Scheduling and Sequencing of Robots for Slim & Speedy Line using Meta Heuristics: – A Case Study

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Abstract: The main objective of manufacturing industries today is to increase productivity through system simplification and incremental improvements by using modern available machine as much as with batter accuracy and maximum output. In this paper case study used one of the important sequencing scheduling techniques Meta heuristics & Johnson's algorithms and examine the change in result after considering and find out the factors which are responsible for maximum output. For completeness, some better alternatives to previously proposed procedures are also provided for the case where the process parameters are assumed known in advance of production.

Keywords: *Job shop scheduling; Manufacturing systems; Meta-heuristics; Johnson's algorithms.*

INTRODUCTION

Scheduling can be defined as "prescribing of when and where each operation necessary to manufacture the product is to be performed." It is also defined as "establishing of times at which to begin and complete each event or operation comprising a procedure". The principle aim of scheduling is to plan the sequence of work so that production can be systematically arranged towards the end of completion of all products by due date. Scheduling is done in all the activities of an organisation i.e., production, maintenance etc. Therefore, all the methods and techniques of scheduling is used for maintenance management [6].Dulluri et al. (2008)[9]: developed a priority based heuristic for limiting the makespan for a turbine fabricating industry. This heuristic created ideal timetable in light of the dynamic needs of the client work orders. Naderi et al. (2009A)[10]: proposed novel simulated annealing for mixture job shop scheduling issue to limit absolute finishing time and complete lateness including sequences subordinate set up. Erenay et al. (2010)[11]: solved bi-criteria scheduling issue with minimization of the quantity of late job and normal job time on a solitary machine. T. Eren(2010)[12]: utilized a bi-criteria m-machine job shop scheduling issue with grouping subordinate setup times with minimization of the weighted whole of all out fulfillment time and makespan. Scheduling assumes a pivotal job to expand the proficiency and efficiency of the assembling framework Mati et al. (2011)[13]. Ponsich, A & Coello, CAC (2013)[14]: In essence TS is a simple deterministic oriented search procedure that constrains searching and seeks to transcend local optimality by storing the search history in its memory. Xiong et al. (2013)[15]: The goal of these procedures is to enable a solution procedure based on the combined elements to yield better solutions than the one based on the original elements. Frijns et al. (2014)[16]: Cloud computing, as market-oriented service utilities begun with task scheduling concept accordingly. Some of the basic scheduling algorithms can be used for scheduling in cloud computing, such as First Come First Serve (FCFS) Algorithm (in the queue the job comes first, is served first).Marco Pranzo & Dario Pacciarelli (2015)[19]: EAs have many advantages. EAs are providing a set of solutions near the optimal one on a wide range of problems .Noor et al. (2015)[20]: hybrid heuristic genetic algorithm for Job shop scheduling problems with minimization of makespan. Hybrid Algorithm describes combining the social and natural behavior of any different search algorithms by reasonably. Souvik Pal, Prasant Kumar Pattnaik(2016)[21]: Cloud computing is a developing worldview of Internet-driven business computing where CSPs(Cloud Service Providers) are giving administrations to the client as indicated by their necessities. Anna Kwasiborska(2017)[22]: The expanding number of air tasks is a test for air traffic controllers. The association of air traffic can be accomplished by better adjusting the planes for landing or sequencing. Manisha et al. (2018)[23]: In the present paper a review has been illustrated, on late improvements in the writing of sequencing what's more, scheduling.

SCHEDULING OBJECTIVES

The scheduling is done to meet different goals. These objectives are decided upon the situation, market demands and the customer's satisfaction. There are two broad categories for the scheduling objectives: i) Time based minimization (ii) Cost based minimization. The objectives considered under the time minimization are minimize machine idle time; minimize the mean flow time; minimize the mean tardiness; finish each job as soon as possible; finish the last job as soon as possible. The objectives considered under the cost minimization are minimize the costs due to not meeting the due dates; minimize the maximum lateness of any job; minimize the total holding cost with no tardy jobs; minimize the number of late jobs.

