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Case Study Analysis of Job Shop Scheduling and its Integration with Material Requirement Planning

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Abstract

Now a days, an integrated manufacturing environment is essential in modern manufacturing industries. To achieve truly integrated manufacturing systems, the integration of Material Requirements Planning (MRP) and job shop is essential. In the job shop scheduling problem n jobs have to be processed on m different machines and each job consists of a sequence of tasks that have to be processed during a fixed length on a given machine for an uninterrupted time period. In this work, enterprise application framework for integrating MRP with job shop scheduling is developed. This integrated system consists of two modules. First module provides a common material representation for material requirement planning and scheduling to tackle the variability in job durations and machine allocations. The second model provides an integrated heterogeneous manufacturing facilities with feasible production schedule. At the first stage, the application accepts the customer's order and performs material requirement planning. Further the master production schedule dispatches the daily planned order with all production resource requirement to job shop. At the same time, MRP sends order to supplier for purchasing raw materials. Shuffled Frog Leaping Algorithm (SFL) is used to find an optimum schedule as well as refine the makespan results. Once the customers add or modify orders, MRP system will update the resource data automatically and respond to the changes of customer requirements rapidly. In this integrated application, the MRP subsystem has been proposed to computerize the existing system with VB.NET and MYSQL Server to perform Business-to-Customer transactions and MRP logic, while the job shop simulator generates different sequences randomly and using Gantt chart initial makespan was calculated. Initial solutions refined with SFL algorithm and optimum schedule is generated. MYSQL Server Module is used for integrating MRP with Job shop simulator using Visual Basic .NET as the front end and MYSQL as the back-end tool. Finally, the computer based integrated system is developed and tested. It performs well in terms of changing requirements of customer and also it minimizes the makespan with SFL algorithm.

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1. Introduction

To develop a window based application which helps the manufacturing industry to attain best procurement practices and supports the operation of procurement activity at the optimum total cost in the correct quality at the correct time and location. Due to the customized production, shorter product life cycle and frequent process reengineering gives a rapid response to changing requirements, reduction in both time and cost of the product realization process [1]. The Materials Requirements Planning (MRP) philosophy is still employed by the majority of manufacturing enterprises for production planning [2].

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MRP has been found to be an effective way explicitly to consider relationships between the end items and the various components and sub-assemblies. MRP systems determine the quantity of each item that will be used in the production of a prescribed volume of final products, and the times at which each of these items must be purchased or manufactured to meet prescribed due dates for the final products. MRP systems are highly detailed and an excellent means for determining and tracking materials requirements. As a means for production scheduling, MRP systems leave a good deal to be desired [3]. MRP only provides the means to make broad scheduling decisions: it does not encompass short term scheduling decisions like machine loading and operations sequencing [4].
Once MRP has set due dates for each stage, it becomes the responsibility of the shop floor scheduling system to meet such deadlines [5]. This is a critical activity because the load on work centres changes over time [6]. There can be such unexpected events as machine breakdowns, raw material shortage, scrap and rework, all causing the actual lead time to differ from the planned one [7]. Production volumes and due dates must be adjusted manually to achieve feasible schedules. However, the main difference between MRP and finite scheduling is that MRP is not an optimization technique. It simply tries to schedule all activities required to meet a given master schedule while holding down work-in-progress inventory. If infeasibility occurs, production management must produce a new master production schedule (MPS) and generate another plan or find alternative sources of production capacity. Finite scheduling is an optimization technique that tries to generate a sequence of operations over a given set of machines with the sole purpose of minimizing some type of shop performance measure like makespan, mean flow time, etc.

Job shop scheduler is used to generate sequences randomly and allocate the tasks to time intervals on the machines and also used to minimize the overall completion time for finding the proper schedule. The maximum completion time is needed for processing all jobs with specified constraints that each job has to processed in specified machines and that each machine can process at most one job at a time. Gantt chart is used to find the initial sequence and makespan in job shop simulator. Bruker [8] and Garey show that the Job shop scheduling is an NP-hard [9] problem. Because of the NP-hard characteristics of job-shop scheduling is usually very hard to find its optimal solution. Optimal solution in the mathematical sense is not always necessary in practices [10]. Researchers turned to search its near-optimal solutions with all kind of heuristic algorithms [11].

In earlier research, the job-shop scheduling problem has been extensively studied with many objectives considering minimizing some functions. For solving job shop scheduling problems, many techniques and different heuristics has been developed. Minimizing mean tardiness and mean flow time multi objective criteria SFHM algorithm was used [12]. An effective SFLA was used for minimizing maximum completion time (i.e., makespan) [13]. In this work SFLA and SFHM algorithm are used for solving the scheduling problem to meet due dates in a simple job shop. It is also used minimize the total holding cost with of in process inventory and product inventory cost.

