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Maximize Throughput and System Utilization By PDM

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Abstract - Analysis and modeling of flexible manufacturing system (FMS) consists of scheduling of the system and optimization of FMS objectives. Flexible manufacturing system (FMS) scheduling problems become extremely complex when it comes to accommodate frequent variations in the part designs of incoming jobs. This research focuses on scheduling of variety of incoming jobs into the system efficiently and maximizing system utilization and throughput of system where machines are equipped with different tools and tool magazines but multiple machines can be assigned to single operation. Jobs have been scheduled according to shortest processing time (SPT) rule. Shortest processing time (SPT) scheduling rule is simple, fast, and generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in-process inventories (less shop congestion) and downstream idle time (higher resource utilization). Simulation is better than experiment with the real world system because the system as yet does not exist and experimentation with the system is expensive, too time consuming, too dangerous. In this research, P.D.M. philosophy and genetic algorithm have been used for optimization.

Key words: Flexible Manufacturing System, design principles of FMS & P.D.M. Software.

I. INTRODUCTION

In today's engaged overall business part, makers need to change their operations to ensure a better and snappier response than prerequisites of customers. The vital goal of any gathering industry is to fulfill an irregular condition of productivity and flexibility which must be done in a PC fused amassing environment. A versatile gathering structure (FMS) is an organized PC controlled setup in which there is some measure of flexibility that allows the system to react by virtue of changes, whether expected or unpredicted. FMS includes three rule structures. The work machines which are routinely robotized CNC machines are related by a material dealing with system(MHS) to streamline parts stream and the central control PC which controls material improvements and machine stream.

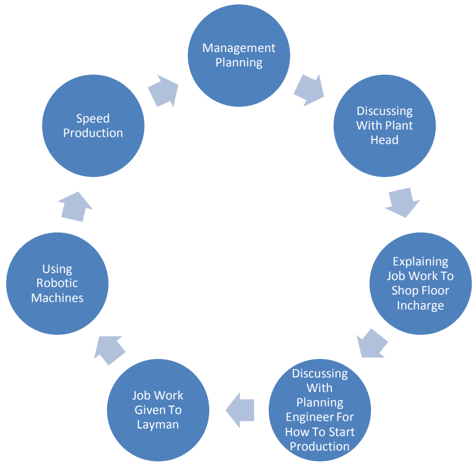
Most FMS comprise of three fundamental frameworks. The work machines which are regularly computerized CNC machines are associated by a material taking care of framework to improve parts stream and the focal control PC which controls material developments and machine stream.

Type of Flexibility:

1. Machine Flexibility.
2. Production Flexibility.
3. Mix Flexibility.
4. Product Flexibility.
5. Routing Flexibility.
6. Volume Flexibility.
7. Expansion Flexibility.

Planning Parameters in PDM Software:

The most important planning parameters in PDM software that impel production or manufacturing plant process is:



Advantages:

1) Reduced manufacturing cost
2) Lower cost per unit produced,
3) Greater labour productivity,
4) Greater machine efficiency,
5) Improved quality,
6) Increased system reliability,
7) Reduced parts inventories,

8) Adaptability to CAD/CAM operations.
9) Shorter lead times
10) Improved efficiency
11) Increase production rate

Thesis Motivation:

Inspiration I got when once I go to the creation business for preparing then I feel for various items they were setting aside too long time for making generation arranging furthermore it will require an excess of investment for stacking and Unloading the crude material furthermore numerous works were utilized to handle one generation in various levels/sages to finish.

II. LITERATURE REVIEW

The significance of hardware administration for the proficient utilization of mechanized assembling frameworks has been as of late focused by a few creators; we allude for case to Gray, Seidmann and Stecke (1988) or Kiran and Krason (1988) for a careful dialog of this issue. Specifically, a focal issue of hardware administration for adaptable machines is to choose how to grouping the parts to be created, and what devices to distribute to the machine, keeping in mind the end goal to minimize the quantity of hardware setups. The issue turns out to be particularly essential when the time expected to change an instrument is huge concerning the preparing times of the parts, or when numerous little groups of various parts must be handled in progression. These wonders have been seen in the metal-working industry by Hirabayashi, Suzuki and Tsuchiya (1984), Finke and Kusiak (1987), Bard (1988), Tang and Denardo (1988a), Bard and Feo (1989), and so on. Blazewicz, Finke, Haupt and Schmidt (1988) depict for occurrence a NC-manufacturing machine outfitted with two apparatus magazines, each of which can deal with eight instruments. The apparatuses are overwhelming, and trading them requires a sizeable division of the real producing time.

