

# Effect of Operational Parameters in a Converging Conveyor System for an Assembly Operation (Simulation Approach)

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**ABSTRACT:** The rapid development in the computer technology and its applications in the production system, the production system has become flexible in producing variety of jobs. Even the flexible production system may take time in setting up the machine to the change in the arrived job. It is often desirable to change the sequence of jobs to save setup cost and time. Conveyor system is the commonly used advanced material handling system that moves jobs from one station to another stations. The conveyor systems used may be of converging or diverging or combination of converging and diverging depending on the type of applications. The most of the assembly operations require converging type of conveyors. The performance of the conveyor system depends on the elements of the conveyor system and its operational parameters. This paper addresses the effect dynamic job sequencing in a converging conveyor system with the objective to reduce the setup cost and its associated time. Discrete event simulation software has been used to model, simulate and investigate the effect of operational parameters associated with converging conveyor system. Three different models have been considered for studying the effect of different elements in the converging conveyor system along with dynamic job sequencing based on sequencing heuristics.

**KEYWORDS:** Converging Conveyors, Sorters, Dynamic Sequencing, Discrete Event Simulation, makespan, production time saving.

## I. INTRODUCTION

Information technology and computerized automation have significantly improved flexibility in recent manufacturing. Today, most high-volume manufacturing systems may appear to be old shaped transfer lines but in fact they have become highly flexible, producing a large family of products such as electronics, automobiles, and other consumer goods. Purpose of striving for flexibility is to reduce the setup cost or time-to-respond to the growing diversity of customer demands. However, even the most flexible systems may still invite some setup cost in job changes. It is often advantageous to change the job sequence to further decrease the setup cost and time.

The research on scheduling in the vehicle industry has mainly been focused on the car sequencing problem, which was first described by Parrello et al [1]. Enumerative approaches, such as the branch-and-bound algorithm of Carlier and Pinson [2], can only conquer small-scale problem instances. The most common heuristic methods devised in the early days include dispatching rules (Sculli, Green and Appel, Kanet and Hayya, Baker) [3], [4], [5], [6] and shifting bottleneck (Adams et al, Holtsclaw and Uzsoy, Balas and Vazacopoulos, Liu and Koza) [7], [8], [9], [10].

Bianco, Dellolmo, Giordani, and Speranza [11] have minimized the makespan in a multimode multiprocessor shop scheduling problem. Each task can be undertaken by any methods in a set of predefined alternative modes, where each mode specifies a required set of assigned processors and a processing time. At any point of time, each processor can be used at most by only a single task.

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Akpan [12] has introduced a network technique that is a very useful tool for analysis of job shop sequencing problems. This technique offers a basis for finding an optimum solution. In this technique, the jobs priority on machines is determined by FCFS (First Come, First Serve) rule. Guinet [13] has proposed a procedure for solving job shop scheduling problems. In this procedure, the objective is to minimize the maximum completion time of jobs. Lee, Piramuthu, and Tsai [14] have proposed to combine capabilities of genetic algorithms and machine learning techniques in order to develop a job shop scheduling system. Blazewicz, Domschke, and Pesch [15] have presented an overview of solution techniques for solving job shop problems. After a brief roundup of all the trends and techniques, they concentrated on branching strategies and approximation algorithms belonging to a class of opportunistic and local search scheduling.

Sabuncuoglu and Bayiz [16] have studied reactive scheduling problems in a stochastic manufacturing environment. An active schedule has the property that no operation can be started earlier without delaying another job. Specifically they have tested several scheduling policies under machine breakdowns in a classical job shop system. In their researches, the performance of the system is measured for the mean tardiness and makespan criteria.

Yu and Liang [17] have presented a hybrid approach combining neural networks and genetic algorithms to solve the expanded job shop scheduling problem. Satake, Morikawa, Takahashi, and Nakamura [18] have proposed a simulated annealing method based on the rescheduling activity of the human scheduler in order to void local search solution for solving job shop scheduling.

Shiqing Yao, Zhibin Jiang, NaLi [20] have presented A branch and bound algorithm for minimizing total completion time on a single batch machine with incompatible job families and dynamic arrival. A flexible dispatching rule for minimizing tardiness in job shop scheduling were presented by Binchao Chen, Timothy I. Matis [21]. Rui Zhang, Pei-Chann Chang, ChengWuc [22] presented A hybrid genetic algorithm for the job shop scheduling problem with practical considerations for manufacturing costs. Xinchang Haoa, Lin Linb, Mitsuo Genc, Katsuhisa Ohnoe [23] presented Effective Estimation of Distribution Algorithm for Stochastic Job Shop Scheduling Problem.

