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Optimization of production cost for integrating job shop scheduling with production resources

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ABSTRACT

New manufacturing technologies are emerging every day, pushing the bounds of possible and redefining the world around us. This is especially true in the world of computing where much work goes into the design and development of new planning systems, tools, and software packages. This led to the development of various process analysis and manufacturing software packages. Many of these packages use the heuristic methods for solving the problems. Optimization is a design technique in which the best design solution for a problem is seeded using multiple execution and comparison of analysis results. Optimization is carried out for one or more responses acted upon by various constraints. Job shop is an environment for the manufacture of large variety low volume products. In general, the integration of production functional areas with job shop scheduling problems is to be considered as too hard and complex problems. The Production functional areas are Material Requirement Planning, Production Resource Planning, Manufacturing Resource Planning, Employee Time tabling, Human Resource Planning and Lot Size etc. To minimize the loss due to resource allocation, integration of production function resources and job shop scheduling is encouraged. Production resources are resourcing the material, human labours and manufacturing machine tools. Manufacturing assumptions are deployed to found difficult integrated manufacturing systems. In this paper, a hierarchy mathematical modelling approach has been developed to integrate the production resources planning and job shop scheduling. In which, material requirement planning system for material resource arrangement, employee timetabling module for human resource allocation and manufacturing resource planning for machine allocations are to be considered. For solving the unique hierarchy model, a shuffled frog leaping heuristic algorithm (SFLA) is proposed and implemented for minimizing the overall production cost. To prove the optimized results, the integrated system has been tested with real time case studies.

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1. Introduction

Manufacturing industries are currently focusing on development of fully automated systems lead to reach the higher profit with low production costs. Production planning is an issue dealing with selection of manufacturing process and process parameters by manufacturing organizations. To reach full-fledged computer integrated manufacturing environment and increase the capability, production functional areas need to be integrated with scheduling [1]. Based on optimum design specification, the computer integrated manufacturing systems performs the transformation of raw materials to a complete product to fulfil the customer satisfactions.

Scheduling is the process of allocating the different operations on different machines to time intervals. Job shop scheduling process is defined as set of n jobs which are to be processed on m machines with a sequence in which each jobs passes between different machines, so such that the each job should satisfies the technological constraints based on performance criterion. Job shop scheduler has been used to generate the sequences randomly and to allocate the tasks to time intervals on different machines [2]. It was found that many researchers used heuristic algorithms for solving job shop scheduling problems to find a schedule which

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gives the minimum overall completion time during an uninterrupted time period in a fixed length [3]. Gantt chart is also used to find the initial sequence and makespan.

Nikisha K et. Al has addressed the problem by using the augmented Lagrangian method to solve the production planning integration with job shop scheduling for multistage and multipurpose batch plants [4]. A new decomposition scheme was developed to address the multistage production planning and scheduling problem. The implementation of the proposed decomposition method gives a faster solution time which has been realized as main advantage of the system [5]. To respond the needs of emerging trends in current generation manufacturing, a innovative integrated model was designed and proposed for automated planning, scheduling and control systems [6]. A unique framework, disputes regarding statistical scheduling and dynamic scheduling were addressed and proposed by considering two time indices and an uncertainty index. It was an evaluated planning, scheduling and control system in which disturbing events are categories in accordance to three major planning [7].

Wenli Shang has introduced an integrated optimization model with an objective of minimizing the sum of total setup cost, total stock holding cost, total production cost and overtime cost of production planning and scheduling for batch production [8]. An integrated model for optimization of job shop production planning and scheduling problem with an objectives of setup cost, work in process inventory, product demand and load equipment has been developed by Zhang [9].

Li & McMahon has been developed the integration model to increase the flexibility and responsiveness of the job shop in the more competitive marks between the job shop scheduling and production planning [10]. Gen M, et. al. has surveyed the evolutionary techniques for optimizing objective functions in integrated manufacturing Planning for product development and manufacturing with utilizing the 'global optimization methods [11]. An algorithm considering computation times were multi resources assignment combined permutation representation into the higher-level chromosomes. Particle swarm optimization application has been implemented for the in integration of process planning and job shop scheduling by Guo [12]. The integrating schedule were obtained by improved the performance together with reliable and fairly results. Laxy Lin et. al. has proposed for solving integrated production planning and scheduling problems by using hybrid evolutionary algorithm [13]. A network modelling way was used for formulating integrated model into a unified model and specifies the need of manufacturing resources and operations.

