International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8, Issue-1C, May 2019

Optimization of System Utilization and Throughput in FMS using Taguchi and ANOVA Approach

Manu G, Vijay Kumar M

Abstract*: *Flexible Manufacturing Systems (FMS) are generation frameworks comprising of indistinguishable multipurpose numerically controlled machines (workstations), computerized material dealing with framework, instruments, stacking and emptying stations, investigation stations, stockpiling zones and a various leveled control framework. Occupation sequencing and directing are central parts of FMS. In this work, four section types and five machines has been utilized, for exact outcomes 'L_{27}' array has been chosen, and the procedure factors as structured by utilizing Taguchi logic has been treated as info work for reproduction model of FMS to produce the throughput and system utilization for each machine every year. With the results obtained after inputting the data into Taguchi and ANOVA framework it is made clear that the system utilization is majorly affected by demand time followed by the distance preference. The velocity of cart plays a very small role in the changes. Whereas throughput is majorly influenced by demand arrival time followed by velocity of cart and the number of carts plays a small role.

Index Terms: Flexible Manufacturing Systems, Shortest processing time, system throughput, system utilization

.

I. INTRODUCTION

The present modern pattern of assembling minimal effort low-to-medium volumes of measured items with high fluctuation requests producing frameworks with adaptability and low conveyance times. This prompted assembling frameworks with little cluster creations, low setup times and numerous decisional degrees of opportunity. Those frameworks are adaptable assembling frameworks (FMS). They are exceptionally computerized frameworks with numerous redundancies, consequently taking into account numerous degrees of opportunity in the choice procedure. Despite the fact that there are no all around acknowledged meanings of FMSs, as indicated by what is proposed by Tempelmeier and Kuhn (1993) and Viswanadham and Narahari(1992) a FMS is made out of:

Revised Manuscript Received on May 23, 2019

Manu G, Mechanical Engineering, SJC Institute of Technology, Chickballapur, India.

Dr. Vijay Kumar M, Industrial Engineering Management, JSSATE, Bangalore, India.

• Numerically controlled (NC) multipurpose machine, with computerized device trade.
• Automated materials and instruments dealing with framework (MHS), made by transport lines, and programmed guided vehicles (AGV), mechanical robots, and so on.
• Load and empty stations that deal with the stacking and emptying of parts (stacked parts are settled on beds);
• Inspection stations (for quality control);
• Storage zones like info, yield and information yield cushions for each machine, or unified supports;
• Tools stockpiling territories;
• Hierarchical control framework that deals with the MHS, every one of the parts and devices developments and stacking and emptying of parts in stations and machines.

II. LITERATURE SURVEY

Maintenance activity is dealt with two approaches, the first to fix the total maintenance tasks to optimize some of them by locating them. For this a genetic algorithm approach is used to solve makespan and minimization of total tardiness problems [1].

An attempt is made to minimize the makespan in FJSP consisting of problems like assigning and sequencing by utilizing Artificial Immune Algorithm. The reproduction is done through selecting individuals and initial population is generated. New individuals are generated using many mutators. Bench mark numerical experiment problems are done to prove the effectiveness of the proposed model [3].
The constraint between machines and heavy data search space make scheduling problem a crucial one. Due to large computing time of branch and bound method a new model is proposed using GA and proved using bench mark scheduling problems by obtaining steady and better results by representing individual schedules and assign individual GA operators[5].

An influence is derived by the literature of generating many ways of initial solution generation. GA integrated with Taguchi experimentation technique is used for the purpose. Confirmatory tests for proving the better combination of parameters is done. The deviation in the signal to noise ratio indicates robust and repetitive parametric combination with better results. Parameter design

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Retrieval Number: A10530581C19/19©BEIESP

hence requires less time by considering GA with Taguchi [9].

Table 1: Processing time of each operation on each machine (min.)

Part/Machine	Operation	M/C 1	M/C 2	M/C 3	M/C 4	M/C 5
P1 (n1=3)	O11	2	5	4	1	2
	O12	5	4	5	7	5
	O13	4	5	5	4	5
P2(n2=3)	O21	2	5	4	7	8
	O22	5	6	9	8	5
	O23	4	5	4	5	5
P3(n3=4)	O31	9	8	6	7	9
	O32	6	1	2	5	4
	O33	2	5	4	2	4
	O34	4	5	2	1	5
P4(n4=2)	O41	1	5	2	4	12
	O42	5	1	2	1	2

Table 2: Sequencing of operation of jobs on machines

M/Ck	Sequence of operation
M/C1	O21-O41-O23
M/C2	O12-O42-O32
M/C3	O31
M/C4	O11- O13-O33-O34
M/C5	O22

III. EXPERIMENT AND MODEL DEVELOPMENT

The model of FMS considered in this work is represented in table 2, which comprises five work stations and five machines and there is four sections delivered by these machines. Each work station comprises one machine.