JOB SHOP SCHEDULING PROBLEM(JSP)

Description of **JSP** Unit production or job shop production involves the manufacture of discrete units. This involves production where the production units are processed either as single entities or in small batches. Scheduling is generally controlled by a routing sheet or short order process rather than by an assembly line system. Job shop production equipment is usually of a general purpose nature in order to provide the flexibility necessitated by the variation in size, shape, quantity, precision, and type of product. Scheduling is the allocation of resources over time to perform a collection of tasks. A general JSP suppose having n jobs {J_1, J_2, J_3 --------- J_n} to be processed through R robotic machine {R_1, R_2, R_3 ----------- R_m} to be scheduled, where each job must pass through each machine only once. Each job has its own processing order and this may bear no relation to the processing order of the any other job. Technological constraints demand that each job should be processed through the robotic machine in a particular order and gives an important special case named as flow shop. Thus in case of flow shop jobs pass between the robot in the same order i.e. if J_1 must be processed on R_1 before machine R_2 then the same the true for all jobs. I am trying to arrange all robots in a proper sequence for batter results. JSP are NP-hard (non-deterministic polynomial-time hardness) problems, so its complexity is more (Mohsen Ziaee, 2014)[17-18]. The job on scheduling robots for production based on algorithm Meta heuristics. In Morden manufacturing sector machines and systems are very complex. In a manufacturing shop commonly various job goes through various robots. Let in an manufacturing shop there are three shop to be specific R1, R2, R3. And each activity must goes through it just once. This technological constraint therefore gives the form like:

Job	processing order			
J_1	R1	R2	R_3	R_m
J_2	R_1	R_2	R_3	R m
....	....	....	....	....
J_n	R_1	R_2	R_3	R m

For a general job shop problem characterized over the quantity of conceivable sequences are $(n!)^m$, where n is number of jobs and m is the quantity of machines. With the above technological limitations if there should arise an occurrence of flow shop number of various sequence reduces to (n!). This diminished number is very huge for even moderate size issues and perceived to be NP hard (Gareyetal., 1976[4]; Gonzalez and Sahni, 1978[5]; Pinedo, 2005[8] and a few others). There has been an endeavor to take care of this issue with commonplace target job being the minimization of normal job time, limiting the time required to finish every one of the jobs or make range, limiting normal delay esteems or lateness, limiting greatest lateness, and limiting the quantity of late jobs.

RESEARCH METHODOLOGY

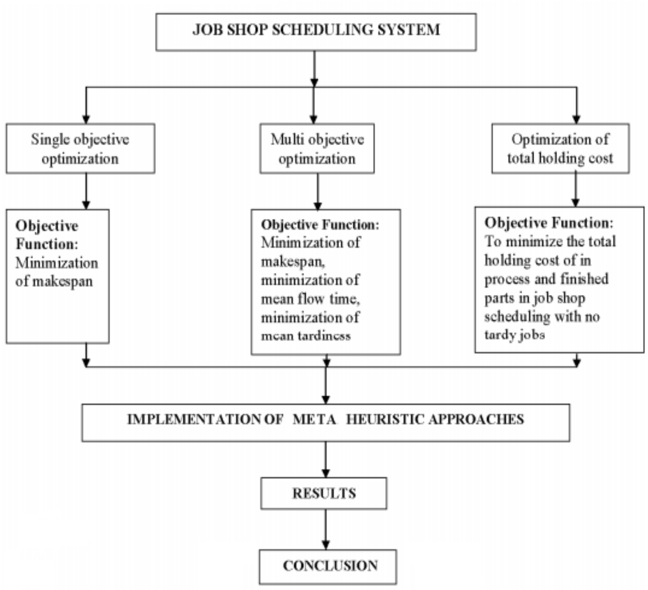

Figure 1 The Research Scheme.

A CASE STUDY ON MACHINE SCHEDULING AND SEQUENCING USING META HEURISTICS

The job on scheduling robots for production based on algorithm Meta heuristics. In Morden manufacturing sector machines and systems are very complex. The trying to arrange all robots in a proper sequence for batter results. The job in a manufacturing company situated at sec **7** Manesar Gurgaon namely as Neel Metal Products Ltd. It is one of the biggest manufacturing companies in India.