Many researchers found that Job shop scheduling problem has been extensively solved with many objectives like minimizing employee cost, production cost, total holding cost, manufacturing cost and material cost. In this work an integrated system has been developed between production functional areas and job shop scheduling at the first stage. Also the second stage to, a heuristic algorithm named as shuffled frog leaping algorithm has been implemented for minimizing the overall production cost. At the last stage describes the implementation of integrated model with real time case study problems.

2. Integrated system implementation

2.1. Structure influence

Structure influence used to develop the manufacturing resource planning based on the resources availability. The resources objectives with different functional names functional ID and their Indies of notations are listed in Table 1.

Table 1
Resource Objectives.

Sl. No.	Function Name	Function ID	Indies
1	Jobs	J	i € I
2	Operations	O	j€ J
3	Material Resources	M	k€ K
4	Human Resources	E	h€ H
5	Manufacturing Resources	Ma	m€ M
6	Resources	R	u€ U

2.2. Integrated model

The design of integrated system consists of material resources, human labour resources and manufacturing resources with certain constraints based on capacity and capability of resources. At the initial stage enterprise resource availability checking, which is used to decide what kinds of resources can be used for production. Normally two kinds of definitions are considered such as material definitions and resource definitions. Allocation and integrating the resources such as Material, Human Labour and machines etc. are described as follows.

Material definitions:

Material iD

Name of the material, Amount of material and Usability of material.

Human iD

Name of the labour, Number of labours, Time schedule and Workload allocation and capability.

Machine iD

Name of the machine, Number of Machines, type of tools, usability and capability.

Resource Definitions:

Material set, $M = \{M_i\}$, where $i = \{ A_k^M, B_k^M, \ldots\}$

$M_i = \{ A_r^M , B_r^M\}$

Human Labour ser, $E = \{E_i\}$,

where $i = \{ A_k^E , B_k^E , \ldots\ldots \}$

$E_i = \{ A_u^E , B_u^E\}$

Machine set, $I = \{I_i\}$, where $i = \{ A_k^I , B_k^I , \ldots\ldots \}$

$I_i = \{ A_{ma}^I , B_{ma}^I\}$

$X_i = \{X_{jkh}\}$ and $Z_j = \{Z_{jkh}\}$ which is operation resource assignment for each machine k, job j and movement resource allocation between operation jj and operation ji.

Decision Variables	
MaterialsM [Mj,Mj^n]	j1= $\{C^M , D^M \}$
EmployeesE [Ej,Ej^n]	j2= $\{C^D , D^D \}$
MachinesI [j,Ij^n]	j3= $\{A^I , B^I \}$

The second step modules invoke checking of master production plan, which is considering production pro-cesses, resources availability, amount and customer requirements etc. The third step modules consisting the production pro-cess, quantity of material to be processed and customer requirement. Production process has been checked for each job which can be formulated as a set of functional operations and production plan has been developed for each job which can be defined with number of products.

2.3. Production process contains

Jobs

Job iD, Job Name and Job operations

Materials

Bill of material (BOM), Import MRP, Ex-port MRP, Purchasing and Material Resource Requirement.

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Employees

Number of Employees, Work Allocation, Work preference, Skill Matrix, Work load creation and Human resource requirement.

Machines

Operation procedure, Operation Time, Number of machines and Manufacturing resources requirement.

2.4. Hierarchy modelling

The production resource planning decisions describes the aggregate capacity of utilization of production resource quantity, number of machines, inventory level of raw materials and labours [14]. The hierarchy modelling of integrated model is shown Fig. 1. The scheduling decisions used to determine the product schedule of each finished goods where they are processed at each machine. The finite schedule of finished goods always comprises total production cost and time of each machine includes starting time and completion time.

3. Formulation of production resource planning based on global optimum

The formulations of scheduling model are used to determining the job shop scheduling decisions of the production resource planning and job shop scheduling problems. The scheduling determines the master production schedule, production plan, material utilization and proper machine utilization. This production resource planning model is input to the scheduling model. Normally scheduling model consists of in-process scheduling and finished product task scheduling [15]. The finished goods always have a specific due date at which orders assigned by the customers. The main objective of the integrated model is to meet the customers' orders with minimum cost of resource utilization and satisfactions.