Here four factors which affect the objective of FMS have been used: these factors and there levels are as follows:

1. Distance preference (X_1):
2. Arrival (demand) time (min.) (X_2)
3. No. of carts(X_3)
4. Speed of carts (feet/min.)

The throughput and system utilization is calculated using the formulae 9 (Text book by M P Grover) and the design of experiments considering Taguchi technique of L27 array.

Table 3: Experimental design of L_{27} array for throughput

Distance Preference	**Demand Time**	**No. of Carts**	**Velocity of Carts**	**Throughput**
Small	10	2	60	29586
Small	10	3	65	29733
Small	10	4	70	29552
Small	15	2	60	19463
Small	15	3	65	19586
Small	15	4	70	19812
Small	20	2	60	14870
Small	20	3	65	14778
Small	20	4	70	14976
Large	10	2	65	29373
Large	10	3	70	29284
Large	10	4	60	29380
Large	15	2	65	19844
Large	15	3	70	19623
Large	15	4	60	19749
Large	20	2	65	14595
Large	20	3	70	14670
Large	20	4	60	14594
Cyclical	10	2	70	29285
Cyclical	10	3	60	29595
Cyclical	10	4	65	29285
Cyclical	15	2	70	19875
Cyclical	15	3	60	19865
Cyclical	15	4	65	19770
Cyclical	20	2	70	14764
Cyclical	20	3	60	14732
Cyclical	20	4	65	14885

Retrieval Number: A10530581C19/19©BEIESP

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

Table 4: Experimental design of L27 array for System utilization

Distance Preference	Demand time	No. of Carts	Velocity of Carts	System utilization
Small	10	2	60	75.313
Small	10	3	65	75.346
Small	10	4	70	75.746
Small	15	2	60	70.139
Small	15	3	65	70.316
Small	15	4	70	70.486
Small	20	2	60	55.483
Small	20	3	65	52.751
Small	20	4	70	53.747
Large	10	2	65	73.842
Large	10	3	70	73.249
Large	10	4	60	73.111
Large	15	2	65	71.236
Large	15	3	70	70.445
Large	15	4	60	71.466
Large	20	2	65	52.381
Large	20	3	70	52.368
Large	20	4	60	52.429
Cyclical	10	2	70	72.518
Cyclical	10	3	60	72.638
Cyclical	10	4	65	72.174
Cyclical	15	2	70	71.295
Cyclical	15	3	60	71.832
Cyclical	15	4	65	70.563
Cyclical	20	2	70	52.861
Cyclical	20	3	60	53.335
Cyclical	20	4	65	54.687

III. RESULTS AND DISCUSSION

A. Experimental design

L27 array as shown in the previous section has been considered in order to visualize the effects of parameters on throughput and system utilization. The four parameters considered above plays a vital role in the total system utilization and the throughput of the material as they are directly linked to the manufacturing lead time. Hence an attempt is made by using ANOVA to obtain a clear picture of the contribution made by the different factors.

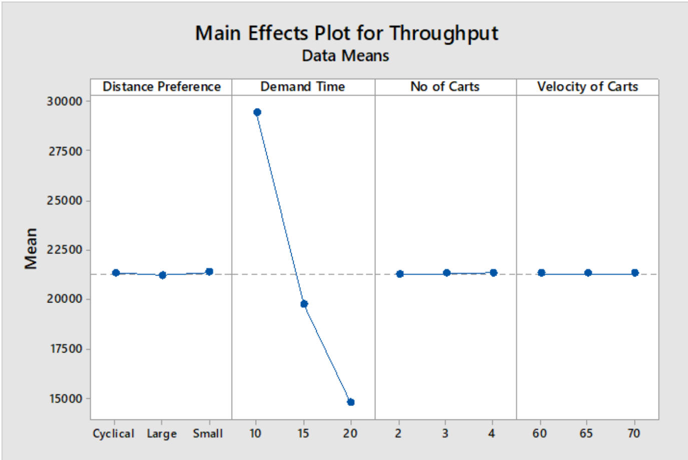

Fig 1: Main effects plot for throughput

The above graph shows the main effects plot for throughput. As the framework of FMS needs to have more throughput it is recommended to get the graph on larger is better basis. From the graph it can be shown that the demand time is the major influencing parameter as with the less demand time the throughput will be more. With the distance preference as the parameter it is seen that the smaller distance is preferred as well as the number of carts and the velocity should me more to obtain more throughput.

