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## Performance Improvement of Flexible Manufacturing System – A Case Study

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## **Abstract**

*Increasing global competition has evolved a manufacturing environment which gleans vast product variety, reduced manufacturing lead times, increased quality standards and competitive costs. Simultaneously, with a rising trend toward globalization, these manufacturing environments must be designed to cater new challenges to survive and grow in the marketplace. To deal with such multifaceted problems, new technologies support increased flexibility and automation. These objectives intended for the improvement of the manufacturing environment have been the key rationales for the introduction of flexible manufacturing systems (FMSs). In this paper a case study of a firm is presented with a contribution to devise some performance improvement strategies for a semi Flexible Manufacturing System (FMS). The study is based on the mathematical model given by Solberg, J.J., (1981) and Mejabi, O., (1988) to estimate possible performance parameters like maximum production rate, make span time and overall utilization. The effort is also made to suggest some improvement strategies to the company as a feedback statement which results in higher production rate and better utilization of system resources.*

**Key words:** Flexible Manufacturing System, Performance Parameters, Production Rate, Mathematical Modeling.

## **1. Introduction**

Evolving business environment offers new pressures to be confronted by the manufacturing systems, such as tailored product (increasing variety) with delivery on time along with emphasize conventional requirements of quality and competitive cost. Therefore, to sustain in the global scenario, the focus is to develop a manufacturing system that can fulfil all the demanded requirements within due dates at a reasonable cost. Among all the existing manufacturing system, they require a manufacturing system having the flexibility to make the customized product with medium volume. Therefore, they are motivated to consider Flexible Manufacturing System (FMS), which is equipped with the several computer-controlled machines, having the facility of automatic changing of tools and parts. The machines are interconnected by automatic material handling devices, pallets and several storage buffers. These components are connected and governed by computer using the Local Area Network (LAN). The exquisiteness of this system is that it gleaned the ideas both from the flow shop and batch shop manufacturing system. A generic FMS is able to handle a variety of products in small to medium sized batches simultaneously. The flexibility of a flexible manufacturing system (FMS) has enabled it to become one of the most suitable manufacturing systems in the current manufacturing scenario of customized and varied products with shorter life cycles. With the aim of combining production flexibility and productivity, the design of flexible manufacturing system (FMS) is subject of high investments. However these decisions of FMS design are strategic and to be taken in preliminary phase with utmost care ensuring that the designed FMS will successfully fulfill the demands of fluctuating market. The design decisions of FMS must be based on the justification of performance improvement. In recent environment where a manager can make use of easily available computing power along with the various commercial tools and techniques, it is quite reasonable to estimate some performance issues of existing and proposed FMS and subsequently suggest the design decisions. The employment of deterministic models to judge the FMS performance could be very useful to evaluate the system parameters like production rate, resource utilization, make span time etc. at a beginning stage of design decision making. This paper attempts to present a case study of a firm which is striving to improve the performance of existing flexible system and setting up to make some investment decisions for up-gradation.

The remainder of this paper is described as following: Section 2 gives an overview of the literature surveyed to conduct the research subsequently section 3 delineates the mathematical model whereas the problem has been described along-with the data collection in section 4. Section 5 analyses the results of the given problem. In section 6, the paper has been concluded with some issues and future intensions of the research.

## **2. Literature Review**

The framework of flexible manufacturing systems (FMSs) combines high productivity, quality and flexibility needed for the fast response to changing market demands (Womack et al. 1990). The term flexible manufacturing system (FMS) is generally used to represent a wide variety of automated manufacturing systems. Flexible Manufacturing System (FMS) may be defined as an integrated system composed of automated workstations such as computer numerically controlled (CNC) machines with tool changing capability, a hardware handling and storage system and a computer control system which controls the operations of the whole system (Mac

Carthy 1993). The flexibility of a flexible manufacturing system (FMS) has enabled it to become one of the most suitable manufacturing systems in the current manufacturing scenario of customized and varied products with shorter life cycles. The prominent literature has several descriptions of FMS and its inherent feature of flexibility has been addressed by many researchers, e.g. Browne et al (1984), Upton (1994), Wadhwa and Browne (1989) etc. To design an efficient flexible manufacturing system, an information system is incorporated to interface and integrate the entities of FMS, the mode of synchronizing the various entities and the method of coordinating them in order to achieve the objectives (Weber and Moodie 1989). Stecke and Solberg (1981) report on an experimental examination of a real FMS. The system consists of 9 machining centers, an inspection station and a control queuing area connected by a automated material handling system. The number of finished parts was considered as the system performance measure. Montazeri and Van Wassenhove (1990) investigated the performance of a number of dispatching rules for FMS. Tunali (1997) developed a simulation model of a job shop type FMS. The model is used to investigate how the performance of scheduling decisions (i.e. mean job flow time) is affected by the use of flexible or prefixed part process plans, in case of a machine breakdown situation. Buitenhik et al. (2002) describe that since the components of an FMS are generally expensive; the design of these systems is an important issue. Chan F.T.S., Wadhwa S., Bibhushan, (2007) initiate an idea to extend the performance analysis to FMS related technologies such as supply chains.