Andrea Rossi [24] studied Flexible job shop scheduling with sequence-dependent setup and transportation times by ant colony with reinforced pheromone relationships. K. Li, J.Y.-T. Leunga, B. Y. Cheng [25] presented an agent-based intelligent algorithm for uniform machine scheduling to minimize total completion time. Wenchang Luo, Min Jib [26] presented Scheduling a variable maintenance and linear deteriorating jobs on a single machine with a goal to minimise the makespan and total completion time.

## II. RELATED WORK

Similar type of work is done on diverging conveyor [27] in which ten batches of jobs are processed in a production line. The jobs arrive from the source belonging to different batches randomly; the arrival time of jobs is modelled as the poisson distribution. There are five processing stations through which jobs must undergo processing operations each batches of jobs have different route to the processing stations and different setup time for each job. The setup and processing time is assumed based on erlang distribution. Three types of layout were modelled to show the saving of setup cost and time. The first layout was a semi-automated layout in which the jobs were transferred manually from the conveyor to the processing stations. The second layout was also a semi-automated layout in which the job were first sent to the buffer (Sorter) and then sent to the processing station. Here the waiting time of jobs were reduced and sorted in buffer to save the setup cost for processing. The third type of layout was fully automated layout here the transfer of job from conveyor to buffer and buffer to processing station were carried by a pick and place robot. The third type of layout is shown in the Fig.1 and the time saved with the use of sorter is shown in table1.

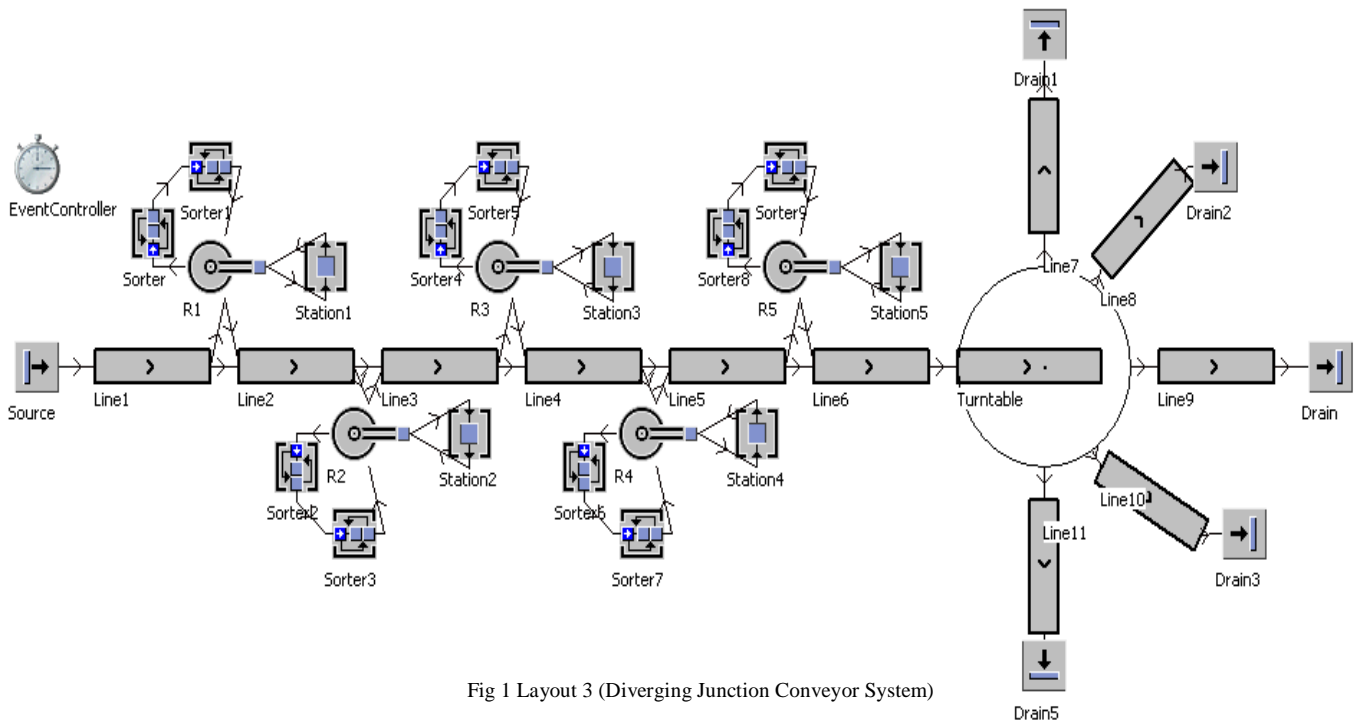


Fig 1 Layout 3 (Diverging Junction Conveyor System)