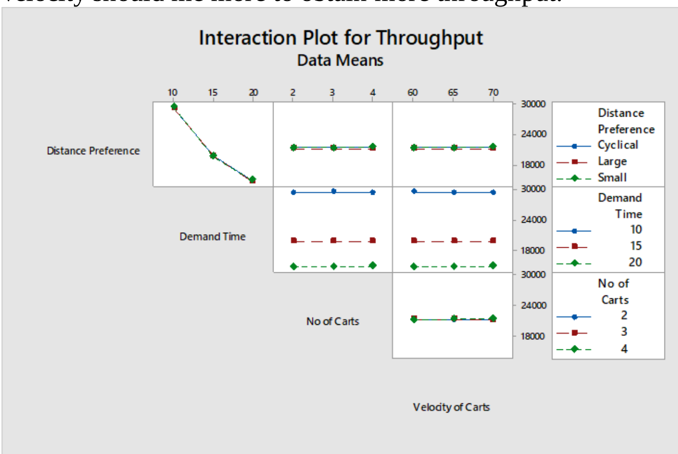

Fig 2: Interaction plot for throughput

The interaction plot of the variables clearly indicates that the very important interaction or the combination to be considered is the relation between distance preference and the demand time. Whereas the other interactions or the combination have less or negligible significance.

Table 5: Variance of components

Source	Var	% of Total	SE Var	Z-Value	P-Value
Distance Preference	3022.066218	0.01%	5244.418628	0.576244	0.282
Demand time	5.58274E+07	99.96%	5.58296E+07	0.999961	0.159
No of carts	0.000000	0.00%	*	*	*
Velocity of carts	0.000000	0.00%	*	*	*
Error	1.96287E+04	0.04%	5918.264664	3.316625	0.000
Total	5.58500E+07				

The graph can also be explained in terms of variance of components as shown in the table. The major influencing factor is the demand time contributing up to 99.96% followed by the distance preference contributing 0.01%. The other two variables have negligible or zero contribution.

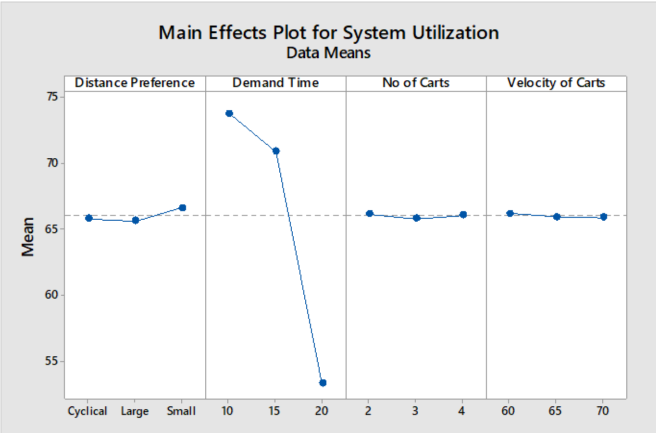

Fig 3: Main effects plot for system utilization

Considering the system utilization as the response the graph is plotted with larger is better ideology as the system utilization is preferred to be greater always. As we can see from the graphs it is visible that the demand time is the factor to be taken care of. Hence by combining small distance preference, minimum demand time more number of carts and highest velocity of carts the maximum system utilization From can be obtained.

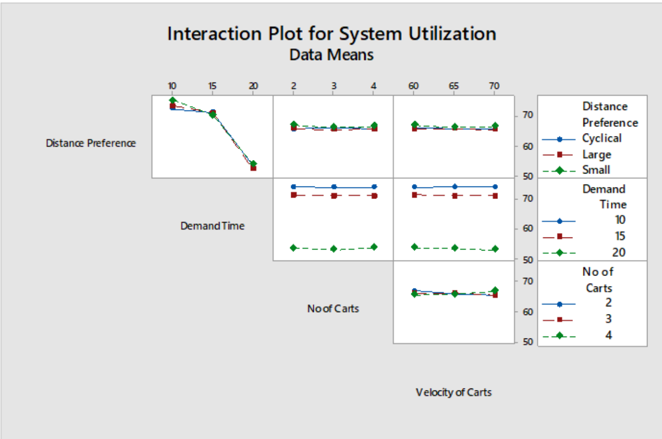

Fig 4: Interaction plot for system utilization

The combination AxB and AxD along with CxD have major effects in fluctuation of the system utilization as visible from the graph. As discussed above the distance preference and demand time must be minimum to obtain higher system utilization. As well as the number of carts and the velocity should be maximum.