Another circumstance where minimizing the quantity of hardware setups might be critical is depicted by Forster and Hirt (1989, g industry by Hirabayashi, Suzuki and Tsuchiya (1984), Finke and Kusiak (1987), Bard (1988), Tang and Denardo (1988a), Bard and Feo (1989), and so forth. Blazewicz, Finke, Haupt and Schmidt (1988) portray for case a NC-manufacturing machine furnished with two device magazines, Tach of which can deal with p. 109). These creators specify that, when the apparatus transportation framework is utilized by a few machines, there is an unmistakable plausibility that this framework gets to be over-burden. At that point, minimizing the quantity of hardware setups can be seen as an approach to diminish the strain on the instrument transportation framework. Poet (1988) says yet another event of the same issue in the hardware business.

They held onto different issues, for example, choice of best dispatching, booking, steering and control rules, assurance of ideal number of machines, ideal number of AGVs and/or cushions/beds, and enhancement of a particular item machining parameter, (for example, full load speed of sheet metal piler) (Basnet and Mize, 1994, Chan et al., 2002). Various elements, for example, AGVs accessibility, variable machining time, framework design, steering and sequencing adaptability and part blend were viewed as (Solot and Vliet, 1994, Chan and Chan, 2004).

Execution criteria, for example, make-traverse (time to finish all occupations), lateness (the contrast between consummation times and due dates), add up to handling time, stream time, generation rate, cost and machine usage were evaluated (Azimi et al., 2010, Joseph and Sridharan, 2011, Kumar and Sridharan, 2011, Singholi et al., 2010). Furthermore, different methodologies and models were utilized as a part of FMS research, for example, scientific programming (Abou Gamila et al., 2000), multi-criteria basic leadership (Karsak, 2000), dynamic programming (Ecker and Gupta, 2005), objective programming (Chan and Swarnkar, 2006), petri-net (Hamid, 2010), straight and nonlinear programming (Chan and Chan, 2004) and venture demonstrate (Bruce and Albert, 1999).

Today, FMS is unpredictable because of variety in design, MHS arrangement, and stochastic parts between entry and handling times, which makes FMS issues multidimensional in nature (Saygin et al., 2001). It may be hard to utilize systematic ways to deal with model a perplexing assembling situations such FMS with their whole working and physical attributes. Systematic displaying will be further confused to utilize when element working situations and control time angle are viewed as (Chan et al., 2007). Moreover, the investigative demonstrating methodologies are typically in light of rearranging presumptions for the framework under study and particular to individual assembling undertakings and procedures (Chan et al., 2002).

These suspicions may not give a genuine picture of FMS execution and may not be illustrative of true cases (Chan et al., 2007). Then again, reproduction based methodologies have been utilized for displaying and investigating complex assembling frameworks, since they can show the factors which are scientifically confounded, and speak to more practical situations (Singholi et al., 2010). It additionally can manage stochastic situations, for which expository models, for example, numerical programming have been second rate without real rearrangements (Chan and Chan, 2004). McLean and Kibira (2002) inferred that recreation could be the best basic leadership help amid plan, break down and change of assembling frameworks.

Talking about execution examination issues, Singholi et al. (2010) directed a genuine FMS contextual investigation to break down its current execution, for example, greatest creation rate, make-traverse and general use, controlled by a quantitative displaying, and arranged a change plan to be contrasted and the current utilizing reenactment demonstrating. The alteration incorporates including assets (i.e., estimating the framework) and executing new design. The outcomes demonstrated that the proposed FMS has expanded of the quantity of servers, greatest generation rate and general use of assets. In the interim, Abou-Ali and Shouman (2004) talked about an investigation of the impact of 12 dynamic and static dispatching techniques on powerfully arranged and impromptu FMS comprising of eight machines, stockpiling cushion ranges, getting zone, and three robots and beds. Yifei et al. (2010) examined AGV armada measure assurance in FMS utilizing estimation and recreation.

