CRITICAL MACHINE BASED SCHEDULING -A REVIEW

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Abstract. This article aims to identify the natural occurrence of the critical machines in scheduling. The exciting scheduling in the real time manufacturing environment is focused on considering equal weight-age of all the machines, but very few researchers were considered the real time constraint(s) like processor/ machine/ workstation availability, etc.,. This article explores the gap between the theory and practices by identifying the critical machine in scheduling and helps the researcher to find the suitable problem in their case study environment. Through the literature survey, it is evident that, in scheduling the occurrence of the critical machine is in nature. The critical machine is found in various names and gives a various range of weight-age based on the particular manufacturing environment and it plays a vital role in scheduling which includes one or more circumstances of occurrence in the production environment. Very few researchers were reported that in manufacturing environment, the critical machine occurrence is in nature, but most of the researchers were focused to optimize the manufacturing environment by only reducing the cycle time. In real-time manufacturing environment, the scheduling of critical machine(s) was keenly monitored and some weight-age was considered.

1. **Introduction**

Nowadays the customer delight is an important criterion in the business environments. The customization products arise diversity of products. Such a global vigorous industrialized scenario intends the manufactures to produce a diversity of products within shortest makespan. On the other hand, utilization of resources, availability of space, fund, and time bound requirements, etc. demands the real time executable manufacturing plan. The Sequencing and Scheduling play imperative role in manufacturing planning in the industries. To avoid the loss of revenues or heavy penalty, etc., for not meeting the deadline.

Today the customer's priority for providing business is based on the earliest delivery. Manufacture a product is not a simple thing it involves many tasks like systematize, prefer, and timing resource to bring out all necessary activities to it in volume (desired output) at the desired time (on or before the due date), while satisfying a large number of times related constraints among the involved activities

and the resources [1,2]. Scheduling problems criteria can be broadly classified as throughput related and cost related [2,3]. The Scheduling problem generally defined by the job which require a number of operations, Number of Jobs to be processed, the nature of machines and its configuration in the environment, single or multiprocessors, if the parallel machines available means which are identical/similar/Unrelated, number of stages, etc. job assignment priorities/ disciplines and the objective or criteria of scheduling [4,5]. Graham et al., and Allahverdi et al., furnished some convenient notations to refer the scheduling models with different conditions [6,7]. In general flowshop problems are using the following notation for denoting the standard fields $\alpha / \beta / \gamma$. The first field α describes the scheduling type; the second field β is reserved for the information and conditions of scheduling, while the third field γ contains the performance criteria.

2. Scheduling environments

The scheduling environment natures are day-by-day incarnation as a form of a new version. The chronological order according to the literature is: Single machine scheduling, Parallel machine scheduling, flow shop and job shop scheduling, hybrid flowshop scheduling, Parallel flowshop schedules and parallel hybrid flowshop scheduling. The insertion of new facilities based on the job's operation requirements in the order is the reason behind the evolution of flowshops. The inclusion of standby machine or rental machine or additional machine to line balancing, etc., are the reason of flexible flow shops (Hybrid of Jobshop and Flowshop). The various scheduling environments and their description furnished in Table 1.

3. Scheduling challenges

The Challenges in scheduling for the manufacturing environment still exist. Even though the single machine scheduling is live in the research. Yoav Ben-Yehoshua and Gur Mosheiov [8] dealt single machine scheduling problem and they proved that the problem is NP – Hard. They introduce a pseudo-polynomial dynamic programming algorithm, for verifying NP-hardness of the problem in the ordinary sense. In the parallel machine environment, the parallel jobs scheduling is a new kind of environment applicable to software industries. Recently Yongsheng Hao et al., [9] proposed an adaptive algorithm used in scheduling the modular non-linear parallel jobs in meteorological Cloud. The adaptive algorithm has a distinctive parallelism that only can be configured at the very beginning of the execution.

