



Profit Based Scheduling Using Agent Based Architecture: A Single Machine

Problem

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Abstract

Today's manufacturing enterprises need to measure the capability to able to improve their profit-earning capacity. Profit-earning capacity of a manufacturing system can be defined as ability of generate profits. Aim of this study is to develop a methodology to increase profitability. For that purpose a profit based scheduling model is generated using agent-based architecture in an integrated manufacturing environment to increase responsiveness, and flexibility of the manufacturing system. Results of profit based scheduling and the advantages for Small and Medium size Enterprise (SME) are introduced.

Keywords: Scheduling, Agent Based Systems, Profit, Single Machine

Introduction

Recently, global environmental challenges as well as the development of advanced computer-based modeling and analysis tools have expanded interest in the use of computational approaches to the study of human systems. As a computer based modeling and analysis tool, simulation techniques introduces the possibility of a new way of thinking about social and economic processes, based on ideas about the emergence of complex behavior from relatively simple activities [1]. Although computer simulation has been used widely since the 1960s, Agent based systems only became popular in the early 1990s. Agent based systems can be used to study how micro-level processes affect macro level outcomes. A complex system is represented by a collection of agents that are programmed to follow simple behavioral rules. Agents can interact with each other and with their environment to produce complex collective behavioral patterns. Macro behavior is not explicitly modeled; it emerges from the micro-decisions of individual agents [2], so Agent Based Modeling Simulation (ABMS) still requires research attention. With the availability of more sophisticated modeling tools, ABMS, can be extensively used by the game and film industry to develop realistic simulations of individual characters and societies. ABMS are also applied in different areas, some of them are about scientific domain; chemistry [3], physics [4], biology [5], ecology [6] etc, some of them are applied to various micro simulation [7], object oriented [8] or individual-based simulation techniques [9], as useful tool for decision making [10], computer games, for example The SIMS™ [11], enterprise improvement [12], military applications [13] etc.

Some features of MABS can be list as follow;

1. *Multi-threading*; the autonomous behavior of each simulation agent can be modeled using a program code executed with in its own thread of control. [14].
2. *High communication-to-computation ratio*. The 'social' behavior of agents embodied in MABS requires that agents communicate with each other or with information directory services to update their knowledge (beliefs) and accomplish a collective task. [14].



3. *Time-step synchronization.* For the simulation to reflect the chronological sequence of events in the real world problem and guarantee causality, a central reference clock needs to be established. The interval between successive 'ticks' of the clock is the smallest possible indivisible period of time for the simulation [18]. The execution of the simulation advances in steps of this unit of time. Each agent executes some task (defined as granularity) corresponding to what the simulated entity accomplishes in the real world between two successive clock ticks [14].

Control of manufacturing functions such as order management has some difficulties when planning operations dynamically. Multi agent-based system is a popular developing area of distributed artificial intelligence that provides integration and coordination between distributed manufacturing function for the management of manufacturing environments. This paper proposes a multi-agent based single machine scheduling model concerning the profit based approach within a manufacturing system. The difference between cost-based approach and profit-based approach could be summarizing as instead of reducing the cost, a profit-based scheduling refers to the profit margin to schedule for the manufacturing orders. The proposed multi-agent based approach works under a real-time environment and generates feasible and most profitable schedules using negotiation/bidding mechanisms between agents. Model components and agent principles are defined in section2

Profit Based Scheduling Model

Single machine scheduling problem is consists of a single machine to process n jobs. In this study is objective function defined as maximization of the profit of these n jobs.

Model is constructed for small reference production system whit n independent job on a single machine under the time constraint. Purposed model is including a set of three integrated agent based modules namely, Order Analysis Agent (OAA), Profit Analysis Agent (PAA), and Reporting and Scheduling Agent (RSA) Figure 1 shows the relationship of these agents where the arcs are indicating the work flow.

