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Production improvement with flow shop scheduling heuristics in Household utensils manufacturing company

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Abstract: This paper aimed at improving the production of a household utensils manufacturing company with flow shop scheduling heuristics. To achieve the planned production volume, a company needs to establish an optimal production sequences. A household utensils manufacturer in Ethiopia was our case company to investigate. We have studied the production sequence of a flat cooking pan, where one packed set of a flat cooking pan comprises seven diametrically ordered flat cook pans. Three production scenarios were developed based on the production line constraints of the case company. Among the various flow shop scheduling heuristics, Campbell, Dudek and Smith (CDC), and Nawaz, Enscor and Ham (NEH) methods were applied. In all production scenarios the applied heuristics yields an optimal production sequences with considerable reduction of a makespan. The optimal production sequences improved the annually planned production volume by more than 22%. Moreover, the paper discusses the performance of the applied heuristics.

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PUBLIC INTEREST STATEMENT

The objective of the study is to improve the production of a manufacturing company; as today's firm competition between manufacturing industries challenged their existence in the market. For them, the rule is either to swim or sink. Therefore, productivity is a welfare for today's manufacturing firm. To enhance productivity, proper production Schedule is required. A Proper production schedule has an optimal production sequence, which increases the production rate by minimizing the manufacturing time. Hence, optimal production sequence improves production volume. This study has conducted the research on a household utensils manufacturing company, in Ethiopia. Among the products, a flat cooking pan production process utilizes 80% of the resources, so that, it was selected for this study. For three production scenarios, an optimal production sequences were determined through flow shop scheduling heuristics. The study resulted in an optimal production sequences and improved the production of the firm.

Subjects: Engineering Education; Industrial Engineering & Manufacturing; Manufacturing Engineering; Engineering Management; Production Engineering; Technology; Transport & Vehicle Engineering

Keywords: planned production volume; production scenario; flow shop scheduling heuristics; makespan; optimal production sequences

1. Introduction

Manufacturing industries sustainability is determined by their competitiveness in the market. To maintain competitiveness their products should be delivered adequately, with best quality, minimum time and price to customers. In order to do so a manufacturing company needs optimized production line. Optimized production line will have a minimum manufacturing time. Minimum manufacturing time can be attained through an optimal production sequences (production sequences with minimum makespan value or completion time), that suits well with the production environment constraints. In this study, the objective is to improve the production capacity through flow shop scheduling heuristics. Scheduling determines the optimum sequence of *n*-jobs to be processed on *m*-machines. In scheduling, it is necessary to consider the production line constraints such as machines breakdown and processing time of specific jobs on machines. The case company has been functioning for several years without systematically scheduling the jobs based on the production environment constraints; as a result, they arbitrarily assigned the *n*-jobs to the *m*-machines. But, a good production schedule enhances production and machine utilization, improves production planning and control, reduces production cost, increases customer satisfaction, supports maintenance planning, and keeps a firm competitive advantage.

The main objective of scheduling is to minimize total manufacturing time, denoted C_{max} (total completion time or makespan), and the values of manufacturing time on each machine denoted P_{ji} ($j = 1, 2, ..., m, i = 1, 2, ..., n$); are previously known, constant and positive in this case (Alharkan, 2005). In industries, manufacturing time includes all the times involved in the technological process. Gupta and Stafford (2006), listed series of assumptions, which are related to jobs, machines and operating policies, considered to solve scheduling problem: all jobs are independent and available at the time $t = 0$, all machines are permanently available, each job can be manufactured at a specific moment on a single machine, each machine can do a single operation at a specific time, the machine cannot be interrupted once it started an operation, the set-up and auxiliary times are included in the manufacturing times, if a machine is not available (being engaged in another operation) the following jobs are assigned to a waiting queue. In literature, this problem with the above assumptions is called Flow-shop Scheduling Problem (FSSP) (Kumar & Tayal, 2012). If the operations sequence on the first machine is maintained during the remaining machines, then the problem is called Permutation Flow-shop Scheduling Problem (PFSP) (Pervaiz & Sehik Uduman, 2014; Pinedo, 1995).