In recent studies pertaining to the FMS, researchers have been very keen to improve the performance of flexible manufacturing system (Wadhwa, S. et al. (2005), Chan, F.T.S. (2003). Some researchers have used deterministic models to estimate the FMS performance, these models are very useful for estimating system parameters like production rate, resource utilization etc. at a beginning stage of design. Solberg,J.J,(1981) and Mejabi, O.,(1988) presented a universally accepted mathematical model (deterministic in nature) to evaluate various performance measures of an FMS. In this paper a case study of a manufacturing firm is presented with a contribution to devise some performance improvement strategies. This paper presents a study of the existing FMS of the plant and utilizes the mathematical model given by Solberg,J.J,(1981) and Mejabi, O.,(1988) to estimate possible performance parameters like maximum production rate, make span time and overall utilization. A simulation model has been developed to estimate the performance measures and simultaneously it identifies the machine or load/unload station as bottleneck point in the FMS. The effort is also made to suggest some improvement strategies to the company as a feedback statement which results in higher production rate and better utilization of system resources. The Result of case shows that estimation of production rate and a measurable effect of bottleneck on other parameters can be achieved. For improvement some strategies of FMS designing have also been suggested to eliminate or shift the bottleneck station from the system

### **3. Mathematical Modeling**

The considered research case involves the assessment and analysis of performance of a semi flexible manufacturing system at operational level under various parameters. Primary step may be to identify the various such parameters that can affect performance of the system. To obtain starting estimates of system performance, deterministic simulation models can be used. These approaches can be successfully implemented to predict various system parameters such as production rate, manufacturing time, and utilization. Important performance measures of an FMS

can be mathematically assessed by a model described by Solberg,J.J,(1981) and Mejabi, O.,(1988). It can be used to provide initial estimates of parameters such as production rate, workstation load etc. The operation parameters used throughout this model for a flexible system of manufacturing are described below:

*2.1 Average Workload:* It is defined as the mean total time spent at a machining station per part.

$$\mathbf{WL}_i = \sum_j \sum_k t_{ijk} f_{ijk} p_j$$

Where  $\mathbf{WL}_i$  = Average workload for station i (min)

$t_{ijk}$  = Processing time for operation k in process plan j at station i (min)

$f_{ijk}$  = operation frequency for operation k in part j at station i

$p_j$  = part-mix fraction for part j

*2.2 Maximum Production Rate:* For all parts, it is defined as the ratio of  $s^*$  and  $\mathbf{WL}^*$ , if  $\mathbf{WL}^*$  is the work load,  $s^*$  is number of servers and  $t^*$  is the processing time (for bottleneck station).

$$\mathbf{R}_p^* = \frac{s^*}{\mathbf{WL}^*}$$

Similarly individual part production rate can be obtained as:

$$\mathbf{R}_{pj}^* = \frac{P_j s^*}{\mathbf{WL}^*}$$

Where  $P_j$  = part-mix fraction for part style j.

*2.3 Utilization:* The mean utilization of each workstation is the proportion of time that the servers at the stations are working and not idle.

$$U_i = \frac{\mathbf{WL}_i (\mathbf{R}_p^*)}{s_i}$$

where,  $\mathbf{WL}_i$  = Workload of station  $i$  (min/pc),  $s_i$  = number of servers at station  $L$ ,  $\mathbf{R}_p^*$  = overall production rate (pc/min).

*2.4 Average Station Production:* the average value for all stations including the transport station.

$$U = \frac{\sum_{i=1}^{n+1} U_i}{n+1}$$

*2.5 Overall FMS utilization:* It can be calculated as below:

$$U_s = \frac{\sum_{i=1}^{n+1} s_i U_i}{\sum_{i=1}^n s_i}$$

#### 4. Problem Description

The research intends to present a performance analysis of the flexible system of manufacturing of a firm using the above mentioned model. The analysis leads us to predict the strategies for the improvements in performance parameters of the system.