Global optimum is the best possible solution of a problem. General global optimization problem formulated as f(x), the objective f (x) defined on the ·set × ϵ D, find the point × and Cor-responding function f(x),

$f^* = f(x) = \min\{f(x) \backslash x \epsilon D\}$--------- (4.1)

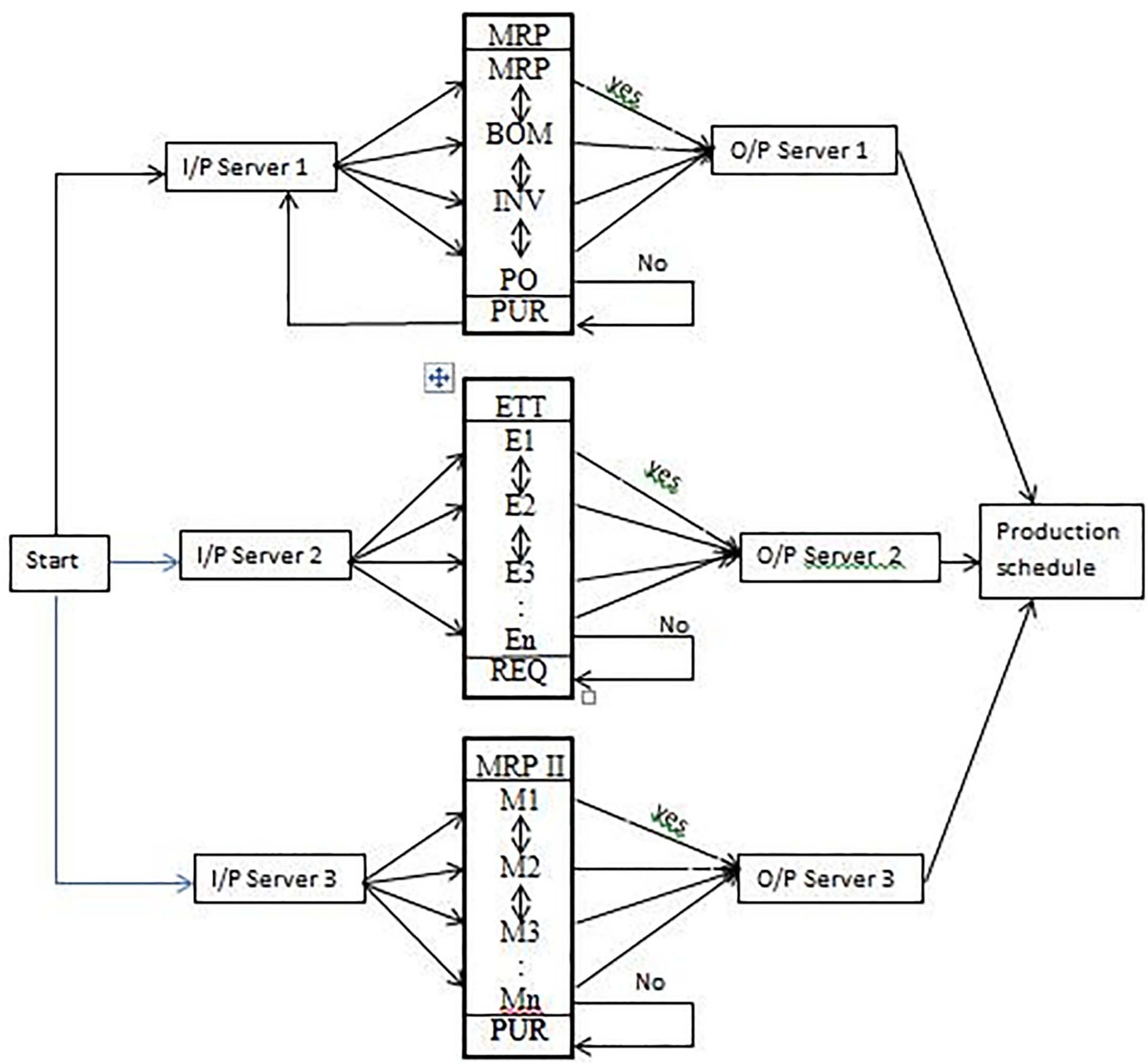

Fig. 1. Integrated Production Resource Planning and Job Shop Scheduling Model.

