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Heuristic Dispatching Rules for Dynamic Scheduling of Heavy Engineering Equipments

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ABSTRACT

Dynamic scheduling problem has been an attractive area for researches to investigate since a long time. Many techniques have been used to tackle such problems, but all of these techniques require high efforts to formulate the dynamic scheduling problems inorder to obtain optimal solution. Using Heuristic or dispatching rules to solve the dynamic scheduling problem is efficient and popular manner to reach an acceptable level of scheduling. In this paper hybrid techniques are used in the proposed developed model. First the switching of four dispatching rules (Earliest Due Date (EDD), Slack Time (SLACK), Slack / Remaining Operations (S/ROP) and Priority Index) with the aim of choosing minimum tardy jobs. Second, scheduling-rescheduling approach is used to tackle the dynamic environment of job-shop problem depending on three level algorithms. Third, proposing three level algorithms, these levels are resource level, process planning level to improve scheduling with the aim of minimizing tardy jobs and shorten "order-to-delivery", and job level to design rescheduling policy depending on identified factors of each job order. The developed model is applied to real data from the Heavy Engineering Equipment State Company/Baghdad, and considerable advantages are observed. Applying the proposed model lead to zero number of tardy jobs (NT) and zero mean tardiness (MT). It is obvious from the obtained results that by adopting such model, a better solution for job orders' due dates can be achieved; hence "order-to-delivery" time can be shortened.

Keywords: Dynamic environment, Job-shop scheduling, Dispatching rules, Dynamic scheduling, Rescheduling, Priority index, Heavy Engineering Equipment.

الجدولة الديناميكية للمعدات الهندسية الثقيلة باستخدام قواعد التوزيع الاسترشادية

الخلاصة

تعتبر مشكلة الجدولة الديناميكية من المجالات التي تتطلب البحث المستمر وتستهوي الباحثين ومنذ فترة زمنية طويلة. لقد تم استخدام عدد كبير من التقنيات لحل مشكلة الجدولة الديناميكية، والتي تطلبت جهود كبيرة في الصياغة الرياضية للمشكلة بهدف الوصول الى الحل الامثل. ان

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استخدام قواعد التوزيع الاسترشادية لحل مشكلة الجدولة الديناميكية يعتبر من الوسائل الفعالة والكفوءة للوصول الى المستوي المرضي للحل. تم في هذا البحث اقتراح نموذج مطور باستخدام تقنيات مختلطة. اولا التبادلية بين اربع قواعد توزيع استرشادية هي (اقرب موعد مطلوب للانجاز، الوقت الضائع، الوقت الضائع مقسوما على عدد الفعاليات المتبقية وقاعدة تسلسل الاسبقيات) بهدف الوصول الى اقل عدد من اوامر العمل المتأخرة. ثانيا استخدام الجدولة واعادة الجدولة للتعامل مع البيئة الديناميكية لمشكلة الانتاج حسب الطلب (job-shop problem) باعتماد خوارزمية بثلاث مستويات. ثالثا اقتراح خوارزمية بثلاث مستويات المستوى الاول الموارد، المستوى الثاني تخطيط العمليات لتطوير الجدولة بهدف تقليل اوامر العمل المتأخرة وتقليص دورة (الامر الى التسليم)، ومستوى الاعمال لتصميم سياسة لاعادة الجدولة باعتماد عوامل معرفة لكل امر عمل. تم تطبيق النموذج المطور باعتماد بيانات حقيقة من الشركة العامة للمعدات الهندسية الثقيلة/ بغداد، وتم الحصول على نتائج جيدة ومهمة. حيث ان تطبيق النموذج المقترح ادى الى الوصول الى (صفر) من اوامر العمل المتأخرة، وبالتالي (صفر) لمعدل التأخير. نستنتج من ذلك انه بتطبيق النموذج المقترح المطور فان الحل يتحسن بخصوص تحقيق مواعيد الانجاز لاوامر العمل وتقليص دورة (الامر الى التسليم).

INTRODUCTION

Scheduling is an important aspect of operations control in both manufacturing and service industries. Efficient scheduling of operations will improve the performance of the systems. The problem of scheduling in dynamic conventional jobshops has been extensively investigated over many years. Schedule generation methodologies can be performed for meeting delivery targets. Production managers would wish to minimize the time taken to process a set of jobs, to keep the system's utilization at maximum .They also want to achieve fairness of individual jobs by minimizing the variance of job completion times or commit to the customer deadlines by minimizing variability of completion times from due-dates (Ganesan,2006). The dynamic job-shop scheduling problem, in which jobs arrive at random during some time interval, leads to solution techniques of an entirely different nature. These solution techniques consist essentially of priority dispatching procedures in which all jobs are assigned a priority such that a job with the greater priority number is scheduled first (Hoitomt,93). Dispatching means actually releasing work orders to employees and machines (Moore,80). The environment which was selected for investigation in this research is the Heavy Engineering Equipments environment. Such environment includes companies specialized in designing and manufacturing of heavy engineering products such as fuel storage tanks of various capacities, various towers, pressure vessels, heat exchangers, steam boilers and variety of equipment for oil production, petrochemical and food industries...etc. Heavy engineering equipments companies compete in its field, its products are Manufacture-To-Order not To-Stock. The process chain of work in such companies is of type Offer-Order-Contract.