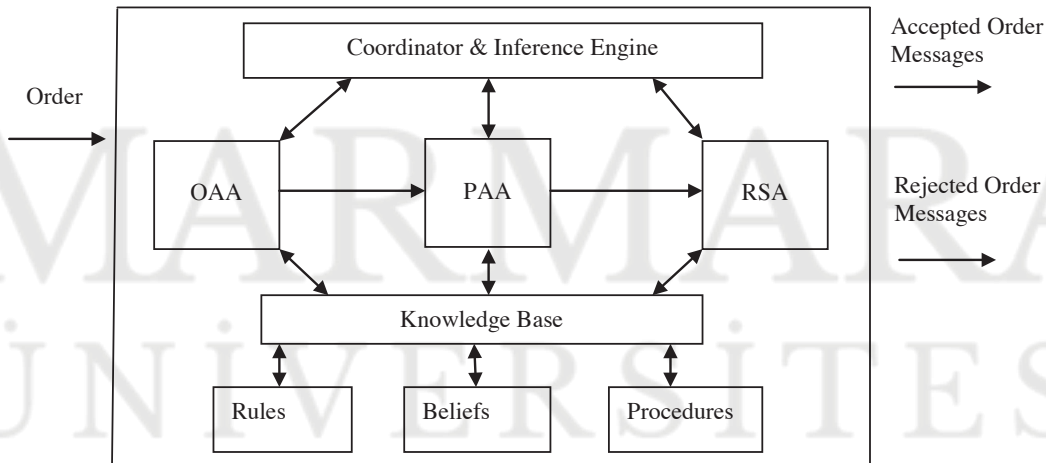


Figure 1. Component of PBSM

Each agent architecture is detailed in respective section

Order Analysis Agent (OAA): Primary task of OAA is to identify predefined set of order of small manufacturing system and support the assessment with respect to whether those are acceptable or not.

After customer orders are generated depends on a given distribution, OAA uses three analysis methods for decision of accepting or rejecting of an order and related production sequence of the orders. First analysis technique is "Model-1: Unit Profit Model (UPM)" which is defined as most profitable product is produced first.



Business rules of UPM are;

- Prepare a list of orders with respective order quantity
- Compute the needed production time of each order
- Elaborate unit profits of each order
- Define most profitable order list from up to down
- Generate a production sequence to report

Second analysis technique is “Model 2: Daily Profit Model (DPM)” which considers that the most daily profitable product is selected to produce first.

Business rules of DPM are;

- Prepare a list of orders with respective order quantity
- Compute the needed production time of each order
- Elaborate daily profits of each order depends on machine capacity
- Define most profitable order list from up to down
- Generate a production sequence to report

And last analysis technique is “Model 3: Total Profit Model (TPM)” where the most profitable order is processed.

Business Rules of DPM are;

- Prepare a list of orders with respective order quantity
- Compute the needed production time of each order
- Elaborate Total profits of each order depends on order quantity
- Define most profitable order list from up to down
- Generate a production sequence to report

Figure 2 shows OAA components where each model represents a different analysis approach.

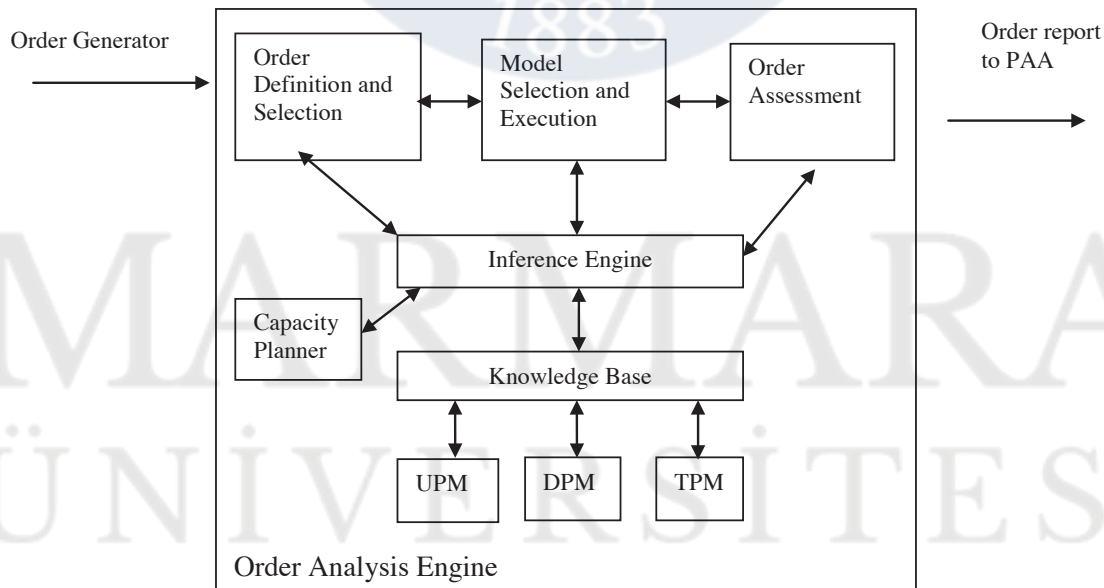


Figure 2. Order Analysis Agent Architecture

OAA engine defines the 3 different manufacturing sequence of orders depends on 3 different models explained above. This information is transmitted to Profit Analysis Agent to make profit analysis

