of 7.6 birr/dollar was considered which reported in the year 1995/96 G.C exchange rate, and this is illustrated in the Table 4.31 below

Table4. 31 machine cost data

S/N	Machine type	Unit cost (birr)	Total machines required	The total cost of machines(birr)
1	SNLS	1596	19	30324
2	COVERSTICH	1900	6	11400
3	4^{TH} Thread	1368	10	13680
4	BH	3040	1	3040
5	BA	3192	1	3192
TOTAL			**37**	**61636**

Source https://www.made-in-china.com/cs/hot-china

Depreciation: depreciation of equipment or machinery defined as the value reduction of an asset due to wear and tear, the passage of time, technological outdated or obsolescence. This determined by incorporating the initial cost of the equipment/asset, its salvage value/scrap value (the money that the machine will be sold after its functionality), and at the same time the useful life of the corresponding equipment or machinery with the following formula.

$$\text{Depreciation} = \frac{\text{Initial cost of an asset} - \text{scrap value}}{\text{useful life of the asset/equipment}}$$

For this calculation, the scrap value of the machines taken as “0” and the useful life of the machines considered 10 years of service life. Applying a straight-line depreciation method which mostly used by Ethiopian government industries.

$$\text{Depreciation} = \frac{61636 - 0}{10} = \mathbf{6163.6}$$

This value is an annual depreciable cost of the item to be paid every year about 10 years equally an amount of 6163.6 birrs. Therefore, the daily cost of the machines would be $\frac{6163.6}{365 \text{ days per year}} = \mathbf{24.3\ birr\ per\ day.}$ Hence, this shows the daily depreciation cost of the 37 machines is about **24.3 birrs/day**. Hence, the daily depreciation cost of the machines for the 16 working hours per day would be,

$$\frac{24.3\text{birr}}{16\text{ hr}} = 1.52\frac{\text{birr}}{\text{day}}$$

Therefore, the daily depreciation cost of the machines is about **1.52 birr/day**.

Power cost: The power cost is the electrical power cost incurred so that to run the machines during the production time. This cost illustrated in table 4.32 below

Table4. 32 sewing unit cost of power

Machine types	SNLS	4TH	CS	BH	BA
Quantity	19	10	6	1	1
Total birr/ kwh	5.51	0.9	0.3	0.08	0.18

From table 4.32 the electric power cost per one hour is about 6.97 birrs/kwh. Therefore, for the 16 machine running hours per day, the total electrical power consumption cost was about 16*6.97=**111.52 birr per day**.

By taking the summation of all the costs required for the sewing operations it would be;

$$\text{Total sewing cost} = \sum(\text{OS} + \text{PC} + \text{DC})$$

Where,

OC= operator cost

PC= power cost and

DC= depreciation cost respectively.

Total sewing cost= 2030.7+111.52+1.52=**2143.74 birr.**

$$\text{Sewing cost per unit} = \frac{\text{Total sewing cost incured}}{\text{total garments produced}}$$

Since this research is investigating, the production cost difference between the existing and the new proposed sequence or schedule of jobs then calculated for the existing schedule and new proposed schedule. Except for the output, the cost incurred is the same for both cases of the calculations since the same machine operator and power are consumed i.e. the only difference is the sequence of jobs. With this job, sequence variation indicated that the production cost varied.

i. **Existing schedule:** With this schedule, the production cost determined for the sequence of jobs **J1-J2-J3-J4.**

$$\text{Sewing cost per unit} = \frac{2143.74}{1855.92} = \mathbf{1.16}\,\frac{\mathbf{birr}}{\mathbf{unit}}$$

Then total sewing cost = unit cost*units produced= 1.16*1855.92**=2152.9 birr**

ii. **New or proposed schedule:** In this case, the sequence of jobs changed to **J3-J2-J4-J1.**

$$\text{Sewing cost per unit} = \frac{2143.74}{20175.4} = \mathbf{0.11}\,\frac{\mathbf{birr}}{\mathbf{unit}}$$

Again the total sewing cost = unit cost*units produced= 0.11*20175.4=**2219.3 birr.**

Having this value, calculated the percentage unit cost reduction of the proposed schedule relative to the existing schedule. The following formula employed to show the unit cost reduction of the proposed schedule of jobs.

$$\%\ \text{Unit cost reduction} = \frac{\text{Existing schedule unit cost} - \text{New schedule unit cost}}{\text{Existing schedule unit cost}}$$

$$\%\ \text{Unit cost reduction} = \frac{1.16 - 0.11}{1.16} * 100 = \mathbf{90.5}\%$$

Here the researcher deduced that by the introduction of the proposed sequence or schedule of jobs it is possible to reduce about 90.5% of the unit production cost of the existing schedule.