THE AIM OF THE RESEARCH

The complexity of the scheduling process in job-shops; especially when job arrival, job processing sequence and the processing times are variables has a significant theoretical attraction for research in this area. This point is obvious in heavy engineering equipment environment. The scheduling problem studied in this research is delayed in achieving due dates required by customers that lead to failure in achieving contracts' promises; by developing and constructing a model that uses heuristics and hybrid techniques to eliminate the number of tardy jobs. This problem faces many of the large international and local firms due to the disturbances caused by the dynamic nature and the specialty of the product specification especially in Engineer To Order (ETO) industrial firms for heavy engineering products. The aim of this research is to overcome the problem of not achieving due-dates in a dynamic job-shop environment for job-order scheduling of heavy engineering equipments by meeting the required delivery dates to achieve promises mentioned in the contracts with customers, minimize lateness in job-orders in order to satisfy customer's due-dates and eliminate extra cost due to penalties that might be paid to them according to contracts, maximize utilization of machines, workstations and manpower resources and shorten "Engineer-to-delivery" to increase competition capabilities.

LITRETURE REVIEW

Over the last decades a significant volume of researches on the issues of scheduling with executional uncertainties has begun to emerge. A review of some of these researches is illustrated**.**

Jeong (1997) proposed an algorithm to get an improved schedule by splitting the original batch into smaller batches, and thereby can meet the due date requirement, and adapt to unexpected dynamic events such as machine failure, rush order and expediting. Lee and Uzsoy (1999) consider the problem of minimizing makespan *Cmax* on a single batch processing machine in the presence of dynamic job arrivals. Aydin and Öztemel (2000) proposed an intelligent agent based dynamic scheduling system. Subramaniam *et al.* (2000), demonstrate that significant improvements to the scheduling performance of dispatching rules can be achieved easily through the use of simple machine selection rules. Three such rules are proposed and their effectiveness is evaluated through a simulation study of a dynamic job-shop. Holthaus and Rajendran (2000), attempt to improve some of the recently reported dispatching rules. Their study has dealt with the proposal of two rules that have been derived from existing rules. These rules seek to minimize mean flowtime of jobs, and maximum tardiness and variance of tardiness of jobs. Zhou *et al*. (2001) proposed a kind of hybrid heuristic Genetic Algorithm (GA) for problem *n/m/G/CMAX*, where the scheduling rules, such as Shortest Processing Time (SPT) and Most WorK Remaining (MWKR), are integrated into the process of genetic evolution. Mohanasundaram *et al.* (2002) seek to develop efficient dispatching rules to minimize the maximum and standard deviation of flowtime and staging delay, and the maximum and the standard deviation of conditional tardiness of jobs. The dispatching rules are based on the computation of the earliest completion time of a job and consequently determining the latest finish time of operations on components/subassemblies of a job. Dominic *et al.* (2004), attempt to provide efficient dispatching rules for dynamic job-shop scheduling by combining different dispatching rules. Results show that, for most of the performance measures, combined rules perform well, these combined rules are MWKR_FIFO (most work remaining _ first in first out) and TWKR_SPT (TWKR=total work remaining) do well under most conditions. Liu *et al.* (2005) provide an experimental justification of the arguments about a complete multiple agents' framework for dynamic job shop scheduling using computational experiments on dynamic job arrivals. Hwang and Choi (2007) propose a workflow-based dynamic scheduling framework, in which a workflow management system (WfMS) serves as a dynamic job-shop scheduler. Kim *et al.* (2008) compare dispatching rules and genetic algorithms for job shop schedules of standard hydraulic cylinders. Genetic algorithms were found to be better than dispatching rules in two ways. However, dispatching rules were found to be better than genetic algorithms in three respects. First, using dispatching rules supports decision-making by creating various solutions based on different rules. Second, each solution obtained by genetic algorithms yielded scattering results, whereas the solution obtained by dispatching rules yielded steady results. Third, genetic algorithms require the use of a computer because of the large number of parameters to specify, whereas simple solutions can be obtained using dispatching rules in an urgent production situation. Leitao and Restivo (2008) presents a holonic approach to manufacturing scheduling, where the scheduling functions are distributed by several entities, combining their calculation power and local optimization capability. The results showed that the proposed approach has potential to improve the system performance, mainly combining agility and global production optimization in terms of throughput, lead time and tardiness. Hwang *et al.* (2008) propose a probabilistic framework for resource scheduling in grid environment that views the task response time as a probability distribution to take into consideration the uncertain factors, they propose three algorithms. Experimental results using synthetic data derived from a real protein annotation workflow application yield better performance. They also compare the relative performance of the three proposed algorithms. Shahzad and Mebarki (2010) presented a data mining based scheduling framework. This approach focuses on the identification of the critical parameters and states of a particular dynamic scheduling environment that contribute to the construction of some efficient solution. The proposed methodology is based upon the implicit assumption about the ability of tabu search to move intelligently in the solution space while providing the opportunity, at the same time, to learn the embedded knowledge about the thinking lines behind these intelligent moves. Azardoost and Imanipour (2011) presented a hybrid metaheuristich algorithm based on tabu search, simulated annealing and genetic algorithms with suitable parameters for solving. In order to evaluate the effectiveness and efficiency of proposed algorithm, obtained results are compared with optimal solutions obtained through solving mathematical model and local approach methods. Results of experiments and computational analysis show that the proposed algorithm in this study has ability to achieve close to optimal points at suitable time for different issues in different sizes.