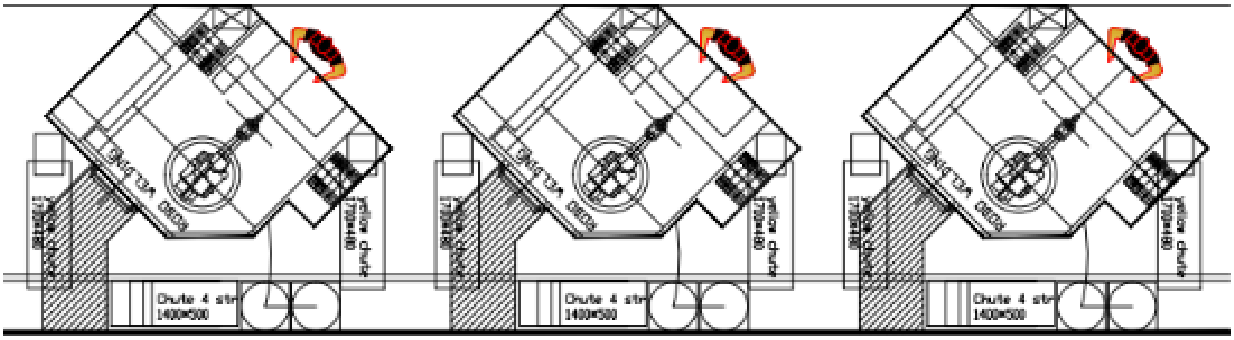

Figure 2 Design of arrangement of robots

In a manufacturing shop commonly various job goes through various robots. Let in an manufacturing shop there are three shop to be specific R1, R2, R3. And each activity must goes through it just once. The open shop scheduling issue is on the other hand called as directed job shop planning issue **(Panneerselvam [7]),** since every one of the machines won't have 100% use all the time subsequently the machines which have comparative handling capacities will be assembled and a clump of single task job s will be planned on these machines at the same time the association might be sharp in upgrading any of the accompanying proportions of exhibitions

- ❖ Minimizing the sum of the completion times of all the jobs.
- ❖ Minimizing total tardiness.
- ❖ Minimizing total lateness.
- ❖ Minimizing the total number of tardy jobs.
- ❖ Minimizing makespan.

Table No 1 Job Sequence

Jobs	**Duration (Hours)**		
	Machine Robot (R_1)	**Machine Robot (R_2)**	**Machine Robot (R_3)**
J_1	24	15	21
J_2	22	12	23
J_3	19	18	19
J_4	21	11	15
J_5	18	16	20

Palmer heuristics approach: A heuristic created by Palmer (1965)[2], with an end goal to utilize Johnson"s rule, is worked around the thought of a slope index. The slope index gives a vast incentive to jobs that have a propensity of advancing from little to huge working occasions as they travel through the stages. The arrangement of tasks is given by need to jobs having the most grounded propensity to advance from brief occasions to long occasions. This implies the activity arrangement can be produced dependent on a non-expanding request of the slope indices. Let *S* (*j*) be the slope index for job *j* and O^t_j be the operating time of job *j* at stage *t*. Palmer"s[2] slope index is determined as pursues

$$S(j) = -\sum_{t=1}^{k}\{[k-(2t-1)]O_j^t\}$$

Let assign +2 to R_3, 0 to R_2 and -2 to R_1 then we have to calculate slope S(J) of each job

$S(J_1) = \{24\times(-2)+(15\times0)+(21\times2)\} = -6$
$S(J_2) = \{22\times(-2)+(12\times0)+(23\times2)\} = 2$
$S(J_3) = \{19\times(-2)+(18\times0)+(19\times2)\} = 0$
$S(J_4) = \{21\times(-2)+(11\times0)+(15\times2)\} = -12$
$S(J_5) = \{18\times(-2)+(16\times0)+(20\times2)\} = 4$

At that point we need to organize the job as per diminishing request of their slope:

J_5	**J_2**	**J_3**	**J_1**	**J_4**

Minimum total processing time to complete all the 5 jobs through all the three.

Table No 2 Job Sequence(Optimal)

Job Sequence (Optimal)	Machine Robot					
	R_1		R_2		R_3	
	In	Out	In	Out	In	Out
J_5	0	18	18	34	34	54
J_2	18	40	40	52	54	77
J_3	40	59	59	77	77	96
J_1	59	83	83	98	98	119
J_4	83	104	104	115	119	134

Minimum total elapsed time= 134 hrs
Idle time on Machine Robot (R_2)=18+6+7+6+6=43hrs.
Idle time on Machine Robot (R_3)=34+2=36 hrs.
So make span related with this grouping is 134. Since this heuristics solution need not be optimal so we need to discover the integrity factor so as to realize how great it is.