Source	Var	% of Total	SE Var	Z-Value	P-Value
Distance Preference	0.162511	0.13%	0.278776	0.582943	0.280
Demand time	122.071690	99.03%	122.185828	0.999066	0.159
No of carts	0.000000	0.00%	*	*	*
Velocity of carts	0.000000	0.00%	*	*	*
Error	1.027202	0.83%	0.309713	3.316625	0.000
Total	123.261402				

Table 6: Variance of Components

From the mixed effect model the above table is generated and the maximum contribution is by demand time with 99.03% followed by the distance preference with 0.13%. The variables have nil or zero effect and can be neglected.

Using the response surface methodology the analysis of variance has been done and the combinational effects have been shown as above. As discussed earlier the demand time is the major contributor followed by CxD. In order to understand the combinational behavior of the variables analysis of variance is done and the table is created as shown above. The major parameter influencing system utilization is the demand time. The parametric combination of BxC CxA and BxD is the levels of contribution in a serial manner. All the other interactions are negligible.

B. Regression equations:

Table 7: Analysis of Variance for Throughput

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	17	1005301824	59135401	3416.96	0.000
Linear	6	1005002849	167500475	9678.50	0.000
No of Carts	1	6728	6728	0.39	0.548
Velocity of carts	1	3	3	0.00	0.990
Distance preference	2	64021	32011	1.85	0.212
Demand Time	2	1004932097	502466048	29033.46	0.000
Square	2	111	56	0.00	0.00
No of Carts*No of Carts	1	101	101	0.01	0.00
Velocity of carts*Velocity of carts	1	10	10	0.00	0.982
2-Way Interaction	9	269231	29915	1.73	0.214
No of Carts*Velocity of carts	1	1579	1579	0.09	0.769
No of Carts*Demand Time	2	5606	2803	0.16	0.853
Velocity of carts*Demand Time	2	48945	24472	1.41	0.292
Distance preference*Demand Time	4	213101	53275	3.08	0.074
Error	9	155758	17306		
Total	26	1005457582			

Table 8: Analysis of Variance for system utilization

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	15	2212.69	147.51	114.05	0.000
Linear	6	1884.66	314.11	242.85	0.000
Demand time	1	1878.74	1878.74	1452.50	0.000
No of carts	1	0.02	0.02	0.02	0.894
Distance Preference	2	4.98	2.49	1.92	0.192
Velocity of carts	2	0.91	0.46	0.35	0.711
Square	2	321.05	160.52	124.11	0.000
Demand time*Demand time	1	320.60	320.60	247.87	0.000
No of carts*No of carts	1	0.45	0.45	0.35	0.568
2-Way Interaction	7	7.32	1.05	0.81	0.598
Demand time*No of carts	1	0.05	0.05	0.04	0.847
Demand time*Distance Preference	2	6.05	3.02	2.34	0.143
Demand time*Velocity of carts	2	0.63	0.32	0.24	0.787
No of carts*Distance Preference	2	0.59	0.30	0.23	0.799
Error	11	14.23	1.29		
Total	26	2226.92			

Throughouut	=	29454.9 + 0.0 Distance Preference_Cyclical-104.9 Distance Preference_Large + 33.3 Distance Preference_Small + 0.0 Demand Time_10 - 9720.7 Demand Time_15 - 14689.9 Demand Time_20 + 0.0 No of Carts_2 + 23.4 No of Carts_3 + 38.7 No of Carts_4 + 0.0 Velocity of Carts_60 + 1.7 Velocity of Carts_65 + 0.8 Velocity of Carts_70
System Utilization	=	73.877 + 0.0 Distance Preference_Cyclical - 0.153 Distance Preference_Large + 0.825 Distance Preference_Small + 0.0 Demand Time_10 - 2.907 Demand Time_15 - 20.433 Demand Time_20 + 0.0 No of Carts_2