III. PROBLEM IDENTIFICATION

In a case of machine-stacking issue of arbitrary FMS in which 8 section sorts are to be prepared on four machines, each having five instrument openings and diverse handling time for every operation. Every part sort comprises of key and discretionary operations, which can be performed on any of the machine without changing the grouping of the operations. The versatility of every machines and its capability to perform various operations encourage a few operation assignments to be copied to create elective part courses. In this manner, there can be genuinely expansive number of blends in which operations of the part sort can be relegated on the diverse machines while fulfilling all the mechanical and limit requirements. Encourage thought of adaptabilities, for example, tooling adaptabilities, part development adaptabilities, and so on alongside the requirements of the framework design and operational attainability make the issue more mind boggling.

Table 3.1 Description of problem

Part type	Operation no.	Batch size	Unit Processing time	Machine no.	Tool slot needed
1	1	8	18	3	1
2	1	9	25	1	1
			25	4	1
	2		24	4	1
	3		22	2	1
3	1	13	26	4	2
	2		26	1	2
	3		11	3	3
4	1	6	14	3	1
	2		19	4	1
5	1	9	22	2	2
			22	3	2
	2		25	2	1
6	1	10	16	4	1
	2		7	4	1
			7	2	1
			7	3	1
	3		21	2	1
			21	1	1
7	1	12	19	3	1
			19	2	1
			19	4	1
	2		2	1	1
			13	3	1
			13	1	1
	3		23	4	1
8	1	13	25	1	1
			25	2	1
			25	3	1
	2		7	2	1
			1	1	1
	3		24	1	3

Numerous specialists have tackled machine stacking issues by creating the pre-decided part sequencing based heuristics, however these strategies don't ensure ideal/close ideal arrangements.

IV. OBJECTIVE & METHODOLOGY

Objective:

The essential objective is to accomplish an abnormal state of efficiency and adaptability which must be done in a PC coordinated assembling environment. The goal of this exploration is to boost machine use, augmenting throughput of framework and improve variables those influences framework use and throughput of framework.

This investigation is to extend machine use and to investigate the full utilization of designers, work and administration by utilizing PDM programming.

The system factors those impacts FMS objectives. FMS to create the throughput and working hours for each machine each year and after that structure utilize and throughput has been progressed as inspected underneath.

Methodology:

The technique for deciding the "operation portion need file" of a section sort can be outlined as takes after: -

In machine stacking issues, in light of the accessibility of discretionary operations of part sorts, choices are to be made for assigning operations on the machines. Taking after documentations and definitions are to be acquainted with clarify the plan of "operation allotment need record" (henceforth named as need file "PI"):.

Operation designation: Operation allotment implies the task of an operation of a section sort on a machine.

Opom-operation "o" of part sort "p" has been distributed to machine "m".

Set of operations assignment: An arrangement of operations allotment of a section sort is characterized as the gathering of particular operations distributions on the machines. The cardinality of this set is same as the aggregate number of operations of that part sort.

ASpq = qth set of operations portion of part sort "p"

Where "q" is the list for set of operation portion number, q=1,2,… … .qmax.

An arrangement of operations portion is spoken to as

ASpq={Op1m, Op2m, Op3m ,… … , OpOpm''}

m,m',m'',… … ,m''' {m}, where m =1 to M and m compares to o.

In the event that a section sort "p" contains operation operations and if operation "o" can be allotted on qmax number of machines then the aggregate number of set of operations designation (qmax) is given by

qmax = M m corresponds to k. p oo 1

Apparatus Slot Index:

Corresponds to every operation allotment of part sort on machine, the device opening file considers the accessible device spaces on machine before assignment, crucial device opening necessity of machine and accessible device spaces on machine after portion.