Layout Model	Total Job Completion Time
Layout1(Production Line without Buffer)	3days:04Hours:15Minutes:05second
Layout2 (Production Line with Buffer)	2days:19hours:43minutes:26seconds
Layout3 (Production Line with Buffer & Pick and Place Robot)	2days:08hours:56minutes

### III. METHODOLOGY

#### A. Problem formulation

In this paper three layout of the assembly line is modelled to study the influence of the production elements like buffer and robot. The first layout is semi-automated model without the storage element and material handling equipments. The jobs are moved over conveyor from one station to another station and the loading and unloading of the parts from conveyor to work station and from work station to conveyor is by using the robot. The second layout is also a semi-automated layout where, the buffer (Sorter) are used and jobs are transported by conveyors and before entering the station it is stored in buffer and accessed by the station based on the sorting criteria defined in exit strategy of buffer. The third layout is fully automated layout the jobs are Loaded/Unloaded to the station by the pick and place robot. The layout of the 3 production lines is shown in the Fig.2, Fig.3 & Fig.4.

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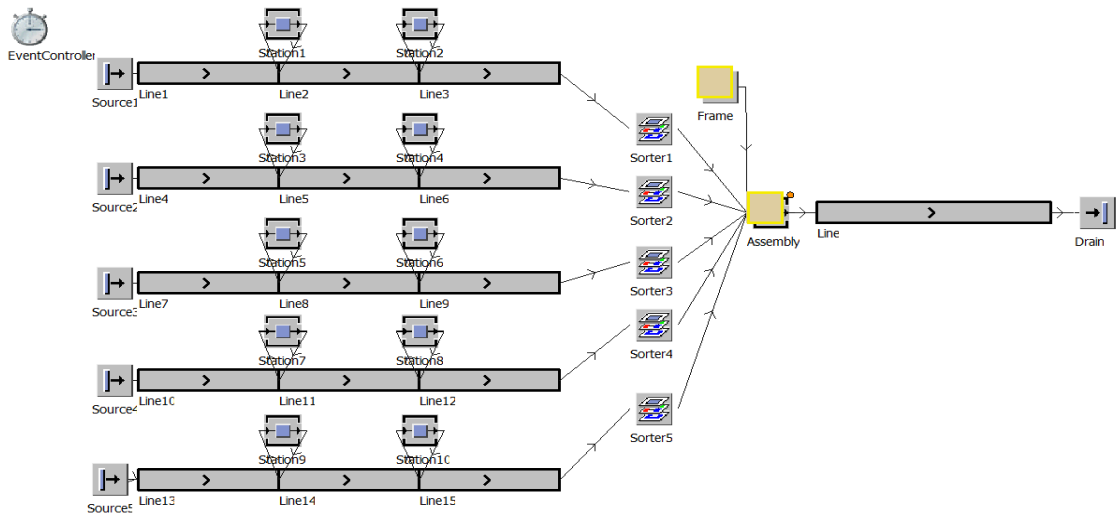


Fig. 2 Layout 1 (Converging Conveyor model without buffer)