2. Problem statement

A manufacturing company may fail to satisfy the planned production volume even though other production parameters such as operators, maintenance, inventory, etc.., are in control. In this case, there problem might be with the production sequences. If a production line has no optimal production sequences the completion time of the jobs along the production line will be long and variable. And, this leads to low production volume. Also, a company should have production scenarios to overcome problems that may occur in the production environment, such as, machines breakdown. Therefore, production scenarios with optimal production sequences are essential. Based on the production environment condition, the manufacturing company shifts to the available production scenario, and continues to function with the scenario's optimal production sequences. This way a company will satisfy the planned production volume. This study was conducted in a household utensils manufacturing company, which failed to satisfy the planned production volume. A case in point, in 2013 a flat cooking pan production line of the case company fulfills only 25.85% of the production plan. The reason for unsatisfied plan associated with poor scheduling, a poor planning and maintenance.

3. Literature review

Scheduling is one of the critical problems in a manufacturing system. The problem in scheduling focuses on how to allocate the limited resources of production (Muni Babu, Himasekhar Sai, & Sreenivasulu Reddy, 2015). Typical manufacturing resources include facilities, human resource, materials and others (Sun & Xue, 2001). So, Scheduling became to ensure maximum utilization of the plant at minimum cost (Kumar & Tayal, 2012). Production scheduling problem had begun by developing algorithms for generating an optimal sequence to complete the required tasks considering either only one processor (machine) or multiple processors (machines) (Baker, 1974). Industrial scheduling problems become complex and difficult for solving an optimum schedule due to the uncertainties in the manufacturing environment (Ancău, 2012; Artiba, Abdelhakim, & Lassinovski, 2012). A production sequence changes due to a disturbance in resources such as machine breakdown or sickness of workers. Therefore, in dynamic and stochastic manufacturing environments; managers, production planners, and supervisors must not only generate high-quality schedules but also react quickly to unexpected events and revise schedules in a cost-effective manner (Artiba et al., 2012). In Scheduling the main objective of the problem is to determine best job sequence that optimizes the makespan of job shop problem (Kumar & Tayal, 2012). In the meantime, effective planning and control of material flows and production processes are a key to the success of a manufacturing company (Robert Jacobs, Berry, Clay Whybark, & Vollman, 2005). There is no denying that scheduling systems brought about process organization and, consequently, monetary improvements (Frauendorfer & Konigsperger, 1996). In general, scheduling deals with the temporal assignment of jobs to the resources within a given time framework while maintaining various constraints (Rajpathak, 2001). Here, we conclude that a good schedule is a key to success in today's competitive market, and have a variety of benefits such as production improvement, production cost reduction, supports resource allocation, plant optimization, etc., and these make the scheduling problem very interesting to deal with.

Scheduling methods vary from manual methods, such as manipulating Gantt charts, to sophisticated computer models for developing optimal schedules (Pugazhenthi, Anthony Xavior, & Arul, 2014). The methods to solve FSSP also grouped into two categories: constructive and improvement heuristics. Constructive heuristics builds the ordered sequence of jobs based on some specific rules or decisions, whereas Improvement heuristics using specific rules makes better solutions starting from an existing feasible solution usually found by one of the previous constructive techniques (Alharkan, 2005). The algorithm of Johnson is a classic method which searches for the optimal sequencing of *n*-jobs on 2 machines in order to minimize the total elapsed time (Johnson, 1954). Later, Johnson expanded 2 machine algorithms for 3 machines and *n*-jobs with specific rules. Pervaiz and Sehik Uduman (2014), puts Johnson algorithm as an efficient one for problems with 2 machines, or 3 machines under specific constraints on job processing time. In Jonson algorithm of *n*-jobs on 3 machines, the jobs are assumed to be simultaneously available at time zero and machines are arranged in processing sequence with unlimited buffering space between them (Atter, 2011). If the processing time (Pji) of jobs is known certainly, then the Jonson rule for sequencing jobs for 2 and 3 machine case can be applied to solve the scheduling problem.