Table1. Scheduling Environments

Scheduling Environments	Description	Reference
Single machine	Assigning a set of tasks to a single resource or machine	8
Parallel jobs on parallel machines.	Some jobs can only be processed on several processors in parallel.	9
Identical Parallel Machines	The processing time of a task is independent of the machine where it is processed	10
Uniform Parallel Machines	Each machine has a different processing speed.	11
Unrelated Parallel Machines	There is no particular relationship between the processing times in the different machines, i.e., there is no proportionality between the processing time of a task on a given machine and the time of the same task on another machine.	12
Permutation Flow shop	Jobs are processed by a series of 'm' machines in exactly the same order	13
Non-Permutation Flow shop	Jobs are processed by a series of 'm' machines not in the same order	14

Job shop	Multiple entries and exits.	15
Hybrid Flow shop with uniform parallel machines	The processing time of a job on a particular machine is the ratio of the processing time of the job on a machine with a standard speed to the speed of the particular machine	16
Hybrid Flow shop with unrelated parallel machines	Different parallel machines at every stage, and speeds of the machines are dependent on the jobs	17
Hybrid Flow shop with identical parallel machines	Parallel machines at a stage are identical in their processing speeds	18
Parallel Flowshop	Parallel-machine Flowshop	19
Parallel Hybrid Flow shop	Hybrid flowshops are connected parallel at the critical machine for the common operation/ process.	20
Open shop	There are 'm' machines and there is no restriction in the routing of each job through the machines. In other words, there is no specified flow pattern for any job.	21
Closed shop	It is a job shop; however, all production orders are generated as a result of inventory replenishment decisions. In other words, the production is not affected by the customer order.	22
Static Type Shops	Jobs available at shop at zero time of execution.	23
Dynamic Type shops	The decision of scheduling a job can only be made online or job arrives over time to the shop.	24

The identical, uniform and unrelated (Non-uniform) parallel machines scheduling also recently solved with the new kinds and combination of constraints [10-12]. The flowshops with permutation [13] and non-permutation [14] were solved with the objective of Minimization of total flow time. The flexibility of job shop leads to multiple entries at a time can be used for High variety low volume production strategies [15]. The hybridization of flow shop and job shop/ Parallel Machines natures to enhance the flexibility of mass production environment incarnates flexible flow shop or Hybrid flow shop. The parallel machines nature like identical [16], uniform [17] and unrelated [18] parallel machines natures are the additional constraints in the flexible flow shop problem.

The evolution of flexible flow shop is the machine insertion with critical machine. The day by day the manufacturing environment scheduling is getting more complex by bulk additional constraints or tremendous changes in existing configurations. The parallel flow shops scheduling (flowshops with parallel machines) and parallel Hybrid flowshops are example for them [19, 20]. The open shop and closed shop nature, dynamic job/ machine [21-23] (stochastic) availability and are static (deterministic) also the notable scheduling environments [24]. The most of the problems in the literature solved with the ultimate criteria of throughput and cost measures and assumed that machines/ facilities are available continuously, set up times neglected, etc. critical machine based scheduling is a new aspect to provide an executable schedule to the environment.

4. Research contribution

There is a huge contribution of research in scheduling. The large volumes of literature were referred and estimated the promotional contribution in environment wise. The specific contribution of the environment is shown in the Figure 1, the criteria wise contribution in Figure 2 and the deterministic and stochastic scheduling contribution in Figure 3. However, in each case of scheduling, there was one or more critical machine(s) and they are not explored transparently in most of the literature.