The company selected for the study is in to production of various types of valves such as dual plate check valve, concentric butterfly valve, double butterfly valves etc. The study has been done by following a standard research methodology, a questionnaire was designed and circulated among various levels of people in the company and thus the data was formulated. Table 1a, 1b, 1c and 1d summarize the data such as processing time of various part-mixes, sequence of operations type of parts etc.

**Table 1a - Dual Plate Check Valve**

Part Range (mm)	Part Mix	Processing Times (Min)									
		Load/Unload	Turning	Welding	Drilling	Milling	Surface Grinding	Lapping	Insp.	Painting	Assly
40	0.00038	20	60	25	12	10	30	90	25	10	30
50	0.0247	20	75	30	15	15	45	120	30	10	30
65	0.02267	20	90	40	20	20	60	156	30	10	30
80	0.03	20	120	50	25	25	75	192	30	15	30
100	0.03787	20	150	60	30	30	90	240	30	20	30
125	0.01193	20	190	80	38	38	112	300	30	20	30
150	0.0305	20	225	95	45	45	135	360	30	25	30
200	0.0252	20	300	120	60	60	180	480	30	30	30
250	0.0101	20	375	150	75	75	160	600	30	30	30
300	0.00528	20	450	180	90	90	270	720	30	35	30
350	0.00528	27	525	210	105	105	315	840	32	35	32
400	0.0016	27	675	240	120	120	360	960	32	40	32
450	0.0013	28	750	270	135	135	410	1080	33	45	33
500	0.001	29	900	300	150	150	450	1220	34	45	34
600	0.001	30	1050	360	180	180	540	1440	34	50	35

**Table 1b - Concentric Butterfly Valve**

Part Range (mm)	Part Mix	Total Processing Time (Min)								
		Load/Unload	Turning	Boring	Drilling	Rubber Matching	Lapping	Insp.	Painting	Assly
50	0.2034	20	60	60	180	20	120	20	15	35
80	0.1426	20	100	100	250	22	180	21	20	45
100	0.11078	20	120	120	360	30	240	23	20	60
150	0.213	20	160	160	550	35	360	25	20	60
200	0.0574	20	240	240	720	40	480	27	30	70
250	0.0283	22	300	300	900	45	600	30	35	80
300	0.01186	25	360	360	1080	50	720	35	35	80
400	0.00568	28	420	420	1260	55	840	35	40	80
450	0.00257	30	480	480	1440	60	960	40	45	85
500	0.00274	32	540	540	1620	65	1080	45	50	90
600	0.00288	34	600	600	1800	70	1200	50	55	95
700	0.00161	36	720	720	2160	75	1440	55	60	95

**Table 1c - Double Eccentric Butterfly Valve**

Part Range (mm)	Part Mix	Total Processing Time (Min)								
		Load/Unload	Turning	Boring	Drilling	Lapping	Rubber Matching	Insp.	Painting	Assly
80	0.00063	20	96	96	288	192	24	20	72	28
100	0.00113	20	120	120	360	240	30	20	90	30
150	0.0013	20	180	180	540	360	32	20	135	32
200	0.00037	20	240	240	720	480	33	20	180	33
250	0.00025	21	300	300	900	600	34	21	225	34
300	0.00056	22	360	360	1080	720	35	22	270	35
350	0.00051	23	420	420	1260	840	36	23	315	36
700	0.00033	26	840	840	2520	1680	38	26	650	38
900	0.00024	28	1080	1080	3240	2160	39	28	870	39
1100	0.00038	29	1320	1320	3960	2640	40	29	990	40

**Table 1c - Triple Eccentric Butterfly Valve**

Part Range (mm)	Part Mix	Total Processing Time (Min)								
		Load/Unload	Turning	Boring	Drilling	Lapping	Rubber Matching	Insp.	Painting	Assly
100	0.00857	20	120	120	360	240	30	20	90	30
150	0.00178	21	180	180	540	360	31	21	135	31
200	0.00131	22	240	240	720	480	32	22	180	32
250	0.00054	23	300	300	900	600	33	23	225	33
300	0.00067	24	360	360	1080	720	34	24	270	34
500	0.00051	25	600	600	1800	1200	35	25	450	35
600	0.0009	26	720	720	2160	1440	36	26	540	36
800	0.00016	28	960	960	2880	1920	38	28	720	38
1000	0.0009	30	1200	1200	3600	2400	40	30	900	40