TSI [Oomp] = (Tropm – ESmp)/(Taopm-ESmp)

Where TSI [Oomp] represents the tool slot index of machine "m" after the allocation operation "o" of part type "p" on machine "m" as per the nth set of operation allocation.

• Priority Index: Priority list of set of operation assignment can be communicated as the result of normal of machining time list and instrument spaces file of machine.

Table 4.1 The different situation, which can arise during the evaluation of PI for a set of operation allocation

Case	MTImq [Oomp]	TSImp[Oomp]	PI(ASqp)	Remarks
1	All positive	All positive	Positive	Set of operation allocation ASpq is feasible.
2	Positive and negative	All positive	Positive and negative	Set of operation allocation ASpq is feasible.
3	All positive	Negative	☐	Set of operation allocation ASpq is infeasible.
4	Positive and negative	Negative	☐	Set of operation allocation ASpq is infeasible.
5	Negative	Negative	☐	Set of operation allocation ASpq is infeasible.
6	Negative	All positive	Negative or Positive	Set of operation allocation ASpq is feasible.
7	Positive and negative	Positive	☐ Tropm is Negative	Set of operation allocation ASpq is

The assurance of part sort grouping utilizing above tenets, have been seen by a few specialists as the shortcoming of arrangement approach for machine stacking issue. Subsequently, in this exploration, endeavors has been made to devise a section sort sequencing criteria, which includes the few parameters, for example, group estimate, add up to preparing time and so on to suit the destinations of issue. According to the recommended criteria of part sort sequencing, commitment of each part sort to these parameters is resolved.

Exact Heuristic Reallocation *Paradigm:*

Step 1 :

(1) Input the total number of part types P.

(2) Input the total number of machines M.

(3) For p=1 to P, input op.

Step 2: For p =1 to P, evaluate αp using equation

Step 3: Arrange part type p, where p=1 to P in decreasing order of the contribution αp and generate the part type sequence.

Step 4: For p =1 to P , input the value of Ip from part type sequence.

Step 5: Input taopm, Taopm, for m=1 to M.

Step 6: Determine ETmp, ESmp for m =1 to M.

Step 7: Initialize Ip=1.

Step 8: Determine ASqp, the set of operation allocation of part type “p”, for q = 1 to qmax.

Step 9: Determine ERMm*, ERTm*, ATMm*, ATSm*.

Step 10: Initialize q =1.

Step 11: Determine tropm, Tropm corresponding to ASqp.

Step 12: Evaluate PI (ASqp) using equation 5.4.

Step 13: If q< qmax, then q = q+1, go to step 11, Else go to step 14.

Step 14: If for ASq

Step 15: Select Asp

Step 16: Update taopm, Taopm, ETmp, and ESmp after allocation of part type “p”.

[Set tropm to taopm, Tropm to Taopm, ESmp to ESmp’ ,ESmp to ESmp’]

Step 17: If Ip < Ip, increase Ip by 1 and go to step 8, Else go to step 18.

Step 18: Find system Unbalance “SU” and part throughput “TH”.

Step 19: If SU is negative, then go for reallocation, else output the final SU and TH.

Step 20: REALLOCATION

For p =1 to P, where p does not ϵ PU_{TSC} and PU_{NSU} , do the following:

(A). Add TPT_p to SU and SU* .

(B) Choose the minimum positive value of SU* and get the corresponding

Throughput TH* and go to step C. If SU is still negative, then add TPTp

to SU and get SU**. Choose the minimum positive value of SU** and

Determine the corresponding TH** and go to step C.

(C) Reject the part type “p” from the set of assigned part types. This part type is rejected due to negative system unbalance.

(D) Add corresponding machining time and tool slots of the part type “p” to the respective machines. Go to step G.

(E) Reject the part type p and p* from the set of pool of assigned part types (due to part types)

(F) Add corresponding machining time and tool slots of the allocate operations of the part type p and p* to m respective machines. Go to step G.

(G) Allocate part type p where $p \epsilon PU_{TSC}$ and obtain SU and TH.

(H) If SU is negative for all part types of PU_{TSC}, reject these part types and obtain the final SU and TH.