In addition to the classic algorithm of Johnson, there were several heuristic algorithms for *n*-jobs and *m*-machines problems. For instance, the Heuristic of Koulamas (HFC) uses in first phase the algorithm of Johnson, and later on improves the previously feasible solution, and those of Palmer (rapid algorithm), Hundal, and Rajgopal make use of a slope index assigned to each job and they use a weight as a sort key to generate a feasible schedule (Alharkan, 2005). Pervious reviews showed that the single iteration palmer's algorithm solution lacks accuracy when compared to others. Gupta and Stafford (2006), proposed a functional heuristic algorithm, first introduced by Johnson (Pinedo, 1995). Another algorithm was Branch and Bound formerly proposed by Ignall and Schrage in 1965, which is based on the permutations schedules and has close similarity to a tree structure, and requires many iterations to reach to a solution (Atter, 2011). In 1977, Dannenbring produces a rapid access procedure for scheduling a flow shop problem. The procedure had a better quality solution as compared to Palmer and Campbell, Dudek, and Smith (CDS) methods; however, it requires extensive computational effort (Pinedo, 1995). CDS algorithm of Campbell, Dudek, and Smith (1970), was also another best heuristic found next to the efficient algorithm NEH (Nawaz, Enscore, & Ham, 1983), and it has the performance to generate a more economical approximate solution to any size of “n” job, “m” machine problem (Campbell et al., 1970). The Algorithm forms a number of auxiliary n-job, 2-machine problems up to $m-1$ sequences and applies Johnson’s algorithm for each auxiliary problems. Finally, the best sequence is chosen among $m-1$ processing sequences. The procedures were simplified and illustrated by Alharkan (2005).

The Nawaz, Enscor, and Ham (NEH) algorithm was stated as efficient and least-biased in research papers (Chakraborty & Laha, 2007; Krajewski, Ritzman, & Malhotra, 1999; Taillard, 1990). NEH is based neither on Johnson’s algorithm nor on assigning weights techniques. It is based on the idea that a job with a high total operating time on the machines should be placed first at an appropriate relative order in the sequence (Krajewski et al., 1999). NEH is solved in an iterative manner. The iterative process continues until all jobs are fixed and complete a sequence (Mohammadi, 2015). The iteration procedures were also available in Alharkan (2005), with an illustrative example.

4. Materials and methods

The study used company visits and literature review for its data analysis. A literature review was conducted to carefully select the flow shop scheduling heuristics. From the selected heuristics to find out which one perform better their reuslts were compared to each other and with previous findings. Frequent company visit and informal interviews were made to gather information about the production plan, processing times and machines. Along the production line seven diametrically ordered jobs *(J1, J2, J3, …, J7)* were processed on three machines to produce a set of a flat cooking pan. Then, the production line constraints were identified. After that, applicable production scenarios or strategies were designed. The research uses data gathered as primary and secondary. The researchers recorded the primary data at the time of constant production run. The primary data were measured in seconds, and includes: the processing times of a job, machine setup and idle times. Machine setup time was the time taken to change tools and fixtures, whereas idle time was the time lost by operators. The idle time of each job on a machine was variable, as a result, the average value was taken. The summation of the processing time of a job with the setup and average idle times gave the total processing time of a job (P_{ji}). The total processing times were inserted into the selected flow shop scheduling heuristics, and then the existing job order makespan was computed and compared with the makespan of the optimal production sequences. The readily available secondary data was the 2013 planned production volume and production output in pieces or cartoons. Subsequently, the production volume of the optimal production sequences were compared with the 2013 planned production volume and production output.