## 5. Results and Analysis

The data collected in previous section was utilized to evaluate the model of manufacturing system; results are summarized in table 2a, 2b, Figure 1, Figure 2 and Figure 3. The flexible manufacturing system was studied and performance analysis has been done. For various operations, the total workload has been calculated. It is found that the maximum workload is on drilling station, which clearly shows that the drilling station is creating a bottleneck in the processing of parts. The system's performance will depend upon the performance of this station only. The overall machine utilization is also evaluated and consequently the percentage utilization of each machine has been estimated and is mentioned in table 2a. For performance evaluation of FMS, various parameters are required to be evaluated such as Maximum Production Rate, Maximum workload per server, identification of bottleneck operation, make span time etc. All these performance parameters have been calculated using the model and are summarized in table 2b.

It is explored that the maximum workload per server is found in drilling station i.e.81.6278 time units which is also verified by the fact in table 2b that machine utilization of this station is 100% altogether these results are the deciding factors for the identification of this process as bottleneck process. Since this process is vital for all part types as per the table 1a, 1b, 1c and 1d, the efforts should be made to

shift this bottleneck from this process to some other less important process. This can be done by restructuring of the system.

**Table 2a - Summary of Results (Calculation of Various Parameters)**

Sl. No.	Machine Type (Type)	Operation (Name)	Total Work Load (Min)	Machine Utilization	
				(Num)	(%)
1	Load / Unload Station	Loading / Unloading	20.85	0.00643	0.6
2	Turning Center	Turning	152	0.05869	5.869
3	Welding Station	Welding	16.4	0.20235	20.235
4	Boring Machine	Boring	138.05	0.10644	10.644
5	Drilling Station	Drilling	324.37	1.00048	100
6	Milling Center	Milling	8.22	0.05069	5.069
7	Grinding Machine	Surface Grinding	24	0.04931	4.931
8	Lapping Machine	Lapping	271.62	0.20945	20.945
9	Manual Operation	Rubber Matching	48.08	0.14831	14.831
10	Manual Operation	Inspection	24.74	0.02543	2.543
12	Painting Station	Painting	23.51	0.07252	7.252
13	Assembly Station	Assembly	48.25	0.14883	14.883
14	Mat. Handling System	Material Transfer	225	0.17349	17.349

**Table 2b - Evaluation of Performance Parameters**

Sl. No.	Performance Parameters	Estimated Value
1	Maximum Production Rate (Parts/Hr.)	0.74026
2	Maximum Workload (Per Server) (Found in Drilling Station)	81.6278
3	Identification of Bottleneck Process	Drilling Station
4	Overall Utilization of System (%)	88.53%
5	Make Span Time of Parts (Min)	1916.78
6	Total Waiting Time in System (Min)	295.74