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Objective is minimization of the function Deterministic methods can be used to determine global optimum. The SFLA heuristic algorithm is used for finding global optimum results.

Objective Function:

f(x1) = Min (I,Xi)

f(x2) = Min (E,Xi)

f(x3) = Min (M,Xi)

Individual Constraints Inv > 0

E > 0

M > 0

System Constraints Inv – PUR $\geq$ 0

E-ReqP $\geq$ 0 ;

Non-negative constraints I + E + M $\geq$ 0

DD = C Decision Variables:

Materials

M (m1, m2, m3……..) i1= $\{A^M, B^M\}$

Employees

E (e1, e2, e3……..) i2= $\{A^E, B^E\}$

Machines

I (i1, i2, i3……..) i3= $\{A^I, B^I\}$

The objective of scheduling is used to minimize labour cost, material cost and manufacturing cost. At first, sub problem was considered for each step of resources before applying heuristic to overall integrated schedule model. To test the integrated application an industrial case study problem was considered. At each time period, the production resource planning system consists of determining labour cost, material cost and manufacturing cost has been solved by Shuffled frog leaping combined local search and particle swarm optimization.

3.1. Shuffled frog leaping algorithm

SFLA performed based on memetic evolution of a group of frogs when seeking for food. The frog's initial population was partitioned into groups/ subsets called "memeplexes" and the frogs number in each subset was equal [16]. Two search techniques in SFLA were local search and global information exchange. Local search was used to reach the makespan, each subset the frog to improve their positions to have more foods. Global information exchange has been done after local search with its obtained information and best sequence way of schedule has to be produced based on between each subset was compared to other [17].

3.2. Optimization of production cost with industrial case study problems

A real time case study data has been tested for the validation of integrated system. The input data were collected from an industry in which many problems in resources such as stocks, inventories and demand capacity are considered. To finding a finite process is to process rapid change in customers' requirements and satisfactions. The resource decisions of the planning system consist of quantity of each product to be produced on each machine, quantity of raw material consumed, quantity of product inventory and in process inventory levels of finished goods.

Table 2 shows the details of resource utilization of component 1 which has been collected for one year. The application provided the motivation to the management for implementing the model. The complete production operation of the company was motivated to the process of using integrated models. The proper integrated model was developed with excel macrons to import the practical parameters. Different Options for the First activity of Example component 1 is shown in Table 3.

4. Case example for finned tubes production cost calculation per day

4.1. Production cost per unit under normal cost calculation

In the normal system, overall production cost is allocated to finished goods based on material, machine and other resource utilization with specified time.

The total production cost as per old order

Rs. 4,800,000

Estimated machine working hours cost:

Table 2
Details of Resource Utilization Component 1.

ActivityDescription	Finning	Defining	Decreasing	Assembly	Welding	Testing	Packing	Dispatching
Activity Number	1	2	3	4	5	6	7	8
Precedent Activities	1	1	1	2,3	4	4,5	6	6
No. of Options	7	5	6	11	3	10	5	8
Types of Required Resources	7	6	6	8	6	6	7	5

Table 3
Different Options for the First Activity.

Number of Resources required											
Option No.	Needed Quantity (Nos.)	Size of the Tube (mm)	(Weeks) Duration	R1	R2	R3	R4	R5	R6	R7	Total Cost Rs/-
1	1200	37	2	4	2	11	0	0	3	1	247,645
2	1800	40	3	4	2	12	0	0	3	1	369,988
3	2200	44	3.5	4	2	12	0	3	3	1	492,331
4	2500	50	4	4	2	14	0	3	4	1	614,674
5	3000	54	4.5	5	3	14	1	3	4	0	737,017
6	3460	60	5	6	3	17	1	3	4	0	859,360
7	3920	64	6	6	3	17	1	3	4	0	981,703

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Table 4
Shows the calculation of allocation rate for each process. The resource allocation rate calculation for each shift has been reported in Table 5.

