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MINIMIZATION OF MAKE SPAN THROUGH A NEW CONCEPT OF SCHEDULING SYSTEM BASED ON RCPSP HEURISTICS

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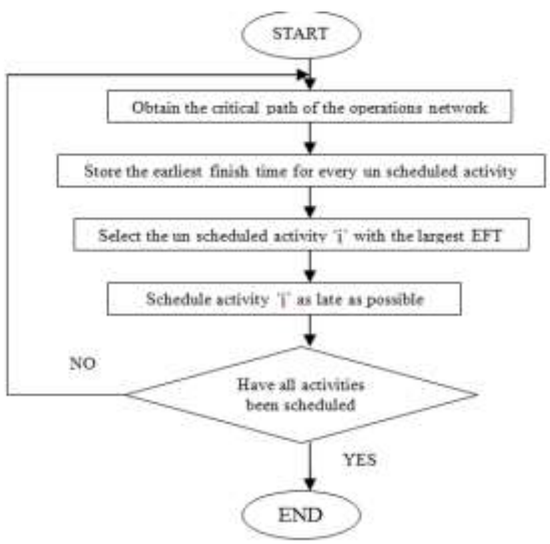
ABSTRACT

In this paper we consider the problem of scheduling the tasks to workers in a make to order manufacturing company where the products are massive vibrating screens. We consider the above problem because the workers had given more importance as they are the main resources to form the structures following a detailed design drawing. As there is limited work force we considered the RCPSP heuristics taking into account the main constraint as work force. In a make-to-order manufacturing company all the production activities commences when the customer order arrives, hence a detailed step by step procedure from execution of order to shipment was explained in the proposed scheduling system. Then scheduling the operations would be done through LESTA,MINSLK,and H1 heuristic using these heuristics an attempt was made to minimize the make span.
I Introduction

KEYWORDS: RCPSP , LESTA,MINSLK, and H1 .

SECTION -1

GLESTA (Generalized lead time evaluation and scheduling algorithm)



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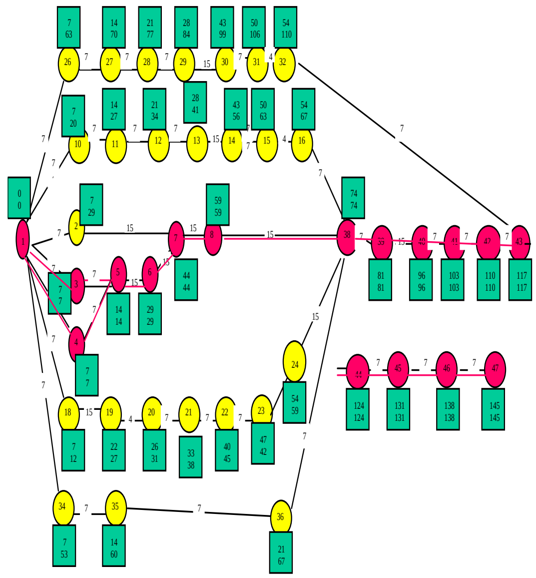

Figure 1 . Operations network for OMNI screens

TABLE-1
Activities Description and their corresponding Resources, Slack, EFT, Duration

ACTIVITY predecessor event(i)	successor event(j)	ACTIVITY DURATION (tij)	EARLIEST start time (TEi)	Tej=Tei+tij finish time (TEj)	LATEST start time (TLi)	Tli=TLj-tij finish time (TLj)	SLACK TLj-TEj
1	2	7	0	7	22	29	22
1	3	7	0	7	0	7	0
1	4	7	0	7	0	7	0
1	10	7	0	7	13	20	13
1	18	7	0	7	5	12	5
1	34	7	0	7	46	53	46
1	26	7	0	7	49	56	49
2	7	15	7	22	29	44	22
3	6	7	7	14	7	14	0
4	5	7	7	14	7	14	0
5	6	15	14	29	14	29	0
6	7	15	29	44	29	44	0
7	8	15	44	59	44	59	0
8	38	15	59	74	59	74	0
10	11	7	7	14	20	27	13
11	12	7	14	21	27	34	13
12	13	7	21	28	34	41	13
13	14	15	28	43	41	56	13
14	15	7	43	50	56	63	13
15	16	4	50	54	63	67	13
16	38	7	54	61	67	74	13
18	19	7	7	14	20	27	13
19	20	12	14	26	19	31	5
20	21	7	26	33	31	38	5
21	22	7	33	40	38	45	5
22	23	7	40	47	45	52	5
23	24	7	47	54	52	59	5
24	38	15	54	69	59	74	5
26	27	7	7	14	63	70	56
27	28	7	14	21	70	77	56
28	29	7	21	28	77	84	56
29	30	15	28	43	84	99	56
30	31	7	43	50	99	106	56
31	32	4	50	54	106	110	56
32	34	7	54	61	110	117	56
34	35	7	7	14	53	60	46
35	36	7	14	21	53	60	39
36	38	7	21	28	60	67	39
38	39	7	74	81	74	81	0
39	40	15	81	96	81	96	0
40	41	7	96	103	96	103	0
41	42	7	103	110	103	110	0
42	43	7	110	117	110	117	0
43	44	7	117	124	117	124	0