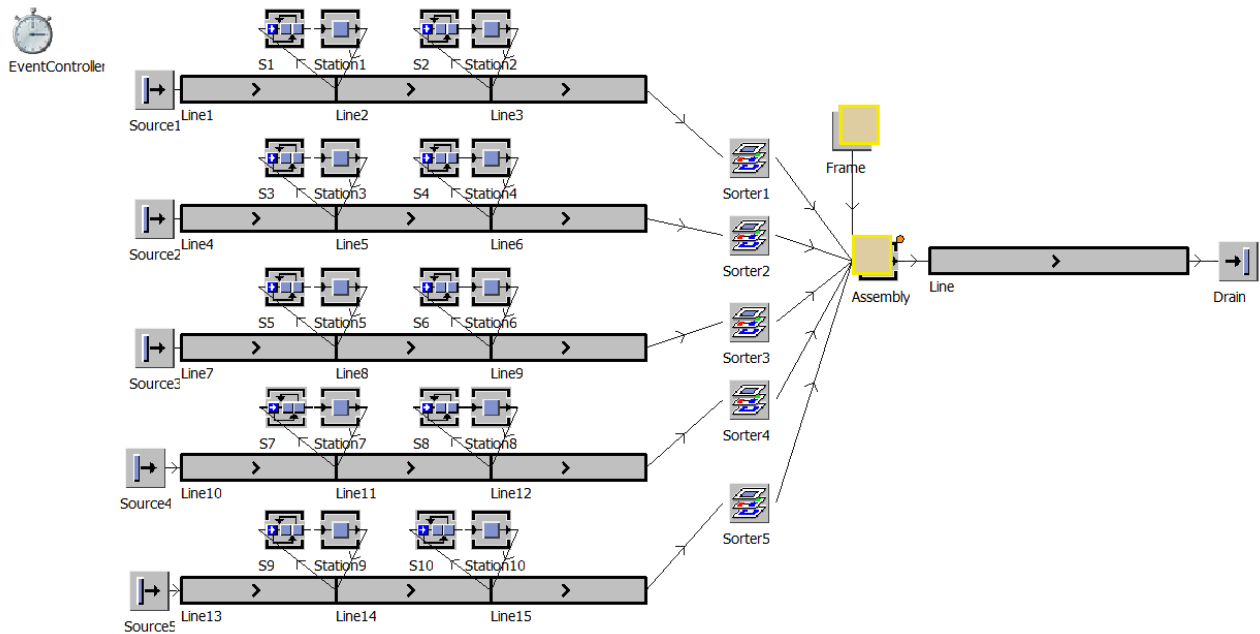


Fig. 3 Layout 2 (Converging Conveyor model with buffer)