This research work focuses on two stages. First stage an integrated system is developed for MRP and Job shop simulator. Second stage is refining the results of makespan with SFL algorithm. The paper describes how to integrate MRP and job shop and SFL algorithm uses to refine maximum completion time.

2. Case Study Analysis

2.1 Integrated System

The integrated application consists of MRP system and Job shop simulator system. At first, the application accepts the customer's order through the MYSQL server. In the backend, material requirement planning will be performed through VB.NET module. Then MRP dispatches daily production jobs to job shop that carries out real-time scheduling and master production schedule. Simultaneously, MRP sends the purchased order to supplier for purchasing the required raw materials. To meet requirement of customer order, after completing production task the job shop simulator returns the finished parts to MRP. The overall system architecture is shown in Fig 1. The traditional term of constraints in the context of integrated system includes scope, nature of the work, schedule baseline and cost baseline. The integrated system consists of input modules, output modules and feasibility modules. Client uses series of commands for performing specific operations because of complex programming.

2.2 MRP System

MRP is a computer modelling technique that allows for demand-driven production plans to be made [14]. It determines what to produce, when to produce and how much to produce. The implementation of MRP system starts with customer order and ends with the production of the corresponding product. The major components of the MRP [15] are the Master Production Schedules (MPS) and the Bill of Materials (BOM), which is discussed in this section. A Master Production schedule contains Material Issued Note and Production Planning, Material Transaction, Material Receipt Note and Material Requirement Alarm. The input and output process details of the MRP system is shown in Fig.1.

1) *Material Issued Note:* It is a module which store the information about the raw materials issued to production. This form will have a control over the raw material movement.

2) *Production Planning:* It is pre-budgeted production planning for matching the demand with supply. In this module, we can analysis the demanded sales quantity and required production units for sales and required raw material for production units.

3) *Material Requirement Alarm:* It is material requirement note which will give a notification when raw material reach its re order level. i.e raw material needs to be ordered for production process.

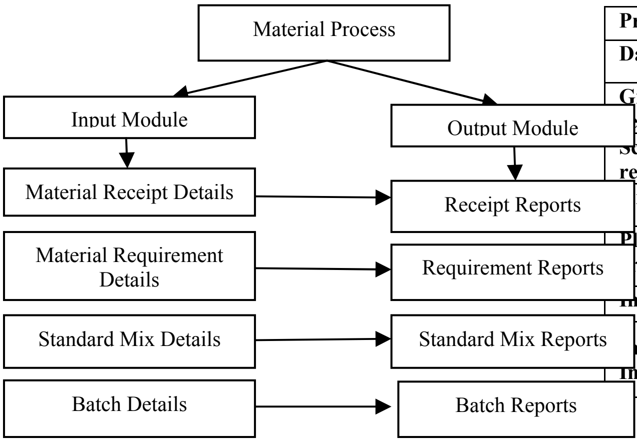

Fig. 1 Overall MRP System Material Process

Product X										
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Gross requirement										
Scheduled receipt										
On hand										
Planned order release										

Initial Parameter				
Initial Inventory	**Forecast**	**Lot Size**	**Lead Time**	**Safety Stock**

Fig. 2 MPS System

4) *Batch Creation:* It is a set of production process. Every batch has different material mix and consumption, this module creates a batch for every production process.

5) *Standard Mix Generator:* Every batch of production requires some standard mix which is predetermined by the experts in concern department. This module facilitates to generate exact mix for given or proposed output quantities. At the time of production, site engineer may use this mix standard to produce effective output from the process.

6) *Process Relationship:* It is a production technique which combines all the steps in the manufacturing. In this module, all the process related to manufacture of pipes have been updated and consolidated. This module consists all the information about the particular range of pipes such as dimension, mix, size, perception, thickness measurement and quality standards.

7) *Output Control Record and Finished Goods:* It is a note which records finished goods movement. All the produced (finished goods) quantities have to be transmitted from factory to warehouse, for which we need some degree of control over movement. This module stores all the information in this regard such as no of quantity, lot size, warehouse, and inspection details.

2.3 MRP Logic

The MPS is a time-phased statement that contained numerous fields - gross requirement, scheduled receipt, on-hand inventory and planned order release [16]. Gross requirement is total actual demand for that item at that time. The expected units that will be completed at that time has been indicted by Scheduled receipt indicates. The planned order release indicates the suggested number of units to order from the job shop. Once the BOM is detected to have zero components, the item is recognized a purchased item and no further explosion took place

[17]. The details of Material Receipt Note and Material Requirement Alarm are shown in Table.1 and Table.2. The Product MPS system is shown in Fig.2.