Profit Analysis Agent (PAA): PAA is responsible to selection of most profitable sequence of three different models. After an order report is prepared by OAA, this information is carried out by Profit Analysis Agent. PAA composed of multiple autonomous agents. Negotiation is a key function of PAA which is satisfies interaction in groups of agents that enables mutual agreement including belief, goal or plan. In this study the simplest case of negotiation is used which could be define as the structure and



contents of the agreement are fixed. For that purpose calculation of accepted order profits for each 3 three sequence is elaborated by PAA and the agents' reasoning models provide the decision making which model attempt to achieve objectives.

Business Rules of PAA are;

- Calculate total profits of 3 types order sequence (UPM, DPM and TPM)
- Select most profitable sequence to schedule manufacturing
- if total profits of three models are equal send this information to order elaborator
- Order elaborator selects the technique which has maximum number of order in it to satisfy more customers and sends the selected profit model schedule to scheduler
- When all total profit values and number of accepted orders are same for each 3 models. Select the model randomly.

After analysis is done, PAA sends related information (selected model and related production schedule) to Scheduling Agent to preparation of a job order and sends to Reporting Agent to preparation of a form to inform customers. Figure 3 shows its components where each component represents model selection and amount determination.

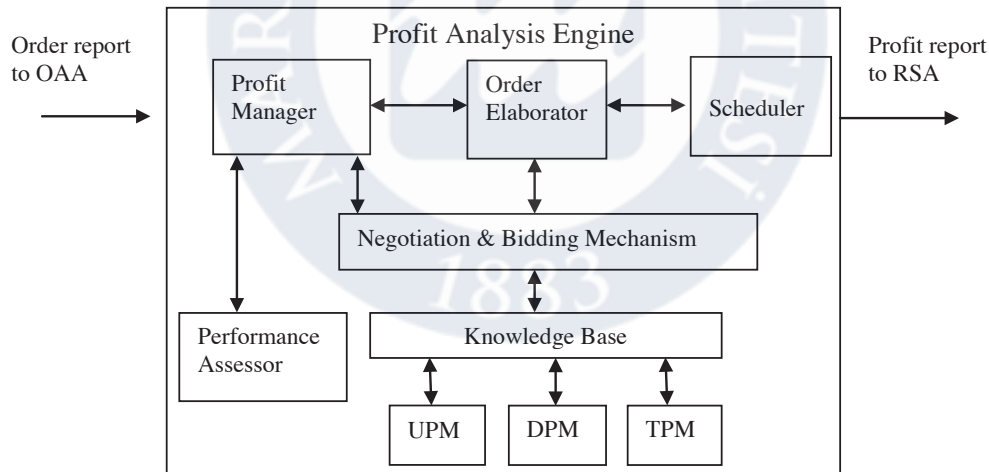


Figure 3. Profit Analysis Agent Architecture

Reporting and Scheduling Agent (RSA): RSA is responsible for preparing a form indicating the status of order acceptance or rejection messages as well as due dates for accepted orders to inform customers. After received selected model information by RSA, Scheduling engine prepares a job order form to use manufacturing which is including accepted order schedule and related due dates.

Business rules of RSA are;

- Prepare job order list for accepted orders.
- Check scheduled delivery date of orders and give an approval form
- if there is a late job send this information to Coordinator & Inference Engine to start new scheduling process
- Prepare an order acceptance report to send customers including delivery date or rejection of given order