TABLE-2
Calculation of EST, EFT, LST, LFT, SLACK

ACTIVITIES	46 to 47	45 to 46	44 to 45	43 to 44	42 to 43	41 to 42	40 to 41	39 to 40	38 to 39	8 to 38	24 to 38	32 to 43	16 to 38	7 to 8
EFT	145	138	131	124	117	110	103	96	81	74	69	61	61	59
DURATION	15	7	7	7	7	7	7	15	7	15	15	7	7	15
SLACK	0	0	0	0	0	0	0	0	0	0	5	56	13	0
SH TIME (hrs)	145	138	131	124	117	110	103	88	81	66	51	100	66	45
RESOURCES ↓	SP	F	TESTING	F	W	F	F	2F	F	2w	2w	DRILL M/C	MILLING M/C	2F
	145	138	131	124	117	110	103	88	81	66	51	100	66	45
F1		45 to 46		43 to 44		41 to 42	40 to 41	39 to 40	38 to 39					7 to 8
F2								39 to 40						7 to 8
F3														
W1					42 to 43					8 to 38	24 to 38			
W2										8 to 38	24 to 38			
C1														
C2														
PACM														
MILLING M/C													16 to 38	
LATHE														
SHAPER														
DRILLING M/C												32 to 43		
SPRAY PAINTING	46 to 47													

31 to 32	15 to 16	23 to 24	30 to 31	14 to 15	22 to 23	6 to 7	29 to 30	13 to 14	21 to 22	20 to 21	5 to 6	36 to 38	28 to 29
54	54	54	50	50	47	44	43	43	40	33	29	28	28
4	4	7	7	7	7	15	15	15	7	7	15	7	7
56	13	5	56	13	5	0	56	13	5	5	0	39	56
96	63	46	89	53	39	30	74	38	32	25	15	60	67
F	W	F	MILLING M/C	F	LATHE	MILLING M/C	2W	2W	SHAPER	DRILL M/C	2F ,2W	F	F
96	63	46	89	53	39	30	74	38	32	25	15	60	67
31 to 32		23 to 24		14 to 15			29 to 30				5 to 6	36 to 38	28 to 29
							29 to 30				5 to 6		
	15 to 16												
								13 to 14			5 to 6		
								13 to 14			5 to 6		
			30 to 31			6 to 7							
					22 to 23								
									21 to 22				
										20 to 21			

TABLE-3
Scheduling activities to resources using GLESTA

The algorithm performs detailed backward scheduling initially it assumes some lead time for the above example 150hrs is the assumed lead time and then it stores the EFTs of all the activities and starts scheduling with the largest EFT first. for example for the above problem largest EFT was 145hrs for activity 46 and its duration was 15hrs so it

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must be scheduled as late as possible at t=150-15, ie 145 and its completion time was 150 hrs and the resource was spray painter, like wise it schedules all the activities to the resources if the resource was not available it schedules at the next available time the above was done with minimum resource requirements. We can vary the workforce depending upon the lead time that customer wants.

The drawback we found was it is not applicable when the company works for only two shifts, at particular time the worker may not be available this makes the schedule to again rework for corrections. Hence we have taken into consideration the workers availability times to make the schedule more realistic, and explained in section 2

SECTION - 2

MINSLK (Minimum slack method)