Generally, as the production cost-benefit analysis result of this research revealed, scheduling of jobs can bring a revolutionary production unit cost reduction however, not yet considered by many producers. This is why the production unit cost reduced because of the increased output of the new proposed sequence or schedule of jobs than the existing schedule. All the inputs labor force, machines, raw fabric, electric power, and time that is required to process the jobs are still the same for the existing and the proposed or new schedule. Therefore, by incorporating a better production schedule in the manufacturing environments, reducing the idle time of the machines and/or operators it's possible to reduce the production cost to a certain extent as the proposed study cost analysis result proved. This production cost reduction technique does not consider any resource consumption variation, which means all the resources consumed in the existing schedule of the case company would not varied for the proposed schedule of jobs. In addition, as the calculated resource utilization result indicated, an improvement of 3.6% resource utilization change in the proposed schedule brought about a 90.5% unit cost reduction.

4.11.3 Productivity analysis

So far, in the literature review, partly discussed what productivity means. Simply it is the ratio of total outputs to inputs. In addition, productivity measured in terms of partial and multi-factor productivity. The partial productivity is productivity measured by dividing the output to the single input/ single resource consumed. In addition, the multi-factor productivity measured by dividing the total output to all the input factors consumed during the production process. Therefore, in this study, the productivity measured for the existing schedule and the new proposed sequence or schedule of jobs. At the same time, both partial and multi-factor productivity are taken into account.

Using the formula given below the productivity calculated in terms of working hours both for the existing and proposed sequence of jobs.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

i. Existing productivity measure

The partial and multi-factor productivity for the existing and proposed schedule carried out.

$$\text{productivity} = \frac{\text{Total garments produced in existing schedule}}{\text{working hours per day}}$$

$$\text{Existing schedule productivity} = \frac{1855.92}{16} = \mathbf{116\ pcs}$$

This productivity result of the existing schedule shows it is possible to produce around 116 pcs of polo shirt an hour by using the 37 operators, and 37 machines.

Now let's measure the productivity of the proposed schedule;

$$\text{Proposed schedule Productivity} = \frac{2175.4}{16} = \mathbf{136\ pcs}$$

In the proposed schedule with the same machines and operators, the productivity changed from 116 to 136 pcs per hr. hence, with the proposed schedule it is possible to produce an additional 20 units of polo shirt every hour without the addition of any resource. Therefore, if the output of a manufacturing company increased without additional usage of any resource then one can deduce the productivity of that company is increased. To indicate the percentage productivity change or improvement of the above calculation the following formula employed.

$$\%\ \text{Productivity change} = \frac{136 - 116}{116} * 100 = \mathbf{17.2}\%$$

As the percentage change, the result depicted the proposed schedule of the jobs brought about 17.2% productivity improvement than the existing schedule. Therefore, it is very important to note that manufacturers have to think critically about how to improve the productivity of their company by rescheduling jobs. In general, this study addressed how the scheduling of jobs brought good productivity improvement; as well the effect of each scheduling algorithm is observed in reducing the idle time of the machines and minimizing the total completion time of the last job on the last machine comparatively. Finally, the result of the best scheduling algorithm is tested or validated with the genetic algorithm by integrating it with visual studio 2017 software. This was to check whether the proposed algorithms can solve the problems, even the problem size increased and arrived with a solution except for its longer time requirement for manipulation. The proposed algorithms can solve whatever type of flow shop scheduling problem might face researchers.

CHAPTER FIVE

5.1 Conclusion

In this research, the main objective was to improve the productivity of the case company Almeda Textile PLC With the help of job scheduling. In the course of actions, the researcher employed different scheduling heuristics algorithms such as NEH, Palmer's, CDS, EDD, and finally, the performance of these heuristics algorithms has validated with the Genetic Algorithm integrated with visual studio 2017. Prior to start the proposed heuristics scheduling algorithms the existing scheduling rule of the case company was calculated and obtained 48.92 minute and 51.1-minute make-span and idle time respectively. After the analysis was conducted by the proposed heuristics algorithms, the most optimal sequence (**J3-J2-J4-J1)** of jobs obtained by Nawaz Enscore Ham (NEH) heuristic scheduling algorithm with 42.43 and 38.27-minute make-span and idle times respectively. This result revealed an idle time of about 13.36 minutes wasted because of poor scheduling of jobs for the case company. In this research attempted different scheduling algorithms and their effect in minimizing the make-span and reducing idle time of machines and the most scheduling algorithm with good effect in reducing the idle time was taken as the best scheduling algorithm with a near to optimal sequence of jobs. As the validity test of this research show, whatever problem size might happen heuristics algorithms such as NEH and CDS are good in providing a good result of job schedule with minimized makes-span and reduced idle time machines. NEH's result revealed that on the last machine there was about 23.3% idle time reduction than the existing schedule.