Type of Process	Process Cost	Allocation Rate
Finning	0.60 per fin tubes	Rs. 942,000/1,570,000
Finishing	43.00 per finishing	Rs. 860,000/20,000
Quality	16.00 per inspection	Rs. 1,240,000/77,500
Purchase control orders	5.00 per purchase order	Rs. 950,400/190,080
Machine hour	0.30 per Machine hour	Rs. 57,600/192,000
Machine setup	25.00 per Machine setup	Rs. 750,000/30,000

Shift (8.0 h × 50,000 units)	Rs. 176,000
OT (4.0 h × 6,000 units)	Rs. 16,000
Total estimated machine hours cost:	Rs.192,000
Estimated allocation rate per machine cost (Rs.4,800,000/192,000)	Rs. 25.00

The total Production cost per unit is the sum of per unit direct material, labor, machine usage, and allocated overhead, as follows:

For a Single Shift:		
Direct material		Rs.12480.00
Direct labor	[1.5 DL hrs × Rs 720]	Rs.1080.00
Machine usage [8 hrs × Rs 108]		Rs.8640.00
Overhead [8 hrs × Rs1500]		Rs.12000.00
Total Production Cost		Rs.34200.00
For a Single OT:		
Direct material		Rs.6240.00
Direct labor	[1.5 DL hrs × Rs 720]	Rs.1080.00

Machine usage [8 hrs × Rs 108]	Rs.	4320.00
Overhead [8 hrs × Rs1500]	Rs.	6000.00
Total Production Cost	**Rs. 17640.00**	

4.2. Production cost per unit under integration calculation

First, calculate the allocation rate for each item. Next, calculate total Production costs allocated to each product under the integrated resource planning system and then calculate the total Production cost per unit. Table 4. shows the calculation of allocation rate for each process. The resource allocation rate calculation for each shift has been reported in Table 5.

The application provided the motivation to the management for implementing the model. The complete production operation of the company was motivated to the process of using integrated models. The proper integrated model was developed with excel macrons to import the practical parameters. In the normal system, overall production cost is allocated to finished goods based on material, machine and other resource utilization with specified time. The cost analysis results are shown in Table 6.

Table 5
Resource Allocation Rate Calculation.

Type of Process	Single Shift Allocation Rate	Process Cost [Rs]
Finning	1,185,000 fins × Rs. 0.60	7,11,000
Finishing	16,200 cutting × Rs. 43	6,96,600
Quality control	56,200 inspections × Rs. 16	8,99,200
Purchase orders	80,100 POs × Rs. 5	4,00,500
Machine power	176,000 mach hrs × Rs. 0.30	52,800
Machine setups	16,000 × Rs. 25	4,00,000
Total Production Cost		31,60,100
Total Production Cost per unit	Rs. 3,160,100/22,000	143.64
Type of Process	Over Time (OT) Allocation Rate	Process Cost [Rs]
Finning	385,000 fins × Rs. 0.60	2,31,000
Finishing	3,800 cutting × Rs. 43	1,63,400
Quality control	21,300 inspections × Rs. 16	3,40,800
Purchase orders	109,980 POs × Rs. 5	5,49,900
Machine power	16,000 mach hrs × Rs. 0.30	4,800
Machine setups	14,000 × Rs. 25	3,50,000
Total Production Cost		16,39,900
Total Production Cost per unit	Rs. 3,160,100/22,000	74.54

This MRP II system is also designed to make the production process more efficient, improve the customer service and to satisfy them. It allows a large amount of data to be securely backed up with makespan and cost effective to make the process easily. This proposed sys-tem developed in scholastic search way to bring optimized results in stipulated time with respect to optimum schedule and also tested in two different Production Industries using Visual Basic .NET as the front end and MYSQL as the back-end tool. The system been tested with various sets of input data and has been found to be working properly.

The integration of Production resource planning with Job shop scheduling implements their objectives based on specific goals. One is to maximize the valve of profit by examining the processes and second is the methods for inclusion and timely exclusion if not meeting the process objectives.

5. Conclusions

An integrated enterprise application has been successfully developed and implemented for the integration of production functions with job shop scheduling. Also the integrated model was validated with real time industrial case study data. The proposed integrated approach monitors the integral flow of the mate-

Table 6
Case Example calculation of production cost by integrated method with Normal method.