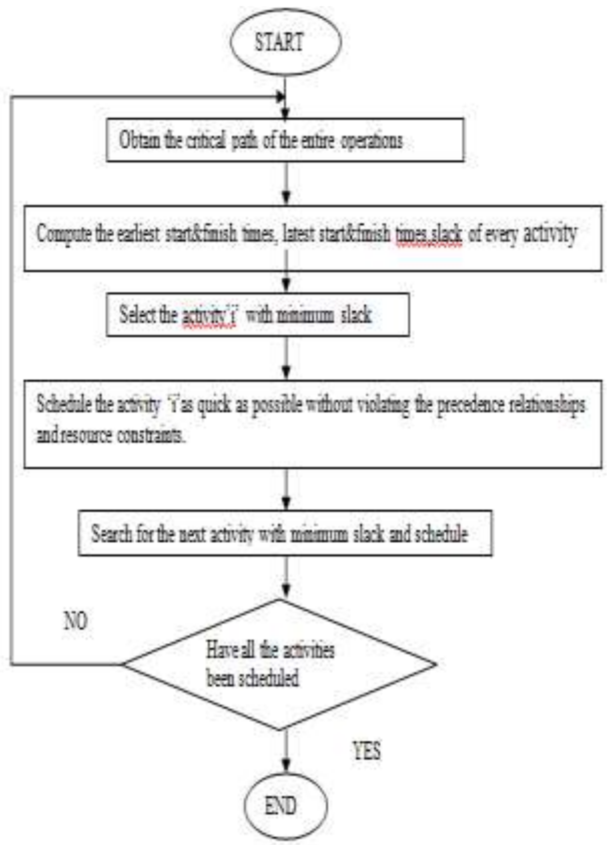

Fig.3 Flow chart for MINSLK

TIME IN HRS→	0	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152
RESOURCES↓																				
F1	3		2		5		7		14		38		39		41		43		45	
F2		2		5		19		7		23		39		40		42		31		
F3					12		35	36		28										
W1					5		13		8		15		24		29				32	
W2				5		13				8		15		24		29				
C1	3		2						27											
C2		2		11																
PACM	4	10	34					26												
MILLING M/C	18	18			6	6							16				30			
LATHE						22														
SHAPER								21												
DRILLING M/C		4					20										32			
SPRAY PAINTING																				46
TESTING																		44		

TABLE-4
Scheduling using LETSA& MINSLK method

The above schedule Was generated considering the key points in LESTA and MINSLK first of all we go for smallest EFT if there is tie, or resource constraint we will select the activity which is having minimum slack first, schedule the activity and then go for next minimum slack activity. While scheduling the scale constituting workers availability times was taken in to account and schedule made correlating the times.

SECTION-3

H1 HEURISTIC

LFT	44	14	29	59	41	63	31	59	84	110	60
LST	29	7	14	44	34	56	27	52	77	103	53
DURATION	15	7	15	15	7	7	4	7	7	7	7
ACTIVITIES	2	3	6	7	12	14	19	23	28	31	35
F1	15	7	15	15	7	7	4	7	7	7	7
F2	18	8.4	18	18	8.4	8.4	4.8	8.4	8.4	8.4	8.4
F3	19.5	9.1	19.5	19.5	9.1	9.1	5.2	9.1	9.1	9.1	9.1
F1	44	14	29	59	41	63	31	59	84	110	60
F2	47	15.4	32	62	42.4	64.4	31.8	60.4	85.4	111.4	61.4
F3	48.5	16.1	33.5	63.5	43.1	65.1	32.2	61.1	86.1	112.1	62.1
MIN(F1,F2,F3)	44	14	29	59	41	63	31	59	84	110	60
	29-F3	7-F2	14-F1,F2	44-F1,F2	34-F2	63-F3	27-F1	52-F3	77-F1	103-F3	53-F2
F1											
F2											
F3											
	7	14	21	28	35	42	49	56	63	70	77

LST	14	59	41	59	84	110					
ACTIVITIES	5	8	13	24	29	42					
DURATION	15	15	15	15	15	7					
W1	15	15	15	15	15	7					
W2	19.5	19.5	19.5	19.5	19.5	9.1					
W3	24	24	24	24	24	11.2					
W1	29	74	56	74	99	117					
W2	33.5	78.5	60.5	78.5	103.5	119.1					
W3	38	83	65	83	108	121.2					
W1	5				13		8		24		
W2		5				13		8		24	
W3											
	14	21	28	35	42	49	56	63	70	77	84