Resource utilization was another focus of this research. As the analysis indicated the proposed scheduling algorithm, provide about 3.6 % resource utilization improvement than the existing scheduling algorithm of the case company. In addition, with this machine utilization improvement, there was also about 90.5% unit cost reduction.

In general, by reducing the idle time of machines and increasing the resource utilization so that to improve the output or productivity of the case company with the considered jobs and machines has addressed and shown that about 17.2% of productivity change obtained with proposed sequence or schedule of jobs.

This research also attempted what if the number of jobs and machines is greater than (4*5). It validated by GA, which proved the proposed scheduling algorithm could provide efficient solutions except for its longer time requirement for manipulation.

Generally, by scheduling, it is possible to increase the productivity of manufacturing industries without any additional usage of resources.

5.2 Recommendation

This study proposed the best scheduling algorithm for the selected jobs and machines. For further study, it is important to consider the effect of reducing idle time over other parameters such as make-span, tardiness, on job shop production environmnets.

In general, as the result of the proposed study revealed following are important points if taken into account.

- Manufacturers need to know what decision strategy to be followed
- In addition, it is important to consider job and customer characteristics
- Taking into account the effect of controlling one parameter over the other is very important for producers and scholars.

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ANNEX

1.1 Result of GA integrated with visual studio 2017 for 4*5 jobs and machines

fitness= Makespan+Idle time		
Makespan	42.64	Data 1
Idle time	38.18	4jobs*5 machines

Fitness= Makespan		
Makespan	42.13	Data 1
Idle time	39.75	4 jobs*5 machines

Fitness= Idle time		
Makespan	44.67	Data 1
Idle time	37.74	4 jobs*5 machines

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Sequence of Jobs

Machine-0	job sequence	start time	f/time
	1	0	6.27
	0	6.27	13.92
	3	13.92	17.5
	2	17.5	23.46
Machine-1	job sequence	start time	f/time
	1	6.27	8.44
	0	13.92	15.99
	3	17.5	19.33
	2	23.46	25.53
Machine-2	job sequence	start time	f/time
	1	8.44	10.89
	0	15.99	19.19
	3	19.33	23
	2	25.53	27.86
Machine-3	job sequence	start time	f/time
	1	10.89	21.39
	0	21.39	29.67
	3	29.67	32.25
	2	32.25	42.24

Sequence of Jobs

Machine-0	job sequence	start time	f/time
	2	0	5.96
	3	5.96	9.54
	0	9.54	17.2
	1	17.19	23.5
Machine-1	job sequence	start time	f/time
	2	5.96	8.03
	3	9.54	11.4
	0	17.19	19.3
	1	23.46	25.6
Machine-2	job sequence	start time	f/time
	2	8.03	10.4
	3	11.37	15
	0	19.26	22.5
	1	25.63	28.1
Machine-3	job sequence	start time	f/time
	2	10.36	20.4
	3	20.35	22.9
	0	22.93	31.2
	1	31.21	41.7

Sequence of Jobs

Machine-0	job sequence	start time	f/time
	0	0	7.65
	1	7.65	13.92
	3	13.92	17.5
	2	17.5	23.46
Machine-1	job sequence	start time	f/time
	0	7.65	9.72
	1	13.92	16.09
	3	17.5	19.33
	2	23.46	25.53
Machine-2	job sequence	start time	f/time
	0	9.72	12.92
	1	16.09	18.54
	3	19.33	23
	2	25.53	27.86
Machine-3	job sequence	start time	f/time
	0	12.92	21.2
	1	21.2	31.7
	3	31.7	34.28
	2	34.28	44.27

Machine-4	job sequence	start time	f/time
	1	21.39	21.81
	0	29.67	30.39
	3	32.25	32.67
	2	42.24	42.64

Machine-4	job sequence	start time	f/time
	2	20.35	20.8
	3	22.93	23.4
	0	31.21	31.9
	1	41.71	42.1

Machine-4	job sequence	start time	f/time
	0	21.2	21.92
	1	31.7	32.12
	3	34.28	34.7
	2	44.27	44.67