Table 1. Material Receipt Note

Table Name: Receipt Details Primary Key: Receipt No.		
Field Name	**Field Type**	**Description**
Receipt no.	Varchar(45)	Receiptno
Receipt date	Varchar(45)	Receiptdate
Production ref	Varchar(45)	Production reference
Date of order	Varchar(45)	Dateoforder
Order givenby	Varchar(45)	Ordergivenby
Designation	Varchar(45)	Designation
Remarks	Varchar(45)	Remarks
DateOfOrder	Varchar(45)	Date Of Order
Ordergivenby	Varchar(45)	OrderGivenby
Designation	Varchar(45)	Designation

Table 2. Material Requirement Alarm

Table Name: Requirement Details Primary Key: Material Selection		
Field Name	**Field Type**	**Description**
Materialcon	Varchar(45)	Material used controlno
Dateofissue	Varchar(45)	Date of issue
Pro_batch_refer	Varchar(45)	Productionbatchreference
Proname	Varchar(45)	Product name
Length1	Varchar(45)	Length
Diameter	Varchar(45)	Diameter
Thickness	Varchar(45)	Thickness

3. Job Shop Scheduling Model

3.1 Communication Between MRP and Job Shop Scheduling

After establishing material requirement system needs to send the daily planned order to the job shop. In addition, because customers may add, modify orders with web server at any time, the computing results of MRP system should be updated to reflect the changes of customer orders. Once the customers add or modify orders, this monitoring system in MYSQL server will invoke the MRP process logic system to update data automatically. Then MRP system initiates a client object that communicates with server object residing in the job shop system to send jobs for processing. When order is completed, the client residing in the job shop will communicate with server residing in system to return finished jobs to timetable coordinator. Then the server residing in system sends relevant data to database or other objects. The communication interface is shown in Fig.3

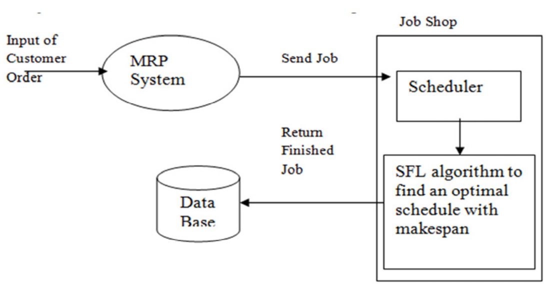

Fig.3 Integration of MRP System and Job Shop Simulator

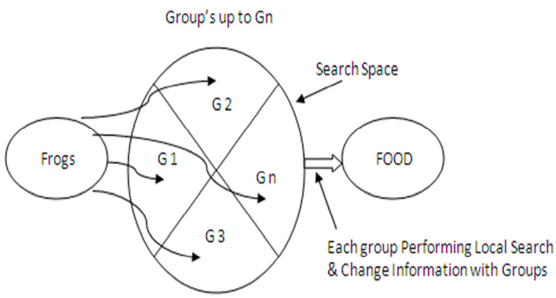

Fig.4 Groups of Frogs Searching for Best food

3.2 Integrated System, Implementation and Evaluations

The application output design is customized based on users input, which will generate the data depending on the user's requirements. The accessibility of the output design is secured in the system with user authentication and rights. Reports can be generated in various formats such as PDF, EXCEL, MS WORD etc… these form of soft copy reports facilitates the fastest communication by sending through mail which reduces the time and transportation charges. The system testing is actually series of different tests whose primary purpose is to fully exercise the computer base system. It is divided into recovery testing and security testing.

3.3 Heuristic Algorithm

To reach the global optimum solution, there are many heuristic algorithms were employed for various engineering application problems. Such algorithms are insisted based on their robustness and convergence of solving problems with producing optimum solutions. An approach without formal guarantee of performance can be considered a "heuristic". Most of the practical applications, heuristic approaches are used. The various best problem solving heuristic approaches are Artificial Intelligence, Bottleneck based heuristics, Local search approaches, Meta Heuristics and Hybrid Approaches [18].

3.4 Shuffled Frog Leaping Algorithm

Eusuff et al. has proposed a new meta-heuristic algorithm for solving scheduling problems with discrete constraints and variable decision parameters called as Shuffled Frog Leaping Algorithm. SFLA is one of the population based cooperative search metaphor. It combines the benefits of the memetic algorithm and particle swarm optimization. It also Inspired by the social behaviour and natural memetics of different heuristics [19], Muzaffar Eusuff and Lansey described the algorithm through observing, imitating, and modeling the behavior of frogs searching for best food [13]. For large number of combinatorial problems were solved and tested by SFLA which is used to be efficient in finding global solutions [20].