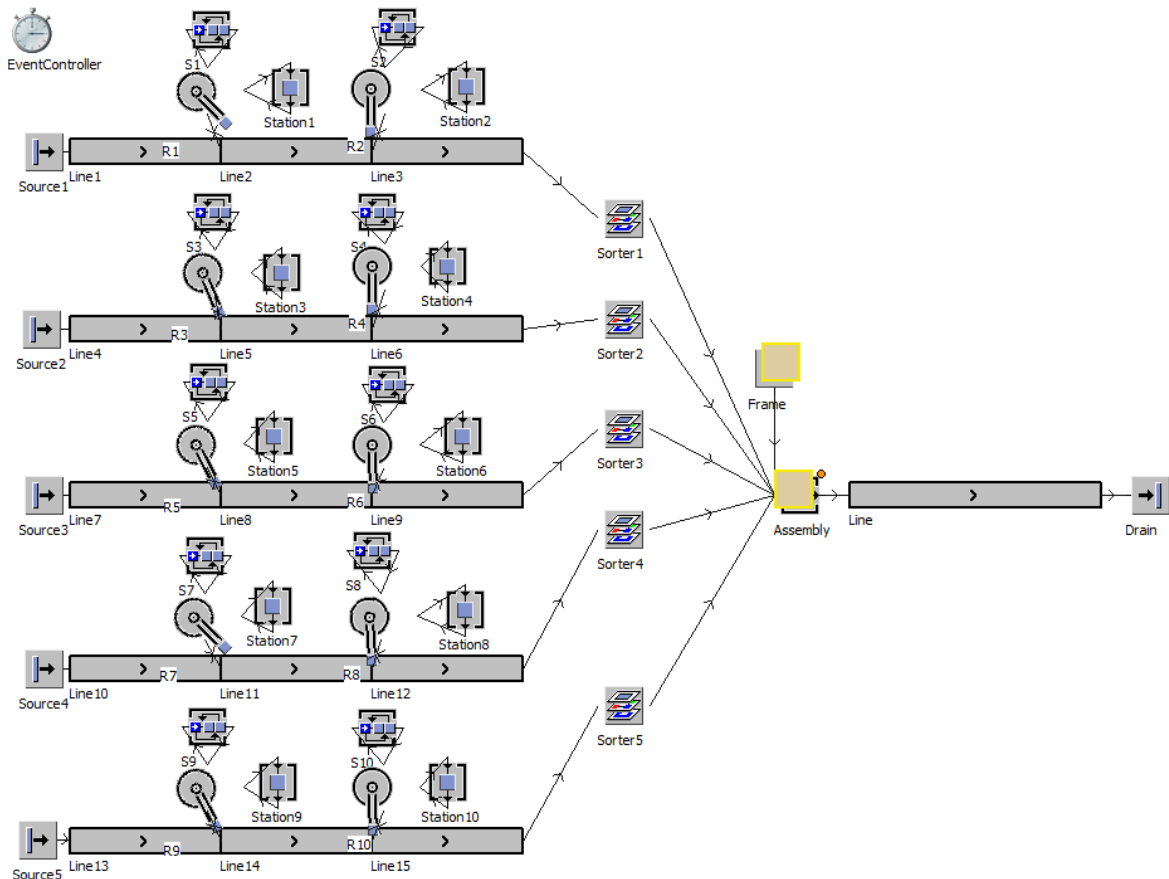


Fig. 4 Layout 3 (Converging Conveyor model with buffer and robot)

### B. Simulation model of the Converging Conveyor System

The simulation of production line is modelled using the Tecnomatix Plant Simulation software. Tecnomatix is an object oriented GUI based discrete event simulation software that supports objective decisions by dynamic analysis, to enable users to safely plan and, in the end, to reduce cost.

The objects such as source, line, single –proc robot, buffer (sorter) and drain have been used to create and simulate the model. The jobs are created in the source and the job arrival pattern is according to the Poisson’s distribution. The jobs are conveyed over the line objects and are transferred to the station using robot object. The processing time and setup time have been modelled using Erlang distribution. The jobs are dynamically sequenced in the buffer as they arrive at the buffer before it is transferred to station. The same robot object is used to unload the jobs from station to the conveyor object. All the jobs after processing will move to the converging junction and exits through the drain.

### C. Processing Time of Jobs

There are 10 types of job which are to be processed in production lines, after the completion of the processing these jobs are assembled in the assembly station and sent for dispatch. There are 5 production lines in the layout, in each production line there are 2 processing stations in which the job has to be processed. The Source1 of first production line sends Job1 & Job2, the second production line Job3 & Job4 are sent. Like this 10 types of jobs are sent for processing. After processing operation the jobs are stored in the buffer (Sorter) and sent batch by batch i.e. set of 10 jobs (job1, Job2 ...Job10) and assembled in the assembly station and finally sent for dispatch. The processing and setup time for each job in each station with randomness in time is shown in the Table2.

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### D. Dynamic job Sequencing through Buffer

The jobs are dynamically sequenced in the buffer (Sorter) based on the sequencing heuristics. The jobs with the similarity are grouped together as and when the jobs arrive the buffer. The reduction in setup time has been studied by job sequencing. The job sequencing with the buffer is shown in fig.3 and fig.4.

### E. Statistical Distribution for modelling the processing time and job arrival pattern

Manufacturing environment is highly stochastic in nature there are various probability distributions used to predict the randomness in manufacturing systems. The jobs arrive from the source randomly into the production line having different processing operations. For modelling random arrival for queuing model Poisson distribution with  $\lambda=5$ , the parameter  $\lambda$  designates the average number of events taking place in one unit of time. The distribution is given by

$$f(k) = \frac{\lambda^k}{k!} \text{EXP}(-\lambda)$$

The service time and setup time is modelled as a Erlang distribution for each processing station because the Erlang distribution is used to model the time to complete  $n$  operations in series, where each operation requires an exponential period of time to complete[19]. The distribution is given by

$$f(x) = \frac{1}{\beta} * \frac{x^{k-1}}{k-1!} * \exp\left(-\frac{x}{\beta}\right)$$

Table 2 Operation Time & Setup time for each station

Station		Operation Time (min)	Setup Time (min)
Station-1	Job1	55	27
	Job2	19	10
Station-2	Job1	20	11
	Job2	29	05
Station-3	Job3	46	20
	Job4	8	23
Station-4	Job3	33	7
	Job4	48	8
Station-5	Job5	6	6
	Job6	5	10
Station-6	Job5	55	20
	Job6	20	29
Station-7	Job7	20	11
	Job8	29	5
Station-8	Job7	46	20
	Job8	8	23
Station-9	Job9	33	7
	Job10	48	8
Station-10	Job9	6	6
	Job10	5	10

**IV. RESULTS**

**A. Total job completion time for different layouts**

The arrivals of jobs are modelled randomly for producing 19 batches of jobs. Total simulation time taken for three types of layout is shown in the Table 3.