Goodness factor is characterizes as a proportion of distinction between heuristic solution and optimum solution to optimum solution. Since don't have the foggiest idea about the optimum solution. So we can supplant **optimum solution** with lower bound.

Lower bound of R_1=Total processing time at R_1 +Minimum sum of processing time of (R_2 +R_3)=104+26=130

Lower bound of R_2= Total processing time at R_2 +Minimum sum of processing time of (R_1 +R_3)=72+36=108

Lower bound of R_3= Total processing time at R_3 +Minimum sum of processing time of (R_1 +R_2)=98+32=130

Maximum bound is best one so we choose lower bound 130.

So goodness factor =(134-130)÷130}=0.03077 e.g. 3.077 %.

In the event that we willing to acknowledge the solution about **3.077 %** of **optimum**, at that point we ought to go for **palmer heuristics.**

Campbell, Dudek, and Smith(CDS)(1970)[3]: It create a standout amongst the most noteworthy heuristic techniques for flow shop problems with makespan criterion, in the accompanying indicated by CDS. Its strength lies in two properties:

1. it uses Johnson‟s rule in a heuristic fashion, and
2. it for the most part makes a few schedules from which a "best" schedule can be picked.

Given these documentations, the working occasions are determined by the accompanying two recipes:

$$a(j,g) = \sum_{i=1}^{g} O_j^i$$

$$b(j,g) = \sum_{i=k-g+1}^{k} O_j^i$$

Here **Sequencing Problem** have some **Assumption**[24]:

1. No machine can process more than one job at time.
2. Processing times are independent of processing of jobs.
3. Each job once started on one machine is continued till completion on it.
4. Time involved in moving a job from one machine to another is negligibly small.

For solving of this kind of problem here use **n jobs and 3 machines(**Johnson‟s algorithm**).**

n jobs and 3 machines: Condition to be satisfied to solve the above problem by Johnson's method. There are three robot machines R_1, R_2 & R_3. Each job has to go through robot machines in order R_1, R_2 & R_3.

1. The smallest processing time on machine $R_1 \geq$ largest processing time on machine R_2.
2. The smallest processing time on machine $R_3 \geq$ largest processing time on machine R_2.

If either or both of the above stated conditions are satisfied, the given problem can be solved by Johnson‟s algorithm.

Procedure[24]:

Step I: Convert the three robot machine problem into two machine problem by introducing two fictitious robot machine G and H. Such that

$$G_i = R_{1i} + R_{2i}.$$
$$H_i = R_{2i} + R_{3i}.$$
$$i = 1,2,3 \ldots\ldots n$$

Step II: Once the problem is converted to n job 2 machine the sequence is determine using Johnson‟s algorithm n job 2 machine.

Step III: For the optimal sequence determined, find out the minimum total elapsed time and idle times associated with machines.

n jobs and 3 machines: Condition to be satisfied to solve the above problem by Johnson's method. There are three robot machines R_1, R_2 & R_3. Each job has to go through robot machines in order R_1, R_2 & R_3.

1. The smallest processing time on machine $R_1 \geq$ largest processing time on machine R_2. The smallest processing time on machine R_1= 18; The largest processing time on machine R_2 =18.
2. The smallest processing time on machine $R_3 \geq$ largest processing time on machine R_2. The smallest processing time on machine R_3 =15; The largest processing time on machine R_2=18. Here one of condition satisfied for **n jobs and 3 machines.**

Since Johnson‟s algorithm is a two-organize algorithm, a k arrange issue must be crumpled into a two-organize problem[24].

Table No 3 Job Sequence of n jobs and 3 machines crumpled into a two-organize

JOB	R_1+R_2	R_2+R_3
J_1	39	36
J_2	34	35
J_3	37	37
J_4	32	26
J_5	34	36

For this sub issue job sequence as per **Johnson's algorithms [1].** The smallest one in the above notice table is 26 so J_4 goes to outrageous right line then next most modest number is 34 so J_5 goes to 2nd extraordinary left row as such we fill the staying empty row as indicated by Johnson‟s algorithms.

J_5	**J_3**	**J_1**	**J_2**	**J_4**

Minimum total processing time to complete all the 5 jobs through all the three.