Figure 4 shows it's the architecture of RSA

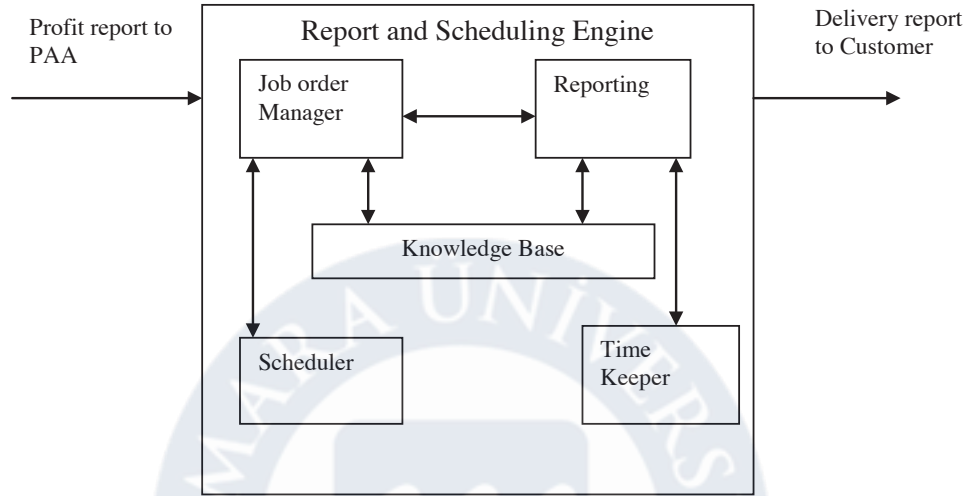


Figure 4. Reporting and Scheduling Agent Architecture

In this section a prototype profit based scheduling model based on agent based architecture is introduced. Model execution of the proposed model is outlined in next section.

Model Execution

In this part of study the capability of the proposed model in a single machine manufacturing environment will be detailed and respective issues will be discussed. First step of the implementation is identification of the model parameters;

- J : set of scheduled operations,
- J^d : candidate to schedule jobs at time t ,
- J^c : set of unscheduled jobs at time t
- t : scheduling time
- P_j : unit processing time of job j
- d_j : due date of job j
- C_j : completion time of job j
- Pr_j : unit profit of job j
- Dm_j : amount of demand of job j
- PR_i : product type i

The problem is identified as $1 \parallel Pr_{max}$. The jobs may not be preempted and each job j is characterized by its processing time P_j , its due date d_j and its profit value Pr_j .

Second step of implementation is definition of assumptions which are;

1. In order to measure the capability of reference model a hypothetical database is constructed which is explained in section 3.1
2. Simulation parameters are; Problem considers n independent jobs ($j=1,2,\dots,n$) on a single machine to maximize total profit. There are no precedence constraints between jobs and each job has a nonnegative due dates d_j ($d_j \geq 0$). Machine is continuously available and can process one job at a time.
 - a. P_j is generated from a discrete uniform distribution between 5 to 250 (in terms of second)



- b. d_j is generated from a discrete uniform distribution between 1 and 9 (in terms of day)
- c. Dm_j is generated from a discrete uniform distribution between 5 and 900 units
- d. Pr_j is calculated from the database (for the calculation method see next section)
- e. Schedule period is assumed 10 day
3. Product range is restricted with 9 different product.
4. It could be more than one order which is included same product.
5. An order could be involve only one type of product order

Model database is prepared including the following information.; Product types (A, B, C, D, E, F, G, H, I) and related product specifications which are given below;

- Maintenance Unit/day, Maintenance Time (min), Setup Time (min), Breaking Unit/day and Breaking Duration (min.) to calculation of lost time of a day;
 - Lost Time is calculated as ;
Lost Time = Maintenance Unit * Maintenance Time + Setup Time + Breaking * Breaking Time
- Daily available Working Time;
 - Daily Working Time = 8 hour * 60 minutes = 480 minutes for a day (for each type product.
 - Daily Available Time is calculated as ; Daily Working Time – Lost Time
For Example Product A is calculated as; 480-39 = 441 hour
- Mean Standard Time to calculation of daily production capacity.
 - Daily Capacity is calculated as ; (Daily Available Time * 60) / Mean Standard Time (sec)
For Example Product A is calculated as; (441*60)/ 210=126
- Unit Cost is calculated as ;((worker cost daily + Fixed Cost) / Daily Capacity + Row Material Cost/Unit)
 - Worker Unit which is necessary to produce each type of product
 - Worker Cost (daily) is calculated as; (1500*Worker Unit)/20 (1500 is the salary for one worker, assumed that each worker will take same salary. And 20 is number work day in a month.)
For Example Product A is calculated as; (1500*1)/20 =75
 - Fixed Cost Daily (includes management cost for company)
 - Row Material Cost for each type of product is given
For Example Product A is calculated as; ((75+1.000)/126) + 30) = 38, 13
- Unit Profit for each type of product is given
Unit price- unit cost
 - Daily Profit is calculated as; Daily Capacity * Unit Profit
For Example Product A is calculated as; 126*50 = 6.300 \$

Model execution;

In this part of study, execution of the purposed model is illustrated on a small example in order to demonstrate the algorithm. Sample order data is given in Table 1.