67	81	88	103	110	117	124
60	74	81	96	103	110	117
7	7	7	7	7	7	7
36	38	39	40	41	42	43
7	7	7	7	7	7	7
8.4	8.4	8.4	8.4	8.4	8.4	8.4
9.1	9.1	9.1	9.1	9.1	9.1	9.1
67	81	88	103	110	117	124
68.4	82.4	89.4	104.4	111.4	118.4	125.4
69.1	83.1	90.1	105.1	112.1	119.1	126.1
67	81	88	103	110	117	124
60-F1	67-F2	81-F1	88-F2	103-F1	110-F2	117-F1
84	91	98	105	112	119	126
	29					
29				42		
91	98	105	112	119	126	
67	81	88	103	110	117	124
60	74	81	96	103	110	117
7	7	7	7	7	7	7
36	38	39	40	41	42	43
7	7	7	7	7	7	7
8.4	8.4	8.4	8.4	8.4	8.4	8.4
9.1	9.1	9.1	9.1	9.1	9.1	9.1
67	81	88	103	110	117	124
68.4	82.4	89.4	104.4	111.4	118.4	125.4
69.1	83.1	90.1	105.1	112.1	119.1	126.1
67	81	88	103	110	117	124
60-F1	67-F2	81-F1	88-F2	103-F1	110-F2	117-F1
84	91	98	105	112	119	126
	29					
29				42		
91	98	105	112	119	126	

TABLE-5

Scheduling using H1 heuristic

In the above method the we have taken in to consideration only workers i.e.(fitter groups &welders)and the processing times taken by different workers. The schedule starts by choosing the least processing times and then scheduling forward matching the latest finish times with the workers availability times. if no past data was available regarding the processing times, skill co efficient of worker is considered i.e. if the worker is most skilled then he will be allotted 1 as skill co efficient (k) k>=1,tij is the minimum time taken by the most skilled worker. Tij is the waiting time, fitting up time, setting time e.t.c[3],then total time=K(tij+Tij).

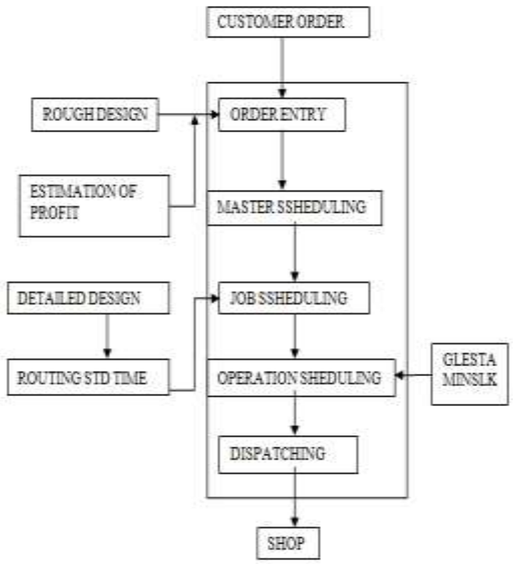

Fig 4 Proposed scheduling system

Order entry system

The function of the order entry system is to screen the order and to set the due date of the order accepted. The decisions to be made in the order entry system, i.e. screening the order and setting the due date of the accepted order, are not always made by the maker side only. Sometimes it is made by negotiations between the maker and the customer.

The customer submits the terms desired on the price, the due date and the specification of the product. The order entry system offers the answers to these terms. If the customer satisfies these answers, the order is accepted. If the customer is not satisfied, negotiations will be held, and if an agreement could be reached between both the sides, the order is to be accepted. If a customer order is accepted, a formal order number is given to it. Newly accepted orders are generally called planned order. As was shown in Fig. 6, at first, the rough design was made on inquiry. Secondly, estimation is made on the manufacturing cost, the specification, and the due date based on the rough design. Thirdly, with these estimates, negotiations are held between the customer and the maker. The criteria of the negotiation are policy, technological possibility, profit, due date and optimal usage of the capacity. If both reach an agreement, the order is accepted, and the due date of the order is decided.

desire of the customer on the due date. In some cases, this filter can be omitted. Following notations are used. *Wi:* rough estimation of work load of order *i*, *B,:* total backlog of the shop at time t, *B,:* standard value for capacity usage filter. If inequality (3) holds well, the order is to be accepted.

$$B_c \geqslant W_i + B_t \qquad (3)$$

Let us make this event the proposition y. Based on these three propositions, another proposition s is made. s: (accept the order).

Then, the following can be thought as examples of the mechanism of screen:

(i) $P \wedge q \wedge \gamma \rightarrow s,$

(ii) $P \vee q \vee \gamma \rightarrow s,$

(iii) $P \wedge (q \vee \gamma) \rightarrow s,$

(iv) $P \wedge q \rightarrow s,$

(v) $P \vee q \rightarrow s.$

In case of (i), if all the propositions are satisfied, the order is to be accepted. In case of (v), if either of the two propositions is satisfied, the order is to be accepted. First of all, the mechanism of screen must be studied. [2]

Definition of the standard value for each filter

Next point is how to define the standard value of each filter that is what kind of variable should be used. For example, as the variable for profit filter, amount of money, its rate to total cost or sales price, and others can be used.