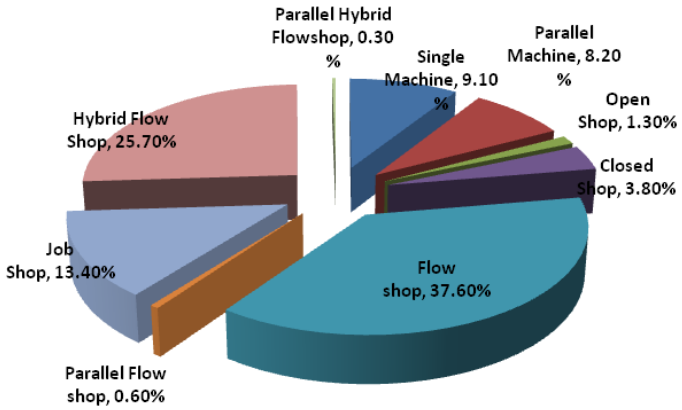

Figure 1. Scheduling Environment wise Research Contribution

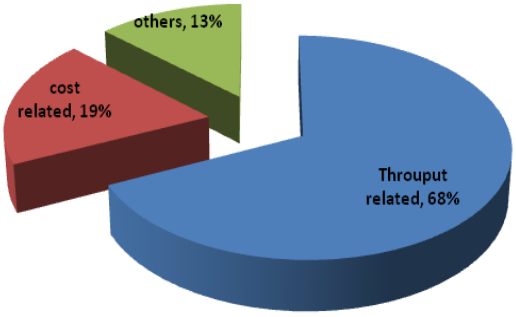

Figure 2. Scheduling Criteria wise Research Contribution

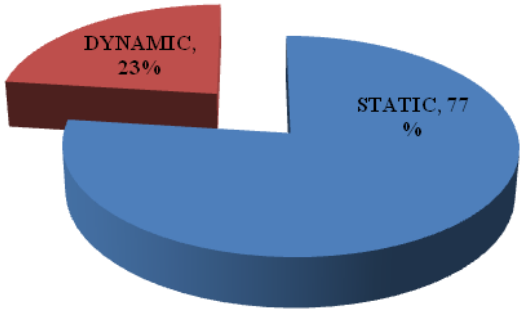

Figure 3. Job/Machine Nature wise Research Contribution in Scheduling

5. Critical machines based scheduling

The critical machine is one, which is most crucial or vital machine in a shop floor, which agrees with the objective and effectiveness of the scheduling environment. It arises in the source for many scheduling environments based on the manufacturing method employed, raw material availability, to avoid penalty for tardiness, require to meet the due date, optimize the cost, and so on. Some example cases are provided in the Table 2. The critical machines based scheduling is has arises a special interest, in recent era. The automatic machine scheduling in one of the examples of critical machine based scheduling. Jiabin Luo et al., [25] investigated the integration of the two problems focusing on the unloading process in an automated container terminal, where all or part of the equipment are built in automation and proposed a genetic algorithm to solve the small and large sized problems. Blender and feeder are very important devices in a polymer processing plant. The accuracy in delivering the polymer to the plastification unit is a fundamental property for the quality of the final product. Nonlinear gain scheduling controller was proposed to maximize accuracy and precision gravimetric feeder are the best available solution, which measure the weight of the hopper and the feeder [26].

The Blender and feeder are very important devices in a polymer processing plant. The accuracy in delivering the polymer to the plasticisation unit is a fundamental property for the quality of the final product. Hence Belloli et al., [27] used a nonlinear gain scheduling controller to maximize accuracy and precision gravimetric feeders are the best available solution, which measure the weight of the hopper and the feeder. Jing-hua Hao et al., [28] dealt a hybrid approach for solving the bottleneck stage scheduling problem (BSP) using the surrogate modelling technique. Sascha Herrmann and Christoph Schwindt [29] considered the continuous process case of the short-term production planning of multi-product continuous plants in the process industries. Due to constraints on material availability

and storage capacity for intermediate products, classical schedule-generation schemes cannot be applied to the scheduling problem and they proposed a new two-phase approach dealing with the two types of constraints separately.