SCHEDULING TECHNIQUES

Production scheduling classification

Production scheduling classification can be summarized in the following way according to Ranky (1986), regarding:

1. Requirement generation, which can be Open shop and Closed shop.
2. Processing complexity, this can be:
   - "n" jobs single resource problem
   - "n" jobs parallel resources problem
   - The multistage flow shop problem
   - The multistage job-shop problem
   - Flexible Manufacturing Systems (FMS), or random manufacturing problem in Computer Integration Manufacturing (CIM).
3. Scheduling criteria, which can be, Scheduling and rescheduling cost and Performance.
4. Nature of the requirement specification, which can be, Deterministic and Stochastic.
5. Scheduling environment, which can be, Static and Dynamic.

Operations Research and Heuristics Approaches to Scheduling

There are reasonably well-known methods of scheduling which fall into the category of operations research approaches. From the point of view of operations research, a decision is a recommendation that a particular course of action, affecting the system, be carried out. The decision maker attempts to choose that course of action which is expected to yield the "best" results in terms of the larger goals of the organization of which the system is a part, or in other words they attempts to render the system more *effective*. Operations research subcategories are Control Theory, Dynamic Programming, Linear Programming LP, Integer Programming IP, Mixed Integer Programming MIP, Non-Linear Programming, Optimization, Game Theory and System Theory. A heuristic is a 'rule thumb' .In other words, these rules are justified purely because, based on experience, they seem to work reasonably well. If an optimal schedule cannot be found within a reasonable time, knowledge and experience of the system can be used to find a schedule which, if not optimal, may at least be expected to perform better than average .The major drawback of the heuristic methods is that they make a lot of computer time for large problems. Rules such as shortest processing time (SPT) and earliest due date (EDD) can be used as algorithms in the one machine environment. However they are usually associated with multiple machine environments, where they are used as heuristics.

Dynamic Job-shop Scheduling

A job-shop will be treated mainly as dynamic, when conditions such as continuously arriving new jobs and deviations from the current schedule need to be accommodated (Dominic, 2004). Job-shop scheduling, in general, consists of a set of concurrent and conflicting goals to be satisfied using a finite set of machines. Each job has a processing order through the machines which specifies the precedence restrictions. Dynamic job-shop scheduling problems (JSSPs) can be further classified as deterministic or stochastic based on the manner of specification of the job release times. *Deterministic* JSSPs assume that the job release times are known in advance. In *stochastic* JSSPs, job release times are random variables described by a known probability distribution (Lin, 1997). Some of the factors that characterize the analysis of dynamic job-shops may be broadly categorized as illustrated in table-1.

Rescheduling

Historically there have been two approaches to scheduling *sequencing*, the approach that seeks to establish an order for all open jobs and *dispatching*, the approach that provides a solution by the use of local rules for selection of one job from the list of available jobs at decision epochs. It has been reported that sequencing approach is more efficient than the dispatching approach in a pure static environment (Kurmathur, 1996). However in a dynamic environment it is practically impossible to adopt a total sequencing approach simply because the problem cannot be solved satisfactorily. Therefore dispatching is probably the only solution. Rescheduling is a goal driven strategy that attempts to involve shop characteristics, shop objectives and dynamic shop status information to perform effective dispatching.

The following are the most common factors identified in rescheduling studies (Vieira, 2003):

- machine failure
- urgent (rush or 'hot') job arrival
- job cancellation
- due date change (delay or advance)
- delay in arrival or shortage of materials
- change in job priority
- rework or quality problem
- over-or underestimation of process time operator absenteeism

The above events may trigger other actions (listed below) that, in turn, suggest rescheduling:

- overtime
- in-process subcontracting
- process change or re-routing
- machine substitution
- limited manpower
- setup times

- equipment release

Rescheduling will be included in the adopted hybrid heuristic model in this paper.

Holonic Manufacturing System

The concept of a *Holon (Holos in* Greek means whole and *-on* means part of) was proposed by Koestler (1967). The basic idea of Holon is a double-face effect, which means every Holon is an autonomous whole and also a part of a larger Holon at the same time. Holonic manufacturing is trying to overcome today's limitations in flexibility of manufacturing systems by autonomous, decentralized and cooperative approach. The Holon posses the basic characteristics of autonomy and co-operation, it is capable to plan and to execute for itself. Furthermore, the co-operation capability enables it to co-operate with other holons in order to achieve a common goal or objective. Koestler also points out that holons are autonomous self-reliant units, which have a degree of independence and handle contingencies without asking higher authorities for instructions. Simultaneously, holons are subject to control from (multiple) higher authorities. The first property ensures that holons are stable forms, which survive disturbances. The latter property signifies that they are intermediate forms, which provide the proper functionality for the bigger whole (Bongaerts, 1998).Holons will be a part of resource level algorithm adopted in the hybrid heuristic model proposed in paragraph (5-1) of this paper.

The Suggested Heuristics Dispatching Rules

Based on previous research work and literatures, dispatching rules have been separated into four classes. These classes are (1) rules involving processing times, (2) rules involving due-dates, (3) simple rules involving neither processing times nor due-dates, and (4) rules involving two or more of the first three classes. The principle advantage of due-date based rules over processing time based rules is a small variance of job lateness, and often a smaller number of tardy jobs. According to the objectives in this research that deals with meeting due-date and minimizes job tardiness, the following rules are suggested to be adopted; these rules are within the class of [Dispatching rules involving due-dates]:

(a) EDD (Earliest Due Date); this rule selects the job with Earliest Due Date.

(b) SLACK (Slack Time); this rule selects the job with least value of its due date and subtract from it the remaining processing time.

(c) S/ROP (Slack / Remaining Operations); select the job with the least value of the slack time divided by the number of remaining operations.

(d) Critical Ratio; in its most general form the critical ratio is computed as follows:

$$Critical\ ratio = \frac{duedate - datenow}{leadtimeremaining}$$

(e) PRIORITY INDEX; the job with the highest priority index will be selected.