V. PERFORMANCE ANALYSIS AND MODELING OF CASE SYSTEM

Writing demonstrates that deterministic investigation of FMS can decrease the vulnerability required in the stochastic studies. There are different all inclusive scientific models accessible to perform deterministic study and in this manner might be used. It is felt that better investigation of a current framework would likewise help in enhancing execution and in planning operational parameters of another FMS. These models have been appropriately checked and approved in the writing to give essential assessments of operational parameters, for example, creation rate, workstation stack and so forth. A few suspicions have been considered for the execution of the model to ponder the case. These are specified underneath:

1. The study is absolutely deterministic in nature.

2. This study is not expected to assess the dynamic parameters.

3. This study is displayed by expecting that the yield of the framework has an furthest utmost it implies the framework has inbuilt bottleneck.

4. It is expected that the item blend moving through the framework is altered.

5. All through the study, operation recurrence is solidarity.

Operational Parameters:

To appraise different execution measures, it is required to first figure the normal workload on every work station of FMS which is characterized as the mean aggregate time spent at a machining station for each part.

Normal workload

$WLi = \Sigma j\ \Sigma k\ tijkfijkPj$

Where WLi = normal workload for station i (Minutes), tijk = Processing time for operation k in process arrange j at station i (Min), fijk = operation recurrence for operation k to a limited extent j at station i, pj = part-blend division for part j. The normal workload ascertained for different workstations of case FMS is summarized in table 5.1

Table 5.1 Average Workload On Workstations

Sl. No.	**Workstations (Description)**	**Average Work Load (Min)**
1	Load / Unload Station	20.85
2	Turning Center	152
3	Welding Station	16.4
4	Boring Machine	138.05
5	Drilling Station	324.37
6	Milling Center	8.22
7	Grinding Machine	24
8	Lapping Machine	271.62
9	Rubber Matching	48.08
10	Inspection	24.74
11	Painting Station	23.51
12	Assembly Station	48.25
13	Mat. Handling System	225

The case FMS has a bottleneck station which can easily be found by calculating following ratio (Table 5.2).

Bottleneck station = Largest workload to no. of server ratio, i.e. WL/i

Table 5.2 Estimation Of Bottleneck Station

Workstations (Description)	**Average Work Load (Min)**	**No. of Servers**	**Bottleneck? (WLi / Si)**
Load / Unload Station	20.85	40	0.52
Turning Center	152	32	4.76
Welding Station	16.4	1	16.40
Boring Machine	138.05	16	8.63
Drilling Station	324.37	4	81.11
Milling Center	8.22	2	4.11
Grinding Machine	24	6	4.16
Lapping Machine	271.62	16	17.74
Rubber Matching	48.08	4	12.02
Inspection	24.74	12	2.11
Painting Station	23.51	4	6.12
Assembly Station	48.25	4	12.13
Mat. Handling System	225	16	14.12

VI. RESULT

Different execution assessment studies can be found in writing and large portions of them have utilized execution measures like make traverse time, lead time, normal stream time, machine use, framework usage and so on. Here well known execution measures have been utilized i.e. creation rate of all parts, generation rate of every part sort, normal use of workstations, assembling lead time and mean holding up time experienced by a section at the stations.

The most extreme generation rate (pc every moment) of all parts is constrained by the limit of bottleneck station and along these lines can be figured as the proportion of s* (No. of servers at bottleneck station) to WL* (Workload at Bottleneck Station).

Maximum production rate of all parts

$$R_p* = s* / WL*$$

Similarly individual part production rate (of part type j) can be obtained by multiplying $R*p$ by the respective part mix ratios *(Pj)*

$R_{pj}* = Pj\ (R_p*) = Pj\ s* / WL*$

Implementing the above formula maximum production rate of all parts is found to be O.74026 Pc./hr. for our case.

Utilization of each workstation:

The mean usage of every workstation is characterized as the measure of time that the servers at the station are working and not sit out of gear. The usage of bottleneck station will be 100% at R*p. considering the previously mentioned documentations, mean usage Ui is spoken to as (Table 6.1)

$Ui = WLi/si\ (RP*\ ) = WLi/si - s*/WL*$

Normal station usage (Uav) can likewise be found by figuring the normal esteem for all stations, including transport framework.