Table 1. Sample Order Data

PR_i	A	B	C	D	E	F	G	H	I
Dm_j	245	825	701	838	746	904	171	698	621
d_j	5	8	7	4	9	4	8	7	6

OAA engine selection mechanism of Unit Profit Model is shown in Table 2.



Table 2. Unit Profit Model Order Sequence Definition

Pri		A	B	C	D	E	F	G	H	I	Needed producti on Time (day)	Decision for due date (*)	Used Tim e (day)
Dmj		51 9	63 1	13	71 6	50 3	52 6	77 9	22 9	682			
d _j		6	7	8	3	8	6	3	3	8			
UPM Order Production Sequence	1	0	0	0	0	0	0	0	1	0	5,5	0	0,0
	2	0	0	0	2	0	0	0	0	0	2,2	1	2,2
	3	3	0	0	0	0	0	0	0	0	7,1	0	2,2
	4	0	4	0	0	0	0	0	0	0	1,0	1	3,2
	5	0	0	0	0	0	5	0	0	0	2,6	1	5,8
	6	0	0	0	0	6	0	0	0	0	0,8	0	5,8
	7	0	0	7	0	0	0	0	0	0	1,7	0	5,8
	8	0	0	0	0	0	0	8	0	0	0,4	1	6,2
	9	0	0	0	0	0	0	0	0	9	0,8	0	6,2

*Decision for due date is an integer variable; 1 for accepted order, 0 for rejected order.

$$=EĞER(M14<0;N13+L14;N13)$$

=EĞER(C6<0;C4/spesificatio
ns!C13;EĞER(D6<0;D4/spes
ificatio ns!D13;EĞER('orders
analysis'!E6<0;E4/spesificati
ons!E13;EĞER(F6<0;F4/spes
ificatio ns!F13;EĞER('orders
analysis'!G6<0;'orders
analysis'!G4/spesificatio ns!G1
3;EĞER(H6<0;'orders
analysis'!H4/spesificatio ns!H1
3;EĞER(I6<0;I4/spesificatio
ns!I13;EĞER(J6<0;J4/spesifi
cations!J13;K4/spesificatio ns!
K13))))))

=EĞER(C6<0;EĞER(L6<=C
5;1;0;0)+EĞER(D6<0;EĞE
R(L6<=D5;1;0;0)+EĞER(E6
<0;EĞER(L6<=E5;1;0;0)+E
ĞER(F6<0;EĞER(L6<=F5;1;
0;0)+EĞER(G6<0;EĞER(L
6<=G5;1;0;0)+EĞER(H6<0;
EĞER(L6<=H5;1;0;0)+EĞER
(I6<0;EĞER(L6<=I5;1;0;0)
+EĞER(J6<0;EĞER(L6<=J5
;1;0;0)+EĞER(K6<0;EĞER(
L6<=K5;1;0;0)

Orders of Product H is produced first than orders of E and G will be produced respectively.

After OAA completed the decision process, PAA starts to calculation of total profit of each model as can be seen in Table 3.

Table 3. Total Profit of Unit Profit Model

	A	B	C	D	E	F	G	H	I
Profit:	0	7965	0	1287 0	0	1248 0	2530	0	0
Total Profit	35845				Number of accepted order			4	

=EĞER(TOPLA(K6:
K14)>=1;'orders
analysis'!K4*spesific
ations!K19;0)

Related data for this sample trial including three model are summarized in Table 4.

Table 4. Summary Information of PAA

UPM	Total Profit	35480
	Number of Accepted Order	4
DPM	Total Profit	23365
	Number of Accepted Order	3
TPM	Total Profit	27880
	Number of Accepted Order	3
DECISION MODEL :		UPM
PROFIT		35480

After this step is completed RSA prepares a report for customer a job order for manufacturing. Report page for sample date is given in Table 5.