Table No 4 Job Sequence(Optimal)

Job Sequence (Optimal)	**Machine Robot**					
	R_1		**R_2**		**R_3**	
	In	**Out**	**In**	**Out**	**In**	**Out**
J_5	0	18	18	34	34	54
J_3	18	37	37	55	55	74
J_1	37	61	61	76	76	97
J_2	61	83	83	95	97	120
J_4	83	104	104	115	120	135

Minimum total elapsed time= 135 hrs

Idle time on Machine Robot (R_2)=18+3+6+7+9=43 hrs.

Idle time on Machine Robot (R_3)=34+1+2=37 hrs.

So make span associated with this sequence is **135.** So make span related with this sequence is **135.** From above talked about two sequences best one is J_5-J_3 -J_1- J_2-J_4 in view of their base fulfillment time for example **135.** Since we effectively characterized goodness factor and we have lower bound is **130.**

So **goodness factor {(135-130)÷130}=0.0384 e.g. 3.84 %.**

Figure 3 Robots after scheduling as per algorithm

On the off chance that we willing to acknowledge the arrangement about **3.077 %** of **optimum,** at that point we ought to go for palmer heuristics.

Table 5 Comparatively Job Sequence

	Palmer Heuristics	**Johnson‟S Algorithm**
Job Sequence	**J_5**	**J_5**
	J_2	**J_3**
	J_3	**J_1**
	J_1	**J_2**
	J_4.	**J_4**
Optimum Solution	**130 hrs**	**130 hrs**
Minimum Total Elapsed Time	**134 hrs**	**135 hrs**
Goodness Factor	**0.03077 e.g. 3.077 %.**	**0.0384 e.g. 3.84 %.**
So best solution of Job Sequence is 3.077 % of optimum by Palmer Heuristics		

Maximum bound is best one so we choose lower bound 130.

So goodness factor =(134-130)÷130}=0.03077 e.g. 3.077 %.

Maximum bound is best one so we choose lower bound 130.

So goodness factor {(135-130)÷130}=0.0384 e.g. 3.84 %. On the off chance that we willing to acknowledge the arrangement about **3.077 %** of **optimum,** at that point we ought to go for palmer heuristics. Meta heuristics approach will in general move moderately rapidly towards exceptionally better arrangement solutions, so it gives a productive method for managing extensive convoluted issues. It is helpful in situations where conventional techniques stall out at neighborhood minima and common area of use is combinatorial improvement issues. Anyway is does not ensure for ideal arrangement but rather in the event that we willing to acknowledge **0 to 4%** of ideal arrangement, at that point this kinds of techniques is helpful.

LIMITATIONS OF THIS RESEARCH

There are some limitations of this research worth to mention.

- Only time based objectives have been considered in multi objective optimization.
- The computational time of multi objective optimization has not been incorporated.
- The tested data for single objective optimization, multi objective optimization and total holding cost optimization are benchmark problems.

CONCLUSION

Meta heuristics approach will in general move moderately rapidly towards exceptionally better arrangement solutions, so it gives a productive method for managing extensive convoluted issues. It is helpful in situations where conventional techniques stall out at neighborhood minima and common area of use is combinatorial improvement issues. Anyway is does not ensure for ideal arrangement but rather in the event that we willing to acknowledge **0 to 4%** of ideal arrangement, at that point this kinds of techniques is helpful.