Table 3 Total job completion time for different layouts - Simulation Results

Layout 1 (Without Sorter & Robot)	1day:18hours:12minutes:05seconds
Layout 2 (With Sorter and without Robot)	1day:13hours:50minutes:30seconds
Layout 3 (With Sorter & Robot-Fully Automated line)	1day:06hours:20minutes:11seconds

**B. Workstation Utilization and performance**

It is observed that, with the use of production elements like buffer and robot the machine can be utilized effectively and its percentage of utilization can be increased. With the increase in the utilization of machine the total job completion time is reduced. Fig 5 shows the utilization of machines for three different layouts.

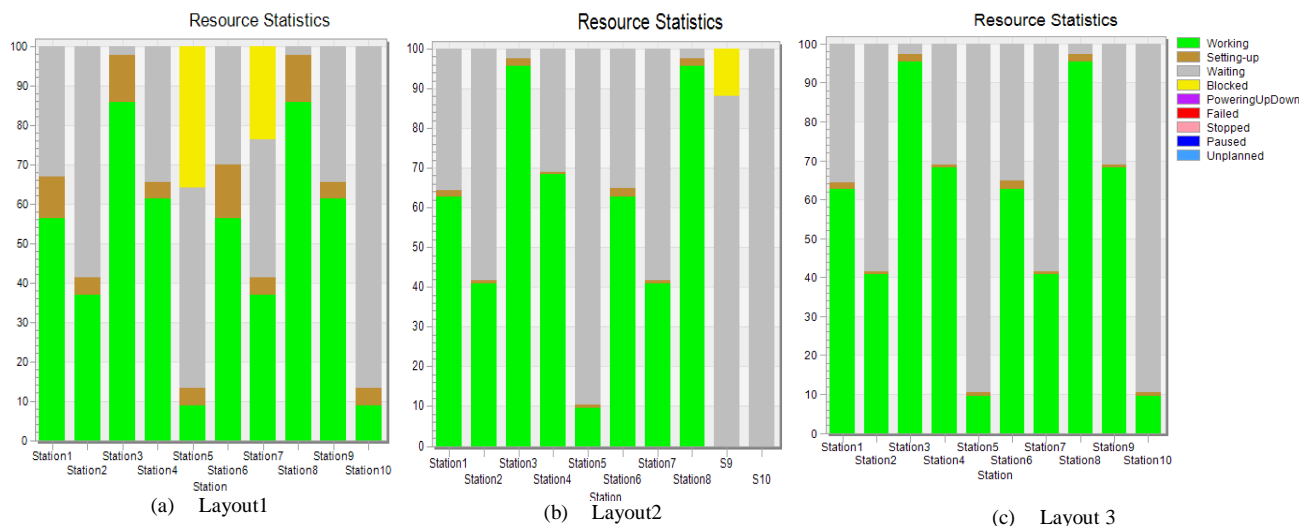


Fig. 5 Workstation Utilization and performance

**V. CONCLUSIONS**

The discrete event simulation approach allows the modelling of complex conveyor system to investigate the effect of operational parameters on the performance of the system by varying the behaviour of different elements in the system. The extreme conditions, the best sequencing heuristics, bottle neck points can be easily identified and corrective measures can be applied. This approach helps to investigate the problems associated with the system before it is implemented. It is observed that the dynamic job sequencing has considerably reduced the total job completion time along with the setup time and cost. The drawback of this kind of approach is very expensive for small companies. The combination of converging and diverging system can be modelled and analysed for its performance in future.