5. Production of the case company

The research was conducted on a leading household utensils manufacturing company in Ethiopia. The products were Flat Cooking Pan, Cooking Pan with handle, kettles, Washbasin, and Roasting Pan and delivered to customers found in the domestic market. The company uses aluminum (raw material), which is imported from abroad, to manufacture the products. The production department puts a production volume, which needs to be satisfied, for each products. Nevertheless, this case did not happen in most of the past production years. Because the production department had no systematically deterimined production sequences. Due to this, jobs were assigned to machines arbitrarily. In 2013, while this study had been conducted, the annual plan was to produce 1,832,000 pieces of products, but only 671,382 pieces were produced at the end of the year. Thus, the department accomplished 36.65% of the production plan. Based on the data collected, a flat cooking pan production consumes 80% of the company resources. Annual production plan of the flat cooking pan of the same year was 581,000 pieces (83,000 Cartoons); however, at the end of the fiscal year, only 150,192 pieces (21,456 Cartoon) were produced. And, this represents 25.85% of the flat cooking pan production plan. The study identified poor job schedule, poor planning, and frequent machines breakdown, as major reasons for poor performance.

5.1. Production line of a flat cooking pan

A flat cooking pan production line was considered for this study, since it consumes huge amount of the company resources. Without changing the production line set ups of a flat cooking pan, the production volume and as well as the maintenances, would be improved through optimal job schedule or sequence. Accordingly, the flat cooking pan production line was considered. Figure 1 depicts the production process of a flat cooking pan.

As observed in Figure 1, the forming operation (drawing) completed by mechanical or hydraulic type press machines. So that, at the beginning a job can be assigned either to mechanical or hydraulic type press machines, and their outputs proceeds to a single production line. In simultaneous usages of the press machines; bottleneck and accumulation of work in process inventory were seen along the production line. Obviously, erecting a separate production line after the mechanical or hydraulic press machines will avoid bottleneck, accumulation of work in process inventory, and enhances the production volume. In fact, due to machine breakdowns, limited number of mechanical or hydraulic press machines are available for production in the case company. Press machines failure emerged from poor preventive maintenance, forming die mix and power interruption.

The Flat cooking pan production line effectiveness relies on the availability of the press machines, speed of the machines and operators. And, these factors were considered in the determination of the optimal production sequences because one way or the other they would be reasons for production interruption or unsatisfied production volume. To avoid or minimize the production interruptions within the existing production environment, the researchers developed three production scenarios. Then, an optimal production sequences were determined for the scenarios.

This means that the firm functions with optimal schedules or sequences at each scenario. Implementation of this approach significantly improves production volume, and it can also further improve machine utilization, maintenance, cost of production and customer satisfaction. The developed scenarios are presented in Table 1.

During the study, there were no standard time to complete a job on a machine or along the production line. Hence, the researchers collected the processing time of a job, machine setup and idle times to set the total processing time of a job on a machine. Table 2 shows the total processing time of jobs on a machine, where J6 and J7 have less processing time on the hydraulic type press machines. This might be due to the smooth and quick-fitting of the forming dies to the machines or due to the operators' skill. And, the total makespan value was higher when jobs visits the hydraulic type press machines.

6. Heuristics approach

The various flow shop scheduling heuristics were devloped to minimize the makespan of *n*-jobs on *m*-machines problem; however, each methods had advantages and some limitaions. For instance:

- The so called Johnson algorthim was best for for *n*-jobs and 2-machines problem.
- Palmer algorthim can be applied to *n*-jobs and *m*-machines problem, though it was found rapid to reach to result but the result lacked accuracy when compared to the best results of other heuristics. And uses a single iteration method or evaluate one sequences to minimize the makespan.

Figure 1. Production process of a flat cooking pan.

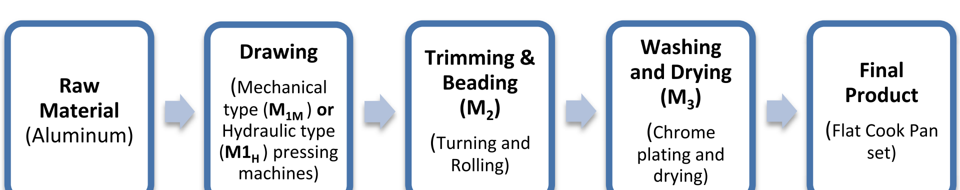

Table 1. Production scenarios

Scenario	Jobs visit $M1_M$	Jobs visit $M1_H$
1	J1–J2–J3–J4–J5	J6–J7
2	J1–J2–J3–J4–J5–J6–J7	Machines on maintenance
3	Machines on maintenance	J1–J2–J3–J4–J5–J6–J7

Table 2. Total processing time (P_{ji}) and total makespan

Jobs	$M1_H$	M_2	M_3	Total makespan	Jobs	$M1_M$	M_2	M_3	Total makespan
J1	156	65	45		J1	120	65	45	
J2	65	16	25		J2	60	16	25	
J3	47	15	26		J3	40	15	26	
J4	39	12	27	784	J4	35	12	27	769
J5	49	14	27		J5	47	14	27	
J6	37	13	28		J6	49	13	28	
J7	45	14	29		J7	57	19	29	

- The extended Johnson algorithm called CDS, which is widely used method, can be applied to *n*-jobs and *m*-machines problem, and evaluates $m-1$ sequences for minimization of the makespan.
- NEH algorithm, which is the efficient algorithm, can be applied to *n*-jobs and *m*-machines problem, and uses many iteration compared with other heuristics. So, NEH evaluates more sequences for makespan minimization.
- Branch and Bound method forms a tree structure and evaluate a number of times to reach to the optimal solution, and yields better quality solution. But it has complex and time consuming computaional method.
- Dannenbring's method was the fastest algorithm to reach to a solution and had a better quality solution as compared to Palmer's and CDS methods; however, it requires extensive computational effort.

Based on the above and the following reasons, the researchers selected CDS and NEH algorithms to solve the considered 7-jobs and 3-machines problem. First and most, NEH was found more efficient in the literature review and has well defined easy steps to compute. Secondly, CDS have less computation effort, involves the most efficient Johnson algorithm in the computational procedure and generates more reasonable approximate solutions to any size of flow shop problem. Accordingly, CDS can also generate a better solution and fits well the case company production process. Furthermore, Park's (1981) study on flow shop sequencing heuristics showed that NEH was the best-performing algorithm over others checked on small-sized (*jobs* = 3–9, *processors* = 4–20) and medium-sized (*jobs* = 15–30, *processors* = 4–20) problems, and puts CDS as the next best algorithm.The considered problem was small-sized, therefore the selected heuristics were appropriate. Applying the computational procedures described below, both variants generate optimal solutions. However, some assumptions and conditions should be there for the practical implementation of the solutions, and these are described at Section 7.

6.1. CDS

CDS algorithm uses the Johnson's rule to solve the new problems formed by the procedures. CDS is categorized under constructive heuristic. The algorithm here converts *n*-jobs and *m*-machine problem into $m-1$ stages. Each stages job order makespan calculated and at the end of the steps, the best makespan is identified from all $m-1$ sequences. If P_{ji} represents the total processing time of the *j*th job (j = 1, 2, 3, ..., n) on *i*th (i = 1, 2, 3, ..., m) machine, then k, where $k = m-1$, auxiliary 2 machines n-job problems can be formulated by the following equations and logical steps. The procedures were directly adopted from Campbell et al. (1970), the algorithm of n-jobs, m-machine sequencing problem. For the z auxiliary problem:

$$T_{J1}^{z} = \sum_{i=1}^{z} P_{ji} = \text{processing time of } j^{\text{th}}\ jobonmachine1\ (M1) \tag{1}$$

$$T_{J2}^{z} = \sum_{i=m+1-z}^{m} P_{ji} = \text{processing time of } j^{\text{th}}\ jobonmachine2\ (M2) \tag{2}$$

Step 1: First develop a $n \times m$ matrix of processing times.

Step 2: Generate auxiliary 2 machines (n-job) problems, where $k = m-1$, then set $k = 1$, for the first auxiliary problem.

Step 3: Compute equation 1 and develop column vector of processing times on M1 for each job for z auxiliary problem.

Step 4: Compute equation 2 and develop column vector of processing times on M2 for each job for z auxiliary problem

Step 5: Use the Johnson's n-jobs 2-machine rule to the formed n-jobs 2-machine problem by the above steps. Calculate makespan and store the job order.

Step 6: Check z with k; if $z < k$, set $z = z + 1$ and repeat; if $z = k$, proceed

Step 7: From the stored job orders, select the job order with minimum makespan as the best sequence.

6.2. NEH

NEH algorithm is also categorized as a constructive heuristic. To minimize the makespan of n-jobs and m-machine problems, NEH sorts the n-jobs (j = 1, 2, 3... n) in decreasing order of the sum of their total processing times (P_{ji}) on all machines, and for the kth job (k = 1, ..., n) from the kth possible it locates the position that minimizes the partial sequence makespan, and then inserts it into the position. The iterative procedure stops after inserting the remaining job into the possible sequence.

Step 1: Sort the n-jobs in decreasing order of the sum of their processing time in machines.

Step 2: Pick the first two jobs and form two partial sequences by interchanging the position of the two jobs. Compute makespan of the partial sequences, and call the partial sequence with a minimum value for the next iteration.

Step 3: For $k = 3$ *to* n do step 4.

Step 4: Insert the kth job at the position, where it minimizes the partial sequence makespan among the k possible ones.

7. Conditions for the FSSP

All jobs have similar processing sequences, different processing times, and no revisit of the machines. These conditions fit the requirement of the selected heuristics, and the problem was catagorized under PFSP. The researchers applied different assumptions and parameters taken from the company production line: the company has uninterrupted runs throughout the year and has a total of 16 working hours per day, raw materials (aluminum) and other required settings are ready at time zero, production interruption is not allowed because of raw material quality defects. It was assumed that the thickness and diameter of the raw materials in stock were imported as per the company specification and checked for defects before it proceeds to the production line.

During press machines breakdown; jobs will wait in the queue and automatically transferred to the available press machines. A well-managed preventive maintenance is always there for trimming/beading, and washing/drying machines, and this conclusion was derived from the fact that there were no recorded interruption of these machines at the time of the study. Lubrication of machines can be done without stopping a machine, forming dies were readily available at time zero, each job is independently manufactured and there is no technological itinerary between them. Operators know their working schedule ahead of time and sick/absent operator will be filled by the reserve operator in line; and finally, a power failure is not allowed.

8. Results and discussion

After applying the clearly defined computational procedures of the methods, the makespan was considerably minimized as compared to the existing ones. Therefore, an optimized result was found from the proposed methods. The computational effort was presented below.

(1) For job order J1–J2–J3–J4–J5, NEH used 4 iterations to reach to the 5 possible solution sequences. And, the 5 sequences were evaluated to find out the optimal sequence. Next, NEH used 1 iteration to find the solution for Job order J7–J6. For both job orders, CDS evaluated 2 possible solution sequences to find the optimal sequence.

(2) For job orders J1–J2–J3–J4–J5–J6–J7, NEH used 6 iteration to reach to the 7 possible solution sequences. Similarly, the 7 sequences were evaluated to find out the optimal sequence. Yet again, CDS evaluated 2 possible solution sequences to find the optimal sequence.

In scenario three, NEH yields more alternative solutions than CDS. And, in case of scenario one and two, both methods provides a single solution with different job order. Also, NEH had the minimum makespan value as compared to CDS. The optimal production sequences daily and annual production volume were evaluated to witness the enhancement in production volume. Then, the results were compared with the planned production volume (83,000 Cartoons) and production output (25.85%) of the year 2013. Tables 3 and 4 below shows the resulted optimal production sequences and the evaluated production volumes respectively; and also, a detail discussion is provided below.

In aggregate, the result shows more than 22% improvement in production volume. With the higher makespan value, which is scenrio three, 40,320 cartoons of a flat cooking pan can be produced, and this represents 48.56% of the planned production volume.