In many continuous process industries, machine breakdowns may affect the planned activities, especially when maintaining high shop performance is desired. Liao and Chen [30] considered a practical problem encountered in a textile company where the machine breakdown occurs frequently and provided a longer setup time (or equivalently, a longer idle time) to reduce the breakdown rate. They used branch-and-bound algorithm for the scheduling. The neglect of buffering requirements in a classical job shop scheduling system often results in inapplicability in many complex real-world applications. So the Shi Qiang Liu and Erhan Kozan [31] made an attempt to overcome this inapplicability, a new and more generalised scheduling problem is proposed under different stage-dependent buffering requirements and parallel use of identical-function machine units at each processing stage in job shop environments. The authors proposed DBPMJSS methodology has a potential to analyse, model and solve many industrial systems with the requirements of buffering conditions, particularly in manufacturing, railway, healthcare and mining industries.

A heuristic approach was used by Enrique Gerstl and Gur Mosheiov [32] to solve at two-stage flowshop, where each job processes in the first (critical) machine, and then continues to one of two second-stage (dedicated) machines. The measure of the performance is to minimize the makespan, total load, and weighted flow-time. Omar Souissi et al., [33] investigated on the single machine scheduling problem taking into account preventive maintenance failures and proposed a hybrid approach by combining mixed integer program and longest processing time first) heuristic in order to solve that problem. The authors used simulation approaches to deal with the stochastic failures.

Table-2. Some samples of occurrence of Critical Machine

S. No.	Critical Machine	Sample Environment	Reference
1	Automated machine	Decentralized scheduling with heterogeneous machines and competing job sets.	25
2	Blender Machine	Gain Scheduling Control of a Gravimetric Blender with Vibrant Duct	26
3	Bottleneck machine	Scheduling bottleneck stages	27
4	Continuous processing machine	Machine breakdown in a continuous process industry	28
5	Breakdown nature machine	Scheduling under machine breakdown	29
6	Buffer or delay required machine	Stage-dependent buffering requirements	30
7	Dominant machine	Deteriorating jobs on no-idle dominant machines	31
8	First stage machine	Scheduling with a critical machine	32
9	High maintenance required machine	Scheduling with preventive maintenance	33
10	Critical machine	Scheduling critical / rental machine with optimal makespan	34

Vivek et al., [34] analyzing the critical machine based permutation flow environment through the heuristic optimal makespan obtained. Pugazhenthi R and Xavior M A [35 and 36] deals the

rental/critical machine in a flowshop; in this a new heuristic was proposed to minimise the idle time of the machine. The effect of grouping technique was studied in a real time multi stage hybrid flowshop environment; the critical machine was considered and an optimum makespan obtained. Pugazhenthi and Anthony Xavior were highlighted the critical machines in various names i.e., High bound machines, Maximum lateness machine, Minimum weighted machine, Slowest processing machines, Parallel machine, Rental machine, Machines in critical path, Identical machine, Maximum work load machine, Semi-automated machine, High maintenance required machine, Minimum tardiness machine, Pivoted machine, High cost machine, Maximum processing machine, Identical parallel machine, Repeatedly shifting machine, Short run machine, Special machine, High operating cost machine, etc., [21].

6. Finding for further research

The present industrial scenario is to produce High Variety at Low Volume with Highest Quality at lowest prices to sustain in the world class market. Hence scheduling plays key role in those industries and includes one or more circumstances of occurrence of the critical machines in the manufacturing environment. For example, it is not economical to procure high cost machines for low volume of production, so the machine may hire on rental basis.

- The cost based criteria paid less attention in the literature and the cost based criteria may fulfil by changing the orientation of scheduling in a critical machine based scheduling.
- The dynamic scheduling, paid less attention by the researcher, the computerization made many things on online and availability of machine may not be dedicated for a single purpose. The stochastic scheduling environment may obvious in forthcoming days. So need more attention in stochastic scheduling (dynamic scheduling).
- Many cases, the occurrence of critical machine(s) are evidenced even though in the scheduling environment, they were not utilized well for meeting the objectives. The new aspect of scheduling may save cost and time effectively.

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