Table 5. Report Page of the PBSM

Product Type / Specifications	A	B	C	D	E	F	G	H	I
Customer Order	519	631	13	716	503	526	779	229	682
Customer Due date	6	7	8	3	8	6	3	3	8
Order Acceptance	reject	accept	reject	accept	reject	accept	accept	reject	reject
Delivery dates	0,00	0,00	6,35	0,00	8,59	0,00	6,64	5,00	0,00
Model Check	model consistent	model consistent	model consistent	model consistent	model consistent	model consistent	model consistent	model consistent	model consistent
Messages	Order rejected	Order accepted	Order rejected	Order accepted	Order rejected	Order accepted	Order accepted	Order rejected	Order rejected
Profit	35480	\$							

=EĞER(C7<=C5;"model consistent";"checkmodel")

=EĞER(TOPLA(J17:J25)>=1;"accept";"reject")

Reference model is operated 100 times (each trial has for 9 jobs) and results are recorded. Success frequency of each profit model is summarized in Figure 5. Model success defined as selected production sequence after each trial. Figure 5 shows that unit profit model gives better solution than others. 57 times of 100 trial total profit of UPM model gives portable solution for the manufacturing system. Contrary to expectations TPM gives only 17 times best solution in others.

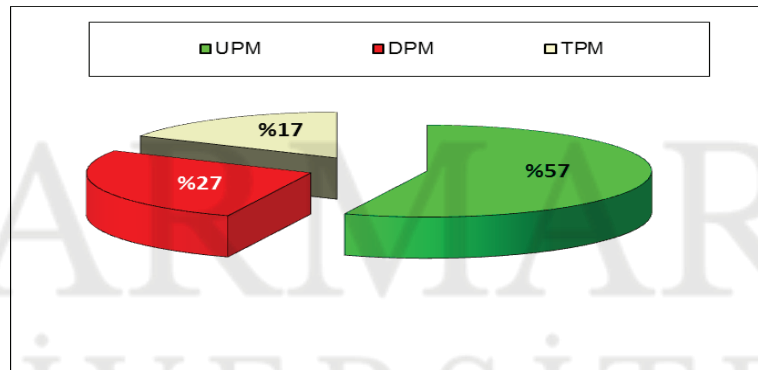


Figure 5. Frequency of the selected profit models

1. Unit Profit Model: %57
2. Daily Profit Model: % 27
3. Total Profit Model :% 17

Table 6 Indicates a hypothetical example including Unit Profit Model, Daily Profit Model, Total Profit Model and Opportunity Cost values calculated after 20 times Simulation run. As can be seen from the Table 6, each trial results are different than others depending on random orders and random due dates. As a result of 20 trials it can be said that 126.008\$ total money will lose that is opportunity cost (if comparison of 3 models is not used and if lowest profit techniques were selected, company will lose this amount of money) for the manufacturing company.



Table 6. Results of the first 20 trials

TRIALS	UPM	DPM	TPM	Opportunity Cost
1	48456	48456	39456	9000
2	42853	42853	42853	0
3	45463	45463	44983	480
4	37690	43225	37690	5535
5	42380	51292	46572	8912
6	52260	52260	52260	0
7	30438	30438	30438	0
8	39805	47151	39805	7346
9	31926	31926	31926	0
10	29340	29340	43405	14065
11	38765	49440	48890	10675
12	42747	42747	42747	0
13	32741	17831	32741	14910
14	41530	41070	41070	460
15	40150	44500	44500	4350
16	30730	28094	32074	3980
17	38235	48003	54258	16023
18	42400	24428	37000	17972
19	40270	51610	51610	11340
20	30027	30987	30987	960
Total	778206	801114	825265	126008

An example calculation of Opportunity Cost for trial 1;
= Maximum profit of – Minimum profit
= 48456 – 39 456 = \$ 9000
“=BÜYÜK(B10:D10;1)-
BÜYÜK(B10:D10;3)”

Discussion and Conclusions

In the reference model a profit based scheduling algorithm is prepared and operated for a small and non-complex system. The current problem is different than Knapsack problem since each order has a different due date . For execution of the model Excel is selected. Reference model could maximize the profit of the given orders depends on three profit techniques under the time constraint. For the short execution time applicability of the reference model is very high. It is seen that if the increase in number of constraints or number of machine excel will not an appropriate tool to solve this problem because of the practicable number of if then loops. This study shows that profit based schedule depends on agent based algorithm gives efficacious solutions for manufacturing systems. Feature work of this study is contraction of a new Java model with increase in number of machine and number of Job.

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