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## REFERENCES

1. Parrello, B.D., Kabat, W.C., Wos, L., 1986. Job-shop scheduling using automated reasoning: a case study of the car-sequencing problem. *Journal of Automated Reasoning* 2 (1), 1–42.
2. Carlier, J., Pinson, E., 1989. An algorithm for solving the job shop problem. *Management Science* 35, 164–176.
3. Sculli, D., 1980. Priority dispatching rules in job shops with assembly operations and random delays. *Omega—the International Journal of Management Science* 8 (2), 227–234.
4. Green, G.I., Appel, L.B., 1981. An empirical analysis of job shop dispatch rule selection. *Journal of Operations Management* 1 (4), 197–203.
5. Kanet, J.J., Hayya, J.C., 1982. Priority dispatching with operation due dates in a job shop. *Journal of Operations Management* 2 (3), 167–175.
6. Baker, K.R., 1984. Sequencing rules and due-date assignments in a job shop. *Management Science* 30 (9), 1093–1104.
7. Adams, J., Balas, E., Zawack, D., 1988. The shifting bottleneck procedure for job shop scheduling. *Management Science* 34 (3), 391–401.
8. Holtsclaw, H.H., Uzsoy, R., 1996. Machine criticality measures and sub problem solution procedures in shifting bottleneck methods: a computational study. *Journal of the Operational Research Society* 47 (5), 666–677.
9. Balas, E., Vazacopoulos, A., 1998. Guided local search with shifting bottleneck for job shop scheduling. *Management Science* 44 (2), 262–275.
10. Liu, S.Q., Kozan, E., 2012. A hybrid shifting bottleneck procedure algorithm for the parallel-machine job-shop scheduling problem. *Journal of the Operational Research Society* 63 (2), 168–182.
11. Bianco, L., Dellolmo, P., Giordani, S., & Speranza, M. G. (1999). Minimizing makespan in a multimode multiprocessor shop scheduling problem. *Naval Research Logistics*, 46, 895–911.
12. Akpan, E. O. P. (1996). Job shop sequencing problems via network scheduling technique. *International Journal of Operations and Production Management*, 16(3), 76–86.
13. Guinet, A. (2000). Efficiency of reductions of job shop to flow shop problems. *European Journal of Operational Research*, 125(3), 469–485.
14. Lee, C. Y., Piramuthu, S., & Tsai, Y. K. (1997). Job shop scheduling with a genetic algorithm and machine learning. *International Journal of Production Research*, 35(4), 1171–1191.
15. Blazewicz, J., Domschke, W., & Pesch, E. (1996). The job shop scheduling problem: conventional and new solution techniques. *European Journal of Operational Research*, 93, 1–33.
16. Sabuncuoglu, I., & Bayiz, M. (2000). Analysis of reactive scheduling problems in a job shop environment. *European Journal of Operational Research*, 126, 567–586.
17. Yu, H., & Liang, W. (2001). Neural network and genetic algorithm-based hybrid approach to expanded job shop scheduling. *Computers and Industrial Engineering*, 39(3/4), 337–356.
18. Satake, T., Morikawa, K., Takahashi, K., & Nakamura, N. (1999). Simulated annealing approach for minimizing the makespan of the general job-shop. *International Journal of Production Economics*, 60, 515–522.
19. Jerry Banks., John S., Carson, Barry L., David M. Nicol. (2007). *Discrete Event System Simulation*. Third edition pg-160.
20. Shiqing Yao, Zhibin Jiang, NaLi (2012). A branch and bound algorithm for minimizing total completion time on a single batch machine with incompatible job families and dynamic arrivals. *Computers & Operations Research* 39 pp. 939–951.
21. Binchao Chen, Timothy I. Matis (2013). A flexible dispatching rule for minimizing tardiness in job shop scheduling. *Int. J. Production Economics* 141 pp.360–365.
22. Rui Zhang, Pei-Chann Chang, ChengWuc (2013). A hybrid genetic algorithm for the job shop scheduling problem with practical considerations for manufacturing costs: Investigations motivated by vehicle production. *Int. J. Production Economics* 145 pp.38–52.
23. Xinchang Hao, Lin Linb, Mitsuo Genc, Katsuhisa Ohnoe (2013). Effective Estimation of Distribution Algorithm for Stochastic Job Shop Scheduling Problem. *Procedia Computer Science* 20 pp. 102 – 107.
24. Andrea Rossi (2014). Flexible job shop scheduling with sequence-dependent setup and transportation times by ant colony with reinforced pheromone relationships. *Int. J. Production Economics* 153 pp.253–267.
25. K. Lia, J.Y.-T. Leunga B.Y. Chenga (2014). An agent-based intelligent algorithm for uniform machine scheduling to minimize total completion time. *Applied Soft Computing* 25 pp.277–284.
26. Wenchang Luo, MinJib (2015). Scheduling a variable maintenance and linear deteriorating jobs on a single machine. *Information Processing Letters* 115 pp.33–39.
27. Shrath Chandra, Y Arun Kumar, Srinath M.S. Multi-Level Dynamic Job Sorting for Increasing Productivity Using Discrete Event Simulation (Diverging Conveyors). *International Journal of Engineering Research and Development*. Volume 11 pp.75-81.