Production cost per unit (Example data)					
Total estimated machine hours in sec	192,000	432,000	512,000	698,000	92,000
Total production cost	48,00,000	52,00,000	59,00,000	63,00,000	9,00,000
Estimated allocation rate per machine cost in sec	11	12	14	15	2
Direct Material cost	12,480	18,720	28,080	42,120	8112
Direct Labour cost	1080	1620	2430	3645	702
Machine usage cost	8640	12,960	19,440	29,160	5616
Overall cost	12,000	18,000	27,000	40,500	7800
Total production cost under normal method	34,200	51,300	76,950	115,425	22,230
Total production cost under integrated model	30,438	45,657	68,486	102,728	19,785

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rial process, production process, machine setup cost, material cost associated with finished goods and inventory tardy jobs. According to the testing results of the application, it shows that the proposed system has good performance in terms of minimizing the overall production cost. The quality of the resource planning is the inherent part of the research work. The extended constraints has rapid responses to the scope introduced and solving managing risk environment for opportunities with optimum utilization of Production resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] R.Kollura et. al. (2000),'' A framework for the development of agile manufacturing enterprise'', Proceeding of the 2000 IEEE international conference on Robotics and Automation, San Francisco, CA, April 2000, Vil.2, PP 1132-1137
[2] Peter Brucker, (2006),''Scheduling algorithms'', Fifth Edition.
[3] Alper Turkyilmaz et. al. (2020), ''A research survey heuristic approaches for solving multi objective flexible job shop problems'', Journal of intelligent manufacturing, Springer.
[4] N.K. Shah, M.G. Ierapetritou, Integrated production planning and scheduling optimization of multisite, multiproduct process industry, Comput. Chem. Eng. 37 (2012) 214–226, https://doi.org/10.1016/j.compchemeng.2011.08.007.
[5] G. Urrutia et al., Solving the Integrated Lot-Sizing and Job-Shop Scheduling Problem, Int. J. Prod. Res. 52 (2014) 5236–5254, https://doi.org/10.1080/00207543.2014.902156.
[6] Z. Li et al., Process scheduling under uncertainty Review and challenges, Comput. Chem. Eng. 32 (2008) 715–727, https://doi.org/10.1016/j.compchemeng.2007.03.001.
[7] An, Y.-W & Yan, H.-S. (2012). Integrated optimization for production planning and scheduling in a two-stage production system. Jisuanji Jicheng Zhizao Xitong/Computer Integrated Manufacturing Systems, CIMS. 18. 796-806.
[8] Shang, Wenli & Fan, Yushun. (2004), ''Integrated Optimization Model of Production Planning and Scheduling for Batch Production'', Volume No. 11. 419-421.
[9] Zhang, X.-D & Yan, Hellen. (2005), ''Integrated optimization of production planning and scheduling for a kind of Job-shop. International Journal of Advanced Manufacturing Technology'', Volume No. 26. 876-886. 10.1007/s00170-003-2042-y.
[10] W. Li, C. McMahon, A simulated annealing based optimization approach for integrated process planning and scheduling, Int. J. Comput. Integr. Manuf. 20 (1) (2007) 80–95.
[11] M. Gen, L. Lin, Multi objective evolutionary algorithm for manufacturing scheduling problems State-of-the-art survey, J. Intell. Manuf. 25 (2014), https://doi.org/10.1007/s10845-013-0804-4.
[12] Y. Guo, W. Li, A. Mileham, G.W. Owen, Applications of particle swarm optimisation in integrated process planning and scheduling, Robot. Comput. Integrat. Manuf. 25 (2009) 280–288, https://doi.org/10.1016/j.rcim.2007.12.002.
[13] Lin, Laxy & Hao, X. & Gen, Mitsuo & Ohno, K.. (2012), ''A hybrid evolutionary algorithm for integrated production planning and scheduling problems'', Proceedings of International Conference on Computers and Industrial Engineering, CIE. 2. 1099-1114
[14] Carvalho, Marcius & Haddad, Rosana. (2012), ''Production Scheduling on Practical Problems'', 10.5772/26319.
[15] Yan, Hellen & Zhang, X.-D. (2007), ''A Case Study on Integrated Production Planning and Scheduling in a Three-Stage Manufacturing System'', Automation Science and Engineering, IEEE Transactions on. 4. 86 - 92. 10.1109/TASE.2006.872107.
[16] Muzaffer Eusuff et. al. (2006), '' Shuffled frog leaping algorithm a memetic meta heuristic for discrete optimization'', J. Eng. Optimization, Volume No. 38, Issue 2.
[17] Ramya G. & Chandrasekaran, Dr.M, (2014). ''Shuffled frog leaping algorithm approach to employee timetabling and job shop scheduling'', Int. J. Int. Manuf. Serv.

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