The last rule is Priority Index rule, which is not a member of due-date family, but it will be adopted for comparison, and has been developed by the researchers.

Problem Overview

Many factors affect the dynamic scheduling nature, in heavy engineering equipments environment. The researcher will study the effect of some of these factors on scheduling using heuristic dispatching rules to solve the dynamic scheduling problem. In such environment heavy and complex products are manufactured, that means a need for special handling and transportation for heavy equipments. Some job orders need to be designed before manufacturing according to customer requirement. The number of products required differs for each job. These factors and others lead to more complicated environment. Optimization is difficult to be reached in such environment; so proposed hybrid heuristic model will be adopted to reach the acceptable level of scheduling. Most likely problems in the studied environment are:

1- Delay in achieving due dates with extra penalties, due to the dynamic nature such as machine stoppage, new arrival of orders, job cancellation, job expediting and so on.

2- Losing of job orders and customers due to delay in achieving target dates.

3- Ineffectiveness workstation usage (slack resources), due to weak planning and scheduling performance.

4- Over load in some workstations due to insufficient work station and lack of laborers.

The objective of proposed scheduling model is to assign jobs to work centers so as to:

1. Meet the required delivery dates for completion of all work of each job-order.
2. Minimize lateness in job-orders in order to satisfy customers.
3. Maximize utilization of machines and manpower resources.

The following performance measurements criticize the behavior of the due-dates model:

NT: number of tardy jobs. The investigation is to reach zero tardiness of the whole joborders in the system.

MT: weightened mean tardiness. The aim is to reach minimum weightened mean tardiness.

WSU: work stations utilization. The aim is to maximize workstation utilization.

C_{MAX}: maximum completion time or Makespan**.** The aim is to minimize Makespan.

PROPOSED MODEL

The proposed model consists of three hybrid techniques. Firstly the switching between four dispatching rules (EDD, SLACK, S/ROP and Priority Index). Secondly, rescheduling approach is used to tackle the dynamic environment of job-shop problem. Thirdly, improve scheduling adopting the three level algorithms; these level algorithms are resource level, process planning level and job level. The first two levels are used to improve scheduling with the aim of minimizing tardy jobs and shorten "order-to-delivery", and the third level is used to design rescheduling policy depending on identified factors of each job. Figure (1) gives the outlines relations of these techniques. Figure (2) shows the details and the steps of implementation. Implementing of proposed model consists from the following steps:

Step1: Assigning of workstations for each job order and required time is calculated according to the process plan.

Step2: According to job orders in the system; schedule using dispatching rules EED (earliest due-date), SLACK (slack time), S/ROP (slack/ remaining operations), PRI.INDEX (priority index).

Step3: Calculate performance measurements NT (number of tardy jobs), MT (mean tardiness), WSU (work stations utilization), and Cmax (maximum completion time or work span) for each Dispatching Rule (DR) used.

Step4: According to the performance measures mentioned above, switch to best Dispatching Rule, taking into consideration:

(i).Choose the DR with minimum NT.

(ii).When NT is the same for 2 DR or more then choose DR with minimum MT.

(iii).When MT is the same for 2 DR or more then choose DR with minimum Cmax.

(iv).When Cmax is the same for 2 DR or more then choose DR with Maximum WSU.

Step5: Improve scheduling focusing on minimizing NT and job tardiness. Studying and investigating of adopted schedule by focusing on most busy workstations. This step is tackled with calculation of job completion time and job tardiness if needed, to adopt one or more of the three level algorithms illustrated below.

Step6: The proposed model adopts rescheduling policy depending on dynamic events that cause disturbance in the system on scheduling. Proposed algorithms are suggested to be followed in rescheduling policy. These algorithms are based on the factors suggested in job level to name a period of checking each job order according to its complexity factor. According to this check and follow up, rescheduling is performed whenever actual progress is less than planned progress.

Step7: The proposed three levels are:

(i) The first level is the resources level for improving scheduling.

(ii) The second level is process planning level for improving scheduling.

(iii) The third level is the job level. This level is tackled with rescheduling policy.

Resource level

The resource level deals with (1) workstations which consist of machines or workers, and (2) material. In this level two categories for classification of workstations are used. These categories of classification are category *one* and *two* as illustrated in table (2):

According to the scheduling performed, focusing on tardy jobs, a careful study on most busy workstation is adopted, inorder to solve expected bottlenecks as follows:

(i) If bottleneck is in category *one*
Then Work overtime and on holidays

(ii)If bottleneck is in category *two*:
Then Make a temporary Holon

On the resource level (material), if a bottleneck is due to lack of raw material, then Making a temporary holons to purchase raw material within a limited supply chain.

Process planning level

In this level restudying of manufacturing process planning for tardy joborders is performed, taking into consideration most crowded workstations inorder to solve their bottlenecks as follows:

(i) Restudy process plan to find alternative possible workstations instead of busy workstations.

(ii) If bottleneck in material availability :

Then restudy manufacturing routes to check the possibility of using alternative available raw materials with additional manufacturing process.

(iii) If a quality error happens in manufacturing process:

Then make a technological team to decide the procedure of repairing or matching with other parts

Job level

Studying the effect of defined factors considered for job orders in a heavy engineering equipment environment is performed. According to these factors scores are assigned to calculate the complexity measure of each job order. Due to the calculated complexity measure rescheduling policy is adopted. These factors are defined as follows:

1.QR: it is the Quantity Required for each job-order.
2,DRQ: it is the Design ReQuirements for each job-order.
3.MA: it is the Material Availability for each job-order.
4.AL: it is the assembly level required for producing each job-order according to the process plan.
5.PW: it is the weight of product in (Ton) for each job-order.
6.NWS: it is the number of workstations required for producing each job-order according to the routes.
7. PP: it is the numbers of parts required for each product of the job-order.