$U_{av} = \Sigma\ n{+}1\ /\ i{=}1\ Ui$

Table 6.1: Station Utilization. Source

Stations	Station Utilization	
	(Num)	(%)
Load / Unload Station	0.001	0.06
Turning Center	0.17	6.1
Welding Station	0.20	20.23
Boring Machine	0.11	10.64
Drilling Station	1.01	100
Milling Center	0.11	5.18
Grinding Machine	0.05	4.93
Lapping Machine	0.21	20.94
Rubber Matching	0.15	14.83
Inspection	0.03	2.54
Painting Station	0.11	7.25
Assembly Station	0.15	14.97
Mat. Handling System	0.23	17.35

Overall FMS utilization

It is an extremely valuable execution measure and can be ascertained utilizing a weighted normal, by considering number of servers at every station (n) without utilizing transport framework. The general FMS usage for the situation has been ascertained as 88.53%.

$UOverall = \Sigma\ n\ i{=}1\ siUi/\Sigma\ n\ i{=}1\ si$

Producing Lead Time:

As considered a shut lining system with work in process stock in FMS and talked about the significance of WIP in FMS operation and estimation of assembling lead time (MLT). WIP (N) and MLT are associated; if N is little, then MLT will be most reduced because of the slightest holding up time. On the off chance that mean holding up time (T) and normal workloads at stations are known then WIP (N) and MLT can be ascertained utilizing taking after conditions.

$MLT = \Sigma n\ i\ WLi + WLn{+}1 + Tw = 1$

$WIP = N = RP(MLT$

Manufacturing Lead Time for Existing FMS = 1621.043 Minutes.

Waiting Time = 295.736 Minutes.

Proposed FMS:

After the count of wanted operational parameters, it is chosen to evaluate the execution of proposed framework by building up the reenactment models. Field is SIMAN based recreation bundle which utilizes different inbuilt modules to display any circumstance in a graphical UI. Models have been created and basic execution parameters, for example, Average Machine Utilization, Production Rate have been resolved. The move estimate utilized for the model run is 480 minutes and the creation of parts per move has been watched likewise the machine use has additionally been noted from the keep running for different conditions. The recreation comes about have demonstrated the enormous increment in the framework execution.

Table 6.2: No. of Servers in Proposed FMS

Workstations (Description)	No. of Servers (Proposed)
Load / Unload Station	4
Turning Center	29
Welding Station	4
Boring Machine	27
Drilling Station	62
Milling Center	2
Grinding Machine	5
Lapping Machine	10
Rubber Matching	52
Inspection	5
Painting Station	5
Assembly Station	10
Mat. Handling System	43

Results:

The execution investigation of existing and proposed FMS has been exhibited in the past area. At first operational parameter like greatest workload on every workstation has been figured and it is found that the normal workload on penetrating station is 324.37(minutes) with the aggregate number of servers 4, on this premise the proportion of normal workload to server turns out to be 81.08 (most extreme in all stations) which plainly demonstrates that the boring station is making a bottleneck in the preparing of parts. Numerical model clarifies that the execution of any framework will for the most part rely on upon the execution of the bottleneck station, thusly any execution change system can be thought either by moving this bottleneck to some other advantageous station or by killing the impact of bottleneck. This finding has been used while planning the proposed framework and the bottleneck has been moved to turning station with the sufficient number of servers to provide food the workload necessity. Another critical execution measure of any FMS is the mean use of workstations.. The workload necessity has been concentrated deliberately and by the utilization of scientific model portrayed in area 6.3, counts for the ideal number of servers for every workstation have been done and introduced in table 6.1 & 6.2.