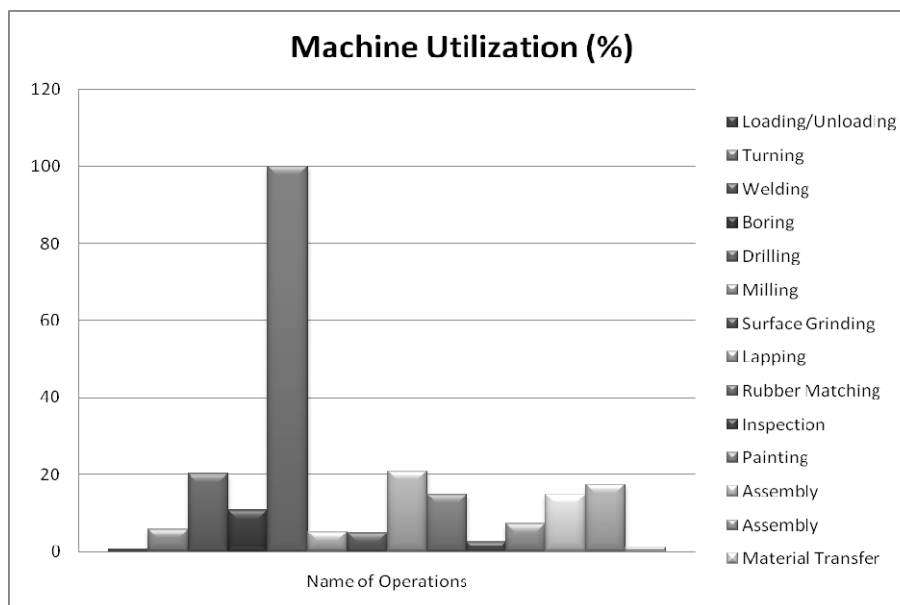


Figure – 1 Percentage machine utilization for the system

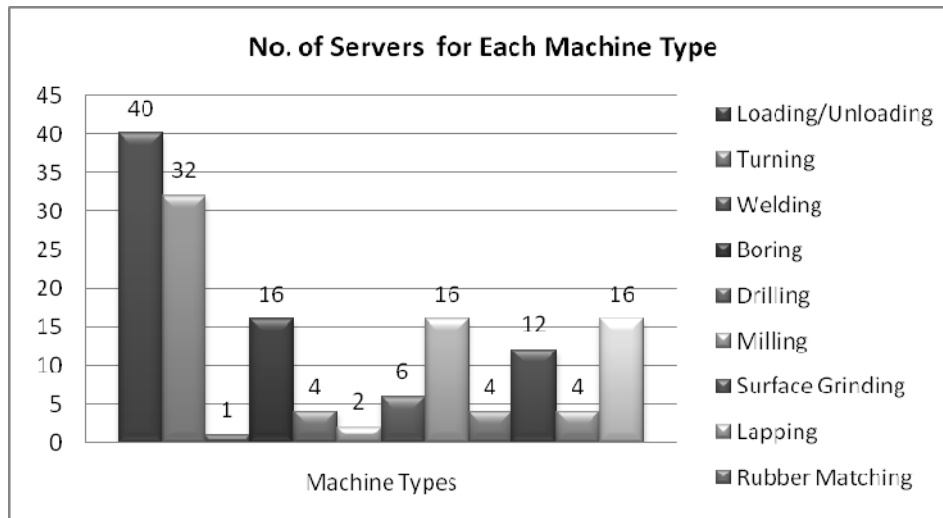


Figure – 2 Number of servers available for processing

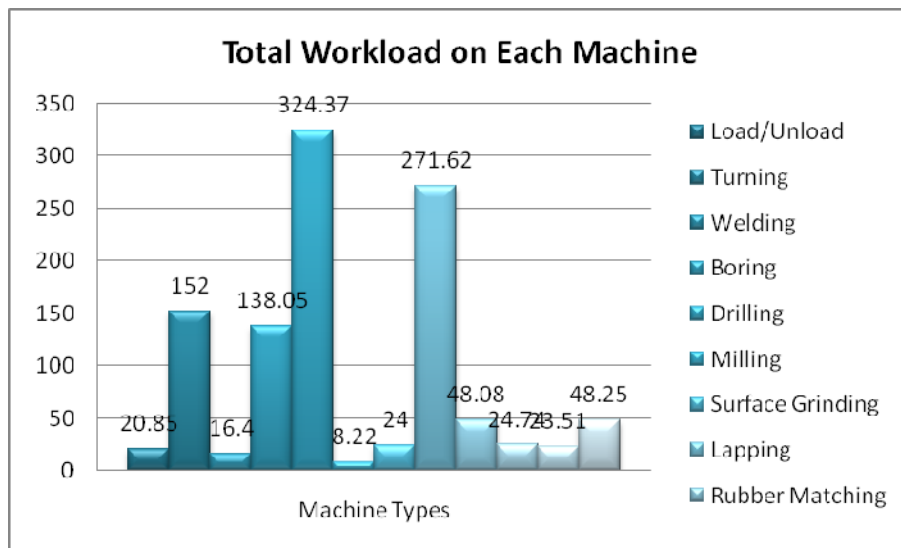


Figure – 3 Total Workload on each machine in the system

## 6. Conclusion

In this paper a case study of a manufacturing firm is presented on the basis of the mathematical model given by Solberg,J.J,(1981) and Mejabi, O.,(1988) to estimate possible performance parameters like maximum production rate, manufacturing lead time and overall utilization. It is discovered that the maximum workload per server is found in drilling station which is also established by the fact in that machine utilization of this station is 100% altogether these results are the deciding factors for the identification of this process as bottleneck process. Since this process is essential for all part types, It is suggested that the FMS should be restructured so that the bottleneck should be shifted from this process to some other less important process. From the results It can be concluded that the overall system utilization is 88.53% which can be further increased by suggesting a new structure of the system, also the machine utilization of some stations like loading/unloading, inspection, grinding, milling and turning is very less ranging from 0.6% to 5.8%. And

therefore it is mandatory to equally distribute the workload on all stations. These results and findings have been diverted to the firm also and the management is in the process of earning funds for the redesign of the system, this can be viewed as the future scope of the research. In future it is intended to conduct various simulation experiments so that system would be robust enough to handle all situation and dynamic market conditions.

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