Setting the practical figure of standard value of each jilter

The practical figure of standard value differs due to the conditions of the shop, i.e. capacity, backlog, etc.

Estimation of the profit and the due date

It is necessary to estimate the profit to be gained, the due date and work load of the order. The profit would be estimated by the cost accounting department. The due date and work load of the order must be estimated in scheduling system. The due date of the order is expressed by Eq. (4) $Di = Ai + Li$ where (4) Ai is the possible start date of order i and Li is the estimated manufacturing lead time of order i. Especially, accurate estimation of the manufacturing lead time is vital to make a good schedule. The method of estimating the manufacturing lead time should be studied.[2]

Master scheduling system

Once the customer order is accepted, it is changed into a planned order and is turned over to the master scheduling system. In this system, what is called master schedule is made. Master schedule consists of detailed design schedule, fabrication schedule, and assembly schedule. Firstly, detailed design schedule is made by forward scheduling method. Secondly, assembly schedule is made by backward scheduling method starting from the due date of the order. Lastly, fabrication schedule is made so as to be inserted between assembly schedule and schedule of detailed design. Fabrication schedule is made on the basis of a general block of product structure. In this phase, capacity planning is also made, and outside order plan is made as occasion demands. An example of the master schedule is shown in Fig. 5.2 As was shown in Fig.5.2 master schedule shows (1) when detailed design should be started and finished, (2) when parts fabrication should be started and finished, and (3) when assembly should be started and finished. After the master schedule is made, the order for detailed design is given to the product engineering department. Input to master scheduling system is planned order, skeletonized routing, overall backlog, shop capacity, and so forth. In order to design an effective master scheduling system, where only rough information's are available, manufacturing lead-time estimation method in such circumstance must be developed.

Job scheduling system

The detailed drawings of the product are made in the product engineering department. And manufacturing methods, facilities, tools and jigs are determined. Based on these data, routing and standard times are made. In job scheduling system, the master schedule

is broken down into much minute schedule with possible start day and due finish day, on job basis and on work center basis. In short, job schedule says that a certain job of a certain order should be done in the designated work center within the span of time from the possible start day to the due finish day. An example of job schedule is illustrated by Fig. 8. The function of job scheduling system is to make the schedule of the jobs constructing the order. When open orders are sent from the master scheduling system to job scheduling system, there exist many jobs which already have been given job schedule. The schedule of new jobs is made so as to put them into the existing schedule. The logics of decision in job scheduling system are classified into two types, namely, loading method and lead-time method. The basic concept of loading method is "a given set of facilities (e.g. work center) has a fixed capacity within a certain span of time (loading horizon)". Thus, the schedule is made by loading the work to the fixed capacity. Then the jobs loaded within a certain horizon must be started and finished within this horizon. In case of the loading method, following should be studied to develop an effective method. (a) How to set the loading horizon? If the loading horizon is too short, delicate schedule may be possible, but jobs with long standard time cannot be loaded in one span. And loading logic will be too complicated. (b) How to estimate the capacity? In case capacity can be expressed by man hour or machine hour per work center, it can be simply estimated by multiplying the number of work station by the length of the loading horizon. However, this estimation can be applied only when no alternative routing is allowed and when work station is free from break down. (c) How much work can be loaded on the capacity, even if it is estimated? If load ratio is l00%, the schedule cannot be feasible because of interference. Then it should be made clear to what percent work can be loaded. In job scheduling system by lead-time method, each job is to be given a lead time in accordance with the backlog of the designated work center and with the attributes of the job itself. Therefore, the schedule made by this method could be fine if these actors are adequately reflected. And this method is free from the problems of the job scheduling system by loading method.

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CONCLUSION

In this paper we had presented RCPSP heuristics to schedule operations and an attempt is made to schedule tasks to workers as per the requirement of the production system within which the worker groups i.e. (fitters & welders) play an important role in forming the structures. Further we proposed the systematic way of scheduling so as to satisfy the customers by delivering the products on time. The proposed scheduling system is having filters to screen the order so that the order which may lead to loss in future cannot be accepted. Thus forming a hierarchal based scheduling system which includes decision to be taken at each stage of the system. Up to now researchers proposed plenty of heuristics and methods for job shop scheduling but scheduling of tasks to workers is very few. Here an attempt was made to minimize the make span with the help of the above mentioned heuristics considering the workers skill to do a particular task. Because specially in this production system the workers are supposed to form structures from detailed drawings which is time consuming unless he is having sufficient experience. Hence taking into consideration the skill and experience plays an important role in minimizing the make span.

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