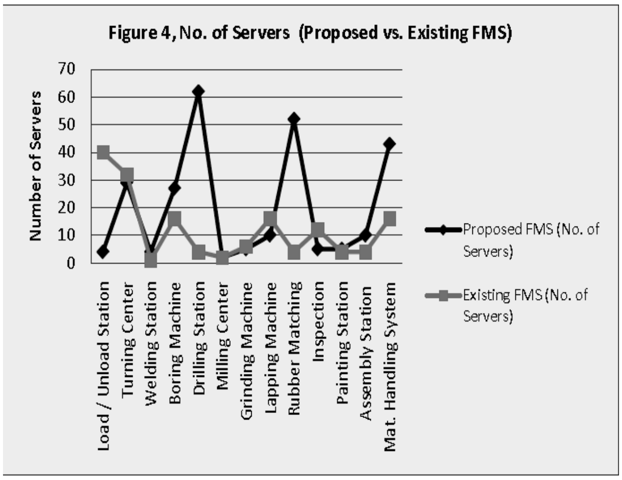


Fig. No 6.1 No. of Servers (Proposed vs. Existing).

The investigation of existing FMS uncovers that because of the issues experienced as over, the most extreme generation rate of all parts was less. The execution change can be seen from the figurings of most extreme generation rate of all parts for the proposed framework and the distinction is tremendous.

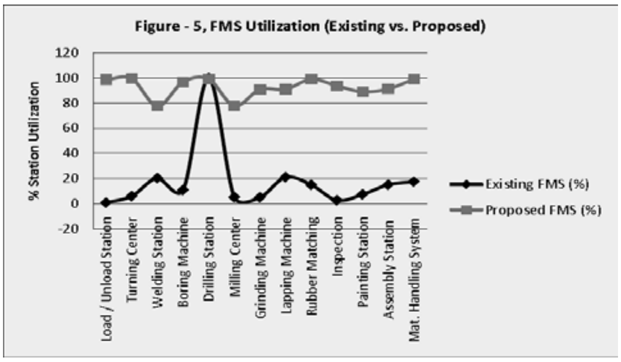


Fig. No 6.2 FMS Utilization

Table 6.3: Comparison Chart of Performance Parameters of FMS

Sl. No.	Performance Parameters	Proposed	Existing
1	Maximum Production Rate (Pcs./Hr)	11.43	0.074
2	Most Utilized Station	99.40%	99.99%
3	New Bottleneck Station	Turning Station	Drilling Station
4	Overall Utilization of System (%)	99.99%	88.53%

VII. CONCLUSIONS AND FUTURE WORK

Conclusion:

The study was to examine the current framework and set up an arrangement to enhance the execution of framework. Reproduction demonstrating has been used to accomplish the destinations. At first different operational and execution parameters were computed then the new FMS has been proposed with the ideal number of servers. It is found that the Maximum yield and will enhance execution. The framework use was another critical issue which has been tended to in this study, it is additionally found that in existing framework the assets were not legitimately used as a few stations like stacking/emptying. Therefore, considering the current framework and the recreation comes about, changes in sources and separations, reproduction streamlining model was displayed.

In future it is likewise planned to direct different reenactment analyzes with the goal that framework would be sufficiently hearty to handle all circumstance and element economic situations.

VIII. REFERENCES

[1] Groover, M. P., (2010), Fundamentals of modern manufacturing, materials, processes, and systems, Edition: 4, Publisher: John Wiley & Sons, pp. 935

[2] Groover, M. P., (2008) “Automation, Production Systems and Computer Integrated Manufacturing”, Edition: 3, Pearson Education. pp. 235

[3] Avonts, L.H. and Wassenhove, L.N., (1988), the part mix and routing mix problem in FMS: a coupling between an LP model and a closed queuing network. International Journal of Production Research, Vol. 26, pp. 1891-1902.

[4] C.B. and Mize, J.H., (1992), an object-oriented framework for operating flexible manufacturing systems. Proceedings: International Conference on Object-Oriented Manufacturing Systems, pp. 346-351. 32

[5] Bensana, E., Bel, G., and Dubois, D., (1988), OPAL: A multi-knowledge-based system for industrial job-shop scheduling. International Journal of Production Research, Vol. 26, pp. 795-819.

[6] Gershwin, S.B., (1989), Hierarchical flow control: a framework for scheduling and planning discrete events in manufacturing systems. Proceedings of the IEEE, Vol. 77, pp. 195-209.