The SFLA is a population-based cooperative search metaphor inspired by natural memetics and consists of a frog leaping rule for local search and a memetic shuffling rule for global information exchange as shown in Fig.4. The SFLA comprises a set of interacting virtual population of frogs partitioned into different groups (memeplex), referred to as memeplex, searching for food. The algorithm functions simultaneously as an independent local search in each memeplex. Furthermore, the SFLA compares favourably with the Genetic Algorithm, the Ant Colony Optimization, and the Particle Swarm Optimization in terms of time processing [21].

4. Case Example

To validate the working of integrated system, a firm which is manufacturing Heat exchanger is considered. Many industries are using different optimizing methods to minimizing material cost. In this case study five step procedure are used, such as problem identification, Material planning and purchasing, Master production scheduling, modeling of mean variance and optimization using heuristic algorithms. The case study involves aluminum, copper tubes used as raw material for manufacturing finned tubes, heat exchangers and air coolers. The current material planning arrangement is done by specifications defined by customers.

4.1 Customer Order

Table.3 shows the customer order for manufacturing finned tubes. It gives details of needed quantity in terms of week.

Table 3. Customer Order

Date of order	Product required	Needed Quantity	Due Date (week)
25/03/2012	Finned Tubes	1000	1
		1500	3
		1400	4
		2000	5
		1400	6
		3000	8

Table 4. Inventory record details for Base Tube (1)

Job/ Part No	Part Description	Lead Time (week)	Stock on hand
j_1	Stainless Steel Tube	3 weeks	3m in 200 nos 2.5m in 50 nos
j_2	Copper Tube Aluminium	4 weeks	3 m in 100 nos 6 m in 150 nos
j_3	Copper Tube Aluminium	5 weeks	3 m in 50 nos 6 m in 100 nos
j_4	Aluminium	2 Weeks	6 m in 50 nos
j_5	Carbon Steel Tube	3 Weeks	6m in 350nos

Table 5. Inventory record details for Fin Material (2)

Job/ Part No	Part Description (Fin Strip)	Lead Time (week)	Stock on hand (size)
j_1	Stainless Steel	3 weeks	Min 6mm to Max 15mm in 150 kg
j_2	Copper Tube	4 weeks	Min 6mm to Max 15mm in 200 kg
j_3	Brass Tube	5 weeks	Min 6mm to Max 15mm in 150 kg
j_4	Mild Steel Tube, Galvanized Iron	2 Weeks	Min 6mm to Max 15mm in 100 kg
j_5	Aluminum, Copper Mild Steel	3 Weeks	Min 6mm to Max 15mm in 350 kg

4.2 Material Requirement Planning Calculations

The material requirements details of each parts/jobs along with inventory record details represented in Table 4 and Table 5. Planned order releases of each parts/jobs are calculated. Based on the planned order release, purchase order is sent to the supplier for procurement as per the time schedule. These procedures are similar for all other material finned tubes. MRP system is mainly used for material requirements calculation, placing purchase order to the supplier and procuring materials at right time with right quantity as per MRP plan. The finalized master production schedule of finned base tube, individual fin material and fin tooling are shown in Table 6, Table 7 and Table 8.

Part: Base Tube (j_1) EOQ =300 numbers in different length ,

Part : Fin Material (j_1) - Stainless Steel EOQ =450 kg with min 6mm to 15mm and

Part : Finning Tools (j_1 to j_6) EOQ = 400 units.

Once the materials are purchased from the supplier as per material requirement planning then purchased raw materials is sent to corresponding workstations for completing the specified production tasks in scheduled machines. Finally, the optimal sequence schedule was generated by the Job shop scheduler.

Table 6. Master Production Schedule – Finned Base Tube

week	0	1	2	3	4	5	6	7	8
Gross requirement		100		150	140	200	140		300
Scheduled receipt				300		300			300
Stock on hand	150	50	50	200 -100	60	160 -140	20	20	20 -280
Planned order release			300			300			300

Table 7. Master Production Schedule – Fin Material

week	0	1	2	3	4	5	6	7	8
Gross requirement			300		300			300	
Scheduled receipt					450			450	
Stock on hand	350	350	50	50	200 -250	200	200	350 -100	350
Planned order release			450			450			

Table 8. Master Production Schedule – Finning tools in different size <100mm

week	0	1	2	3	4	5	6	7	8
Gross requirement			30.0		30.0			30.0	
Scheduled receipt					40.0			40.0	
Stock on hand	32.5	32.5	2.5	2.5	12.5 -27.5	12.5	12.5	22.5 -17.5	22.5
Planned order release				40.0			40.0		