These variables are defined in five groups; each group is assigned within two limits Critical and Minimum

8. RPP: it is the Rescheduling Performance Percentage for producing each job-order, and it is calculated as follows:

(i) According to schedule check planning Performance Percentage per day =PPP

(ii) Follow-up performance of job-order and check Actual Performance Percentage =APP

(iii).Whenever APP<PPP then reschedule

These measurements and their scores are summarized in table (3), they will have a score range from critical to minimum, and figured are defined by scheduler according to the case study.

The summation of scores of named factors; is assigned as a complexity measurement, which will be used as a point of rescheduling according to a rescheduling policy as follows:

(i) If total score is A1-A2,

Then check APP daily

(ii) If total score is A3-A4,
Then check APP every two days
(iii) If total score is A5-A6,
Then check APP every three days
(iv) If total score is A7-A8,
Then check APP every four days
(v) If total score is A9-A10,
Then check APP every five days*)*
Whenever APP<PPP then reschedule

Different variables are used to control variability of each factor. These variables are A1-A10, B1-B7, C1-C4, D1-D7, and E1-E7. They differ according to the environment of implementation.

IMPLEMENTATION

The company which is selected to implement the hybrid proposed model is the Heavy Engineering Equipment State COmpany (HEESCO).HEESCO is an important industrial company in Iraq .Originally it was established in 1963, it has a long experience in steel fabrication. Delay in achieving job orders within due dates was the main problem in this company.

Scheduling Using hybrid proposed model

The application of the proposed model can be explained through seven cases (C1-C7). The steps of this implementation are as followed:

Case1:C1. Scheduling is performed for 10 different job orders applying the suggested dispatching rules on 30 workstations mentioned in table (4), as the first step determine no. of WS required. Then categories of classification according to resource level are also mentioned in the same table. Evaluating by 4 performance measurements, we get the results mentioned in table (5). Comparing NT, it is noticed that EDD, SLACK and PRI.INDEX have the same NT=3.Then by comparing MT, it is noticed that minimum MT is according to SLACK DR. So, SWITCH to SLACK DR and schedule.

Case2: C2 Improving solution after studying the job schedule, it was noticed that WS17 is a bottleneck, which need to add overtime shifts. Adding overtime shifts is according to resource level, for ws17 is of category *one* as mentioned in table (4), the suggested working overtime is three shifts to ws17, in order to eliminate bottlenecks then rescheduling is performed. By applying the same dispatching rules and comparing the results of performance measurements mentioned in the table (5), SWITCH to PRIORITY INDEX dispatching rule and schedule

Case3: C3 Improving solution by studying the job schedule, it was noticed that still job 2 has along waiting for ws7, this ws is of category *two*. According to the resource level the solution is by making a temporary Holon, let's name it as ws 31.After adopting the same dispatching rules and comparing of performance measurements mentioned in the table (5), SWITCH to EDD dispatching rule for it is the best to be adopted, then schedule.

Case4: C4 As a dynamic event, two new jobs enter the system. By applying rescheduling, adopting the same dispatching rules, we get performance measurements mentioned in the table (5). After comparing performance measurements mentioned in the table (5), SWITCH to EDD DR. for it is the best to be adopted and schedule.

Case5: C5 As another dynamic event, job4 is canceled, so rescheduling is performed. After adopting the same dispatching rules and comparing the performance measurements mentioned in table (5), SWITCH to EDD DR. and schedule

Case6: C6 Another dynamic event is by reducing due-date of Job1 from 720 to 630, so rescheduling is performed. After adopting the same dispatching rules and comparing the performance measurements mentioned in table (5), SWITCH to PRIORITY INDEX DR. and schedule.

Case7: C7 In order to improve the solution another group for preparing was adopted; let it be ws32, so rescheduling is performed. After adopting the same dispatching rules and comparing the performance measurements mentioned in table (5), SWITCH to EDD and schedule.

Calculating of Complexity Measure on Job Level

According to the proposed model for rescheduling policy depending job level algorithm, calculation of complexity measure was performed, adopting 12 different job orders. These job orders are mentioned with theirs' defined factors in table (6).
For the case of the selected implementation environment in HEESCO, the variables mentioned in 4-3 and table (3) is defined as follows:

A1-A10: range number is given to each variable, A classification is as follows:
A1=35, A2=31, A3=30, A4=25, A5=24, A6=21, A7=20, A8=18, A9=17, A10=7.
B1-B7: range number is given to each variable, B classification is as follows:
B1=1, B2=2, B3=5, B4=6, B5=10, B6=11, B7=20.
C1-C4: range number is given to each variable, C classification is as follows:
C1=0.3, C2=1, C3=3, C4=10.
D1-D7: range number is given to each variable, D classification is as follows:
D1=3, D2=4, D3=10, D4=11, D5=15, D6=16, D7=20.
E1-E7: range number is given to each variable, E classification is as follows:
E1=1, E2=2, E3=10, E4=11, E5=20, E6=21, E7=30.
CRITICAL=5, MAXIMUM=4, NEAR MAXIMUM=3, MODERATE=2, MINIMUM=1
By calculating of scores of each factor for each job order according to the algorithm mentioned and discussed above, we get the results illustrated in table (7).