[7] Chen, Y.J., and Askin, R.G., (1990), A multiobjective evaluation of flexible manufacturing system loading heuristics. International Journal of Production Research, Vol. 28, pp. 895-911.

[8] Avonts, L.H. and Wassenhove, L.N., (1988), the part mix and routing mix problem in FMS: a coupling between an LP model and a closed queuing network. International Journal of Production Research, Vol. 26, pp. 1891-1902.

[9] Hutchison, S.H. and Hove, L.H., (1989), the part mix and routing mix problem in FMS: a coupling between an LP model and a closed queuing network. International Journal of Production Research, Vol. 28, pp. 861-902.

[10] Chan, T. S., R. Swarnkar, R., Tiwari, Manoj K., (2009), A random search approach to the machine loading problem of an FMS. IEEE International Symposium on Intelligent Control (ISIC) Vol. 29, pp. 32-40,

[11] Jaikumar, R., and Van Wassenhove, L.N., (1989), A production planning framework for flexible manufacturing systems. Journal of Manufacturing Operations Management, Vol. 2, pp. 52-79.

[12] Montazeri, M., and Van Wassenhove, L.N., (1990), Analysis of scheduling rules for an FMS. International Journal of Production Research, Vol. 28, pp. 785-802.

[13] Montegomery, D. C., (2006) “Design and Analysis of Experiment”, Wiley edition,

[14] Maddulety, K, Mdgil, S., Patyal, V. S., (2012). Application of “taguchi design and analysis” for ‘ modeling optimization’. International conference on advances in engineering. Science and management pp. 85-92

[15] Davis, L. (1991) Handbook of Genetic Algorithms. Van Nostrand Reinhold. New York, NY.

[16] Randall, M.C. (1995) The Future and Applications of Genetic Algorithms . In Proceedings of Electronic Technology Directions to the Year 2000. (Ed. Jain, L.C.) Adelaide, Australia. May 23-25. IEEE Computer Society Press. Vol. 2. pp. 471 - 475.

[17] Ali, M., Wadhwa, S. "Performance analysis of partial flexible manufacturing systems", Global Journal of Flexible Systems Mgt, 6(1), 9-19,2005.

[18] Ajay Singholi, Deepti Chhabra, MohammadAli, " Towards improving the performance of flexible manufacturing system: a case study", Journal of Industrial Engineering and Management, 3(1), 87-115, 2010.

[19] Buitenhek, R., Baynat, B., Dallery, Y. " Prod capacity of flexible mfg. systems with fixed prod ratios", International Journal Flexible Manufacturing Systems, 4(3), 203–226, 2002.

[20] Chan, F. T. S., Wadhwa, S., Bibhushan, "Inventory performance of some supply chain inventory policies under impulse demands", International Journal of Production Research, TPRS--IJPR-0111, 2007.

[21] Kumar, S., Sridharan, R. "Simulation modeling and analysis of tool sharing and part scheduling decisions in single-stage multi-machine flexible manufacturing systems", Robotics and Computer-Integrated Manufacturing, 23, 361–370, 2007.

[22] Kusiak, A. "The part family's problem in flexible manufacturing systems", Annual Operation Research, 3, 279–300, 2008.

[23] Montazeri, M., Van Wassenhove, L. N. "Analysis of scheduling rules for an FMS", International Journal of Production Research, 28(4), 785–802, 2006.

[24] Mejabi, O. "Modeling in flexible manufacturing systems design", Ph.D. Dissertation, Lehigh University, Bethlehem, Pennsylvania, USA, 2010.

[25] Solberg, J. J. "Capacity planning with a stochastic work flow model", AIIE Transaction, 13(2), 116-122, 2011. Tunali, S. "Evaluation of alternate routing policies in scheduling a job-shop type FMS", Comp Ind Eng, 32(2), 243–325, 2010.

[26] Wadhwa, S., Rao, K. S., Chan, F. T. S. "Flexibility-enabled lead-time reduction in flexible Sys", International Journal of Production Research, 43(15), 3131-3163, 2005.

[27] Weber, D. M., Moodie, C. L. "An intelligent information system for an automated, Integrated Mfg System", Journal of Manufacturing Systems, 8, 99–113, 2007.