4.3 Manufacturing and Material Flow Chart

The preparation of required material is always performed based on customers need and inventory storage. The reason for formulation of the material requirement planning is the need to specify the monitoring of material flows. This schedule is contained in the MRP system, purely to generate a demand for materials. During planning of material arrangement process, it was necessary to perform the reconstruction of material flows by individual process. The knowledge of the material flow process and cost of the raw materials were used for calculation of material cost of the finished goods and losses. Inputs costs for the raw materials are shown in Table 9. The material cost is obtained based on sum of all product manufacturing material losses during production which is represented in Table 10. The material cost for each individual process are shown in Table 11. based on normal method and Table 12. represents integrated method material cost calculation.

Table 9. Cost of Raw Material

Size				Raw Material Cost per meter			
Fin OD, mm	Base Tube OD	Fin Thickness	Fins/Inch	Main Tube	Base Tube Grade		
				Aluminium	mild steel	Stainless Steel	Copper
			8	110	50	160	450
37	16	0.4	9	120	50	160	450
			10	130	50	160	450
			11	130	50	160	450
			8	120	50	175	475
40	19.05	0.4	9	130	50	175	475
			10	140	50	175	475
			11	140	50	175	475
			8	140	50	185	470
44	19.05	0.4	9	147	50	185	470
			10	154	50	185	470
			11	161	50	185	470
			8	150	50	200	495
50	22	0.4	9	157	50	200	495
			10	164	50	200	495
			11	171	50	200	495
			8	168	50	210	490
54	25.4	0.4	9	175	50	210	490
			10	182	50	210	490
			11	189	50	210	490
			8	178	50	225	515
57	26.7	0.4	9	185	50	225	515
			10	192	50	225	515
			11	199	50	225	515
			8	196	50	235	510
63	31.8	0.4	9	203	50	235	510
			10	210	50	235	510
			11	217	50	235	510
			8	206	50	250	535
70	38.1	0.4	9	213	50	250	535
			10	220	50	250	535

Table 10. Material cost for each individual process

Item Elements	Finning	Defining	Decreasing	Packing	Dispatching
Total Product Cost	76576	23633	12456	2680	2503
Total Material Losses	31954	5045	7300	1742	1771
Total % of Material Usage	42%	61%	59%	65%	71%
Total % of Material storage in Inventory	58%	39%	41%	35%	29%

Table 11. Cost of Material in manufacturing process for heat Exchangers / month /order / Normal Method

Item Cost	Quantity	Material Cost per Process (Rs)
Direct Material	Rs 6248 x 10 units	62480
Material Handling	5 components x Rs30 x 100 units	15000
Finning	150 hrs x Rs 20	3000
Cutting	50 parts x Rs 80	4000
Assembly	2 assembly hrs x Rs 50	100
Inspection	10 units x Rs 250	2500
Dispatching	1 order x Rs 1500	1500
Inventory material	1 component	9700
Total Material Costs for order		98280

Table 12 Cost of Material in manufacturing process for Heat Exchangers / month /order Integrated Method

Example	Job 1 per Process		Job 1 per Process	
Item Cost	Quantity	Material Cost (Rs)	Quantity	Material Cost (Rs)
Finning	150 hrs x Rs 20	3000	1050 hrs x Rs 20	21000
Cutting	50 parts x Rs 80	4000	200 parts x Rs 80	16000
Assembly	2 assembly hrs x Rs 50	100	30 assembly hrs x Rs 50	1500
Inspection	10 units x Rs 250	2500	200 units x Rs 250	50000
Dispatching	1 order x Rs 1500	1500	1 order x Rs 1500	1500
Direct Material	Rs 970 x 10 units	9700	Rs 300 x 200 units	60000
Inventory material	15 item x Rs 750	11250	-	-
Total Material Costs	per single order	32050	per single order	150000
Total Material Costs per unit	per 10 units	3205	per 200 units	750

5. Conclusion

In this work, an enterprise application is developed to integrate material requirement system with job shop simulator by using excel macrons. The proposed integrated approach monitors

- The flow of the material process and material cost associated with finished goods, inventory tardy jobs and material losses.
- It shows that the proposed system has good performance in terms of response to customer.
- Mainly used for once the customers add or modify orders, data automatically updated in MRP system as per the changes of customer requirements rapidly.
- The progress of materials through Job scheduling enterprises physical schedule based on material availability is used to find optimal sequence.
- Finally, MRP system effectively collaborates with Job Shop to meet requirement of production with minimum material cost utilization.

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