CONCLUSIONS

The developed model is applied to real data from the Heavy Engineering Equipment Company, and considerable advantages are observed. Applying the proposed model lead to zero number of tardy jobs (NT) and zero mean tardiness (MT). Seven scenarios were applied successfully including dynamic events such as entering of new jobs, changing due date and job canceling. The results show improvements toward minimizing tardy jobs with all of the implemented scenarios, i.e. in 100% scenarios. According to the implementation performed in HEESCO depending real-data from the industrial environment, zero tardy jobs as an optimum scheduling situation was gained in four out of the seven applied scenarios. That means optimum solution is reached in 57% of the applied scenarios. It is obvious from the obtained results that by adopting such model, a better solution for job orders' due dates can be achieved; hence "order-to-delivery" time can be shortened. The most important impact on improving scheduling inorder to minimize NT was according to adopting resource level, NT was eliminated from 3 NT, 50.4 MT to zero NT, zero MT, and those results were gained even with disturbance according to dynamic events.

In order to avoid any unexpected disturbances that may affect completing jobs within due dates, rescheduling module is involved using the complexity measurement to check the need for applying rescheduling. Rescheduling policy is designed to calculate the period required for rechecking of each job order in order to reduce the impact of disturbance in workstations toward achieving promises mentioned in the contracts with customers. Calculation of complexity measure was successfully adopted according to the proposed method mentioned in job level algorithm. This measure for the twelve job-orders applied shows that rechecking and rescheduling required was 2 days for 1 job-order, 3 days for each of 3 job-orders, 4 days for each of 5 job-orders and 5 days for each of 3 job-orders.

Future work could be done depending on improving combination of complexity factor to be used as priority index.

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Table (1) [P10] Job-shop scheduling approaches

Category	Comments
Heuristic or dispatching rules	• Most common approach in industry • It determines the ranking of the order in which jobs waiting at machine queues are to be processed when the machines become available. • Modified or combined to make use of other available information from the job-shopfloor.
Schedule permutation	• A feasible schedule is first generated • This initial schedule is systematically permutated and after a period of time, the best schedule found to date is returned. • Examples include genetic algorithms, simulated annealing and taboo search.
AI Approaches	such techniques that have found increased use in job-shop scheduling are: • Search • Neural Networks • Fuzzy logic
Analytical/ semianalytical Methods	• Formulate job-shop scheduling problem in terms of mathematical models using differential or difference equations • These models are highly coupled and nonlinear • Assumptions are required to make the equations more tractable

Table (2)Workstations categorization

	Workstation	category
1	Work station depends on Machine and group of workers	*one*
2	Work station depends on group of workers	*two*

Table (3)Complexity Measurements

	ores				
Factor	**Critical**	**Max**	**Near Max**	**Moderate**	**in**
QR	**>B7**	**B6-B7**	**B4-B5**	**B2-B3**	**B1**
DRQ	**THERMAL & MECHANICAL Design Req. (RMD,RTD)**	**MECHANICAL DESIGN Req. (RMD)**	**-**	**DESIGN Avai. WITHOUT BLUEPRINT (AD,NB)**	**DESIGN Avai. +BLUEPRINTS (AD,AB)**
MA	**INTERNATIONAL MARKET**	**LOCAL MARKET**	**-**	**FROM CUSTOMER**	**IN STORES**
AL	**> 1 WORKSHOP & SITE**	**> 1 WORKSHOP**	**-**	**1 WORKSHOP**	**1 0PERATION**
PW	**>C4**	**C3-C4**	**C2-C3**	**C1-C2**	**<=C1**
NWS	**>D7**	**D6-D7**	**D4-D5**	**D2-D3)**	**<=D1**
PP	**>E7**	**E6-E7**	**E4-E5**	**E2-E3**	**E1**
RPP	**CHECK PPP & APP ACCORDING TO SCHEDULE WHENEVER APP<PPP THEN RESCHEDULE**				

Table (4)Workstation and its categories

Operation code	Name of the manufacturing operation (work station)	Work station Category	Operation code	Name of the manufacturing operation (work station)	Work station category
1	Material releasing and handling from stores	Two	16	Cutting of shell	two
2	Sand blasting	Two	17	Drilling of tube sheets	one
3	Preparing	Two	18	Turning	one
4	Quality inspection	Two	19	Tubes inserting	two
5	Rolling	One	20	Tubes expanding	one
6	Rerolling	one	21	Hydrostatic test	two
7	Assembling	two	22	Painting	two
8	Pointing of nozzles holes	two	23	Building of heating bricks	two
9	Cutting of dish-heads	two	24	Coating	two
10	Manual grinding	two	25	Heat-treatment	one
11	Manual welding	two	26	Wiring	two
12	Pressing of dish-heads	one	27	Operating test	two
13	Final inspection	two	28	Handling	one
14	Pulling of damaged tubes and cleaning of their holes	two	29	Automatic welding	one
15	Pulling of damaged bundle from the heat-exchanger shell	two	30	Shearing of the heat-exchanger	one

Table (5) Dispatching Rules and Performance Measurements According To implementation of Proposed Model

	Dispatching Rules and Performance Measurements															
Dynamic cases	EDD				SLACK				S/ROP				PRI. INDEX			
	Cmax	MT	NT	WSU	Cmax	MT	NT	WSU	Cmax	MT	NT	WSU	Cmax	MT	NT	WSU
C1	1034	50.9	3	0.1137	1044	50.4	3	0.1126	1005	59.5	4	0.1169	1034	50.9	3	0.1137
C2	858	26.2	2	0.1213	777	30.4	2	0.1244	837	52.7	3	0.1244	858	26	2	0.1213
C3	812	0	0	0.1241	739	8.5	1	0.1363	804	19	2	0.1253	858	26.2	2	0.1213
C4	885	3.6	1	0.1310	833	0.4	1	0.1392	924	59	3	0.1255	931	57	2	0.1246
C5	855	0	0	0.1224	856	9	1	0.1223	849	50	3	0.1233	855	0	0	0.1224
C6	874	5	1	0.1198	856	12	2	0.1223	849	61	4	0.1233	855	0	0	0.1224
C7	850	0	0	0.1193	839	9	2	0.1209	849	59	3	0.1194	880	51	2	0.1152

Table (6) Defining of 12 Job orders according to the named factors

Job no.	job name	QR.	DRQ.	MA	AL	PW(T)	NWS	PP
1	fabrication of horizontal LPG tank	2	AD,NB	company/IM	1ws	19	13	28
2	retubing of heat-exchanger EA-1503	1	AD,AB	customer	1ws	15	17	500
3	fabrication of 10 Ton steam boiler	1	AD,NB	company/S	1ws	11	11	19
4	fabrication of 55 m3 storage tanks	1	AD,AB	company/LM	>1ws	6.2	7	15
5	Fabrication of shells	6	AD,NB	customer	>1ws	3	8	6
6	fabrication of storage tanks	3	AD,AB	company/S	1ws	18.5	9	12
7	fabrication of Desalter H-A-V104	1	AD,NB	company/IM	1ws	32	13	55
8	Fabrication of E-213	1	AD,AB	customer	1op	3	15	185
9	fabrication of degassers	2	AD,NB	company/IM	1ws	9.5	13	26
10	fabrication of dish-heads	4	AD,NB	company/S	1ws	1.6	10	4
11	fabrication of 5.5Ton steam boiler	2	RMD,RTD	company/S	>ws&s	6	9	18
12	fabrication of 55 m3 storage tanks	3	AD,NB	customer	1ws	18	7	22

Table (7) Scores of complexity measure and rescheduling point for proposed factors

JOB NO.	QR SCORES	DRQ SCORES	MA SCORES	AL SCORES	PW SCORES	WS SCORES	PP SCORES	Sum	Point of rescheduling
1	2	2	5	2	5	3	4	23	Every 3 days
2	1	1	2	2	5	4	5	20	Every 4 days
3	1	2	1	2	5	3	3	17	Every 5 days
4	1	1	4	2	4	2	3	17	Every 5 days
5	3	2	2	4	3	2	2	18	Every 4 days
6	2	1	1	4	5	2	3	18	Every 4 days
7	1	2	5	4	5	3	5	25	Every2 days
8	1	1	2	2	3	4	5	18	Every 4 days
9	2	2	5	2	4	3	4	22	Every 3 days
10	2	2	1	5	2	2	3	17	Every 5days
11	2	5	1	4	4	2	3	21	Every 3 days
12	2	2	2	2	5	2	4	19	Every 4 days