REFERENCES

1. **Johnson, S.M.(1954),** “Optimal two-and three-stage production schedules with setup times included. Naval Research Logistics Quarterly 1, 61-68.
2. **Palmer, D.S., (1965),** “Sequencing jobs through a multi-stage process in the minimum total time a quick method of obtaining a near optimum”, Operations Research Quarterly 16(1), pp.101–107.
3. **Campbell, H.G., Dudek, R.A. and Smith, M.L.(1970),** “ A heuristic algorithm for the n-job m-machine sequencing problem”, Management Science 16(10), pp.169–174.
4. **Garey, M.R., Johnson, D.S. and Sethi, R.R.(1976),** “The complexity of flow shop and Job shop scheduling”, Operations Research 1,pp.117–129.
5. **Gonzalez, T. and Sen, T.(1978),** “Flow shop and job shop schedules: complexity and approximations”, Operations Research 26, pp.36–52.
6. **Elwood S.Buffa & Rakesh K.Sarin(1987),** “Modern Production/Operations Management”, Wiley; 8 edition handbook.
7. **Panneerselvam, R. (1999),** “Heuristic for Moderated Job Shop Scheduling Problem to Minimize Makespan”, Industrial Engineering Journal, 28, pp.26-29.
8. **Pinedo, M.(2005),** “Scheduling theory, algorithms, and system”, Prentice-Hall.
9. **Dulluri, S., Mahesh, V. and Rao, C.S.P. (2008),** “A heuristic for priority-based scheduling in a turbine manufacturing job-shop”, International Journal of Industrial and Systems Engineering, 3(6),pp.625 – 643.
10. **Naderi, B., Zandieh, M., Balagh, K.K.G. and Roshanaei, V.(2009A),** “An improved simulated annealing for hybrid flow shops with sequence-dependent setup and transportation times to minimize total completion time and total tardiness”, Expert Systems with Applications: an International Journal 36(6), pp.9625-9633.
11. **Erenay, F.S., Sabuncuoglu, I., Toptal, A. and Tiwari, M.K.(2010),** “New solution methods for single machine bi-criteria Scheduling problem: Minimization of average flow time and number of tardy”, European Journal of Operation Research ,201(1), pp.89 – 98.
12. **T. Eren(2010),** “A bicriteria m-machine flowshop scheduling with sequence-dependent setup times”, Applied Mathematical Modelling, 34(2),pp.284–293.
13. **Mati, Y, Dauzère-Pérès, S & Lahlou, C (2011),** “A general approach for optimizing regular criteria in the job-shop scheduling problem”, European Journal of Operational Research, vol. 212, no. 1, pp. 33-42.
14. **Ponsich, A & Coello, CAC (2013),** “A hybrid Differential Evolution Tabu Search algorithm for the solution of Job-Shop Scheduling Problems”, Applied Soft Computing, vol. 13, pp. 462-474.
15. **Xiong, J, Xing, LN & Chen, YW (2013),** “Robust scheduling for multiobjective flexible job-shop problems with random machine breakdowns”, International Journal of Production Economics, vol. 141, pp. 112-126.
16. **Frijns, R.M.W.; Adyanthaya, S.; Stuijk, S.; Voeten, J.P.M.; Geilen, M.C.W.; Schiffelers, R.R.H.; and Corporaal, H. (2014),** “Timing analysis of first-come first-served scheduled interval-timed directed acyclic graphs”, Design, Automation and Test in Europe Conference and Exhibition (DATE), Proceedings IEEE, pp.1-6.
17. **Mohsen Ziaee (2014),**“An efficient heuristic algorithm for flexible job shop scheduling with maintenance

constraints", Applied Mathematics and Sciences: An International Journal (MathSJ), vol. 1, no. 1, pp. 19-31.

18. **Mohsen Ziaee (2014),**"Job shop scheduling with makespan objective: A heuristic approach", International Journal of Industrial Engineering Computations, vol. 5, no. 2, pp. 273-280.
19. **Marco Pranzo & Dario Pacciarelli (2015),** "An iterated greedy metaheuristic for the blocking job shop scheduling problem", Journal of Heuristics, springer, vol. 1, no. 1, pp.15-22.
20. **Noor Hasnah Moin, Ong Chung Sin & Mohd Omar (2015),** "Hybrid Genetic Algorithm with Multi parents Crossover for Job Shop Scheduling Problems", Mathematical Problems in Engineering, vol. 20, pp. 1-12
21. **Souvik Pal, Prasant Kumar Pattnaik(2016),** "Adaptation of Johnson sequencing algorithm for job scheduling to minimise the average waiting time in cloud computing environment", Journal of Engineering Science and Technology Vol. 11, No. 9 ,pp.1282 – 1295.
22. **Anna Kwasiborska(2017),** "Sequencing landing aircraft process to minimize schedule length", Transportation Research Procedia, 28 ,pp. 111–116.
23. **Manisha Sharma, Himansha Sharma and Meenakshi Sharma(2018),** "Recent trends in sequencing and scheduling", Malaya Journal of Matematik, Vol. S, No. 1, pp.75-78.
24. **Martand Telsang(2018),** " Industrial Engineering and Production Management:3rd edition", S.Chand Publication, ISBN :81-219-1773-5, New Delhi, pp.304-311.