Table 3. Makespan and optimal production sequences

Scenario	Makespan		Optimal production sequences	
	CDS	NEH	CDS	NEH
1	466	464	J1–J5–J4–J3–J2–J7–J6	J1–J2–J5–J3–J4–J7–J6
2	447	447	J1–J7–J6–J2–J3–J5–J4	J1–J7–J2–J6–J5–J3–J4
				J1–J2–J5–J7–J3–J6–J4
				J1–J2–J5–J7–J6–J3–J4
				J1–J2–J5–J6–J7–J3–J4
3	477	477	J1–J7–J2–J3–J6–J5–J4	J1–J2–J6–J5–J7–J3–J4
				J6–J1–J2–J5–J7–J3–J4
				J1–J6–J2–J5–J7–J3–J4

Table 4. Production volume and improvement

Scenario	Optimal production sequences	Daily production in cartoons per shift	Annual production in cartoons	Production volume (%)	Improvement (%)
1	J1–J2–J5–J3–J4–J7–J6	62	41,664	50.19	24.34
2	J1–J7–J6–J2–J3–J5–J4	64	43,008	51.82	25.96
	J1–J7–J2–J6–J5–J3–J4				
	J1–J7–J2–J3–J6–J5–J4				
	J1–J2–J5–J7–J3–J6–J4				
3	J1–J2–J5–J7–J6–J3–J4	60	40,320	48.56	22.72
	J1–J2–J5–J6–J7–J3–J4				
	J1–J2–J6–J5–J7–J3–J4				
	J6–J1–J2–J5–J7–J3–J4				
	J1–J6–J2–J5–J7–J3–J4				

In Scenario one, NEH had the minimum makespan value, and it was developed by splitting the jobs to mechanical and Hydraulic press machines. Accordingly, the company could use this option to enhance the service life of the press machines. Clearly, job segmentation reduces the failure rate of the machines as it has flexibility for planning maintenance.

In Scenario two, both variants had the same makespan value and the option provides the highest production volume improvement (25.96%). Here, both CDS and NEH algorithms outperforms with different production sequences.

Scenario three had the less production volume as compared to the others. In this case, both variants resulted in equal makespan value. However, NEH provides more alternative schedules, and therefore the scenario had the most flexible production schedules. From this scenario, the company will gain flexibility advantage in production planning, and has more options for greater production

To summarize, the proposed scenarios had close production volume. Both algorithms perform equally when all jobs were assigned to one type of press machines. On the other hand, when jobs split to both types of the press machines the makespan value became different, and NEH yields a better solution. Also, in scenario three NEH offered six alternative schedules and this support the fact that the algorithm is efficient. Lastly, based on figures, the company could not achieve the planned production volume with the existing production set ups.

9. Conclusion

In this paper, the job sequence of a flat cooking pan production line was considered. The problem had 7-jobs and 3-machines. Flow shop scheduling heuristics were used to improve the production of the flat cooking pan production line. The case company had no systematically determined production sequences for flat cooking pan, and achieved 25.85% of the production plan in 2013. To solve the problem with the existing production line set ups; three production scenarios were developed based on the production line constraints, such as machines breakdown and specific jobs processing time on machines. After, critically reviewing literatures on flow shop scheduling methods, CDS and NEH were selected. And, this methods were applied on the production scenarios. For all scenarios, they resulted in optimal production sequence with minimum makespan value. And, the optimal production sequences improved the annually planned production volume by more than 22%. However, there might be slight changes with the results in actual implementation of the solutions. Because, the recorded total processing time was prone to errors and also disregards the time taken to transfer jobs between machine stations.

Based on the study outcome, the conceivable way to meet the annual production plan (83,000) is to erect a separate production line after the press machines. Consequently, the company needs to reconsider the plan or evaluate the plant capacity.

With easy and manual computational effort, CDS and NEH generates better production sequences. And, NEH evaluates more sequences than CDS; as a result of this, NEH yields more quality solution. In all scenario, both methods optimal production sequences offered higher production volume than the job order at work. So that, both methods performs well to solve the problem, but NEH provides more schedules for greater production. Finally, we also conclude that NEH is the best algorithm as compared to CDS. This result was also in line with previous findings, which stated "NEH as more efficient and highly structured constructive heuristic", and puts CDS as the next best algorithm.

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