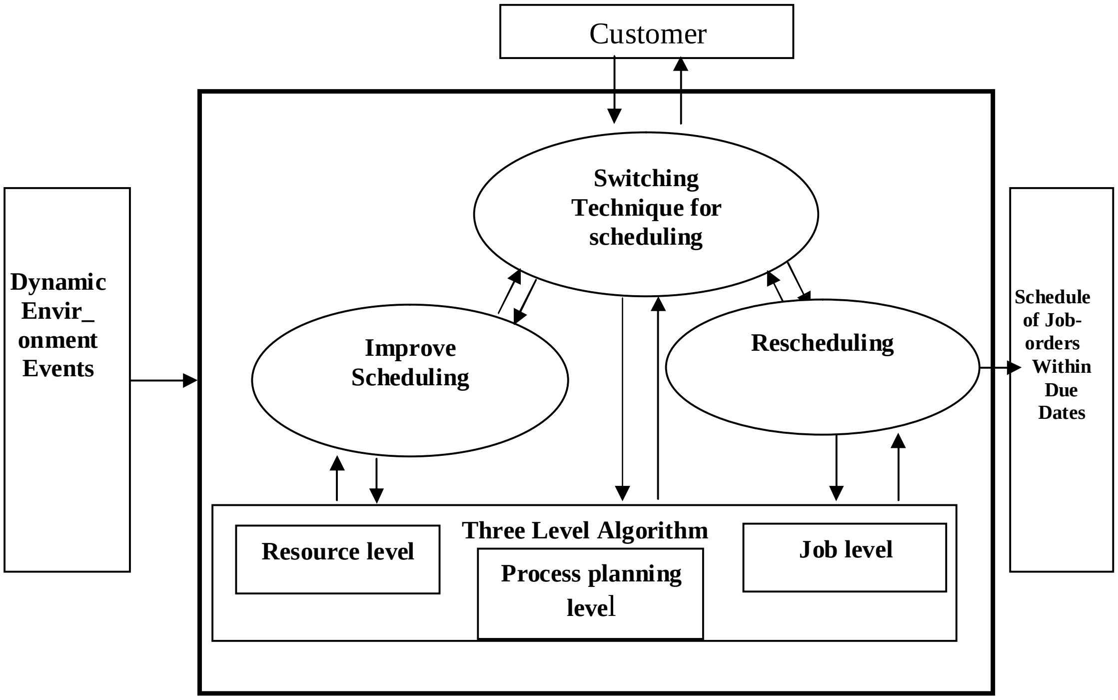
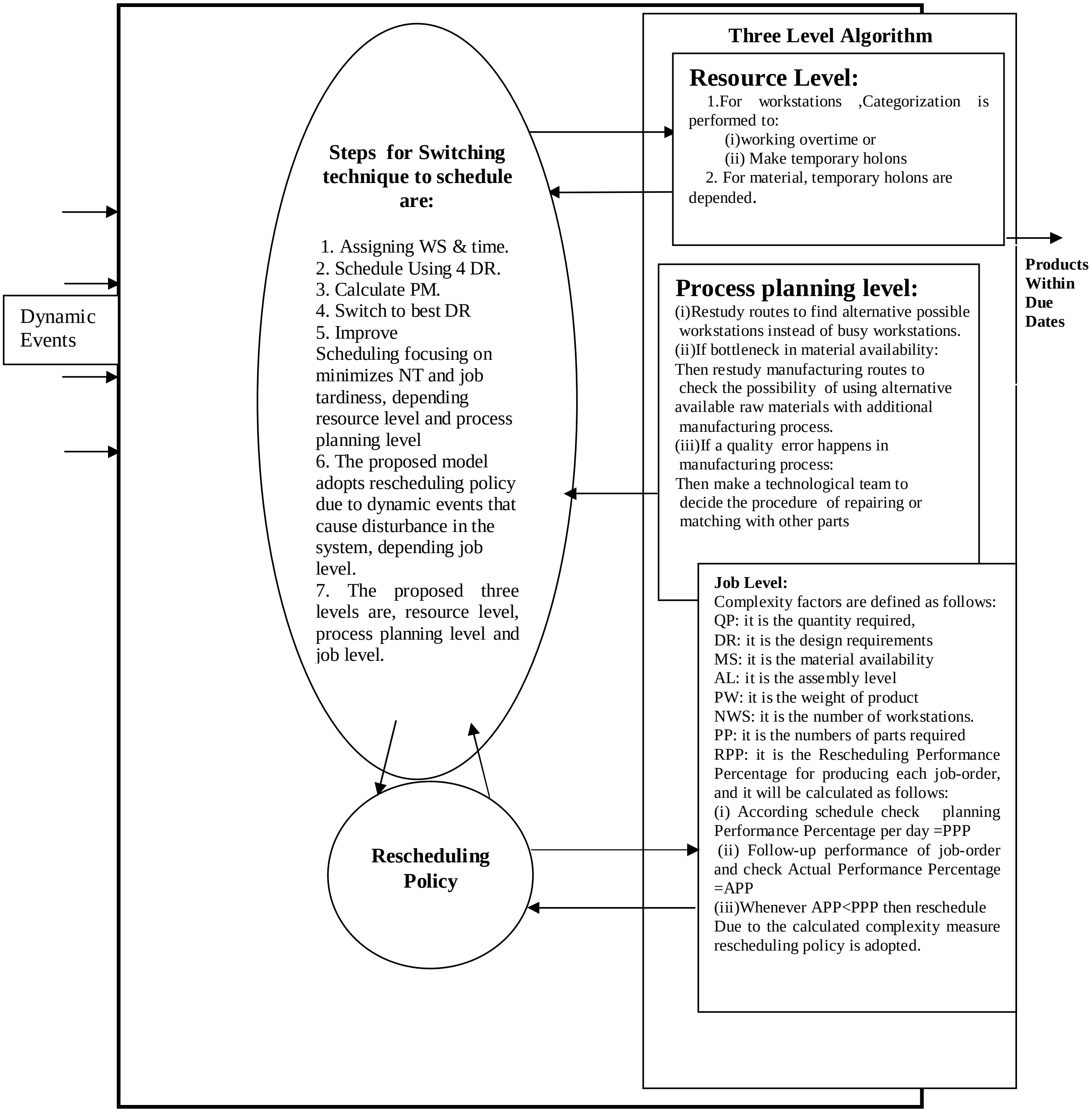


Figure (1)The outlines relations of hybrid techniques.



Steps for Switching technique to schedule are:

1. Assigning WS & time.
2. Schedule Using 4 DR.
3. Calculate PM.
4. Switch to best DR
5. Improve Scheduling focusing on minimizes NT and job tardiness, depending resource level and process planning level
6. The proposed model adopts rescheduling policy due to dynamic events that cause disturbance in the system, depending job level.
7. The proposed three levels are, resource level, process planning level and job level.

Three Level Algorithm

Resource Level:

1.For workstations ,Categorization is performed to:
(i)working overtime or
(ii) Make temporary holons
2. For material, temporary holons are depended.

Process planning level:

(i)Restudy routes to find alternative possible workstations instead of busy workstations.
(ii)If bottleneck in material availability:
Then restudy manufacturing routes to check the possibility of using alternative available raw materials with additional manufacturing process.
(iii)If a quality error happens in manufacturing process:
Then make a technological team to decide the procedure of repairing or matching with other parts

Job Level:

Complexity factors are defined as follows:
QP: it is the quantity required,
DR: it is the design requirements
MS: it is the material availability
AL: it is the assembly level
PW: it is the weight of product
NWS: it is the number of workstations.
PP: it is the numbers of parts required
RPP: it is the Rescheduling Performance Percentage for producing each job-order, and it will be calculated as follows:
(i) According schedule check planning Performance Percentage per day =PPP
(ii) Follow-up performance of job-order and check Actual Performance Percentage =APP
(iii)Whenever APP<PPP then reschedule
Due to the calculated complexity measure rescheduling policy is adopted.

Figure (2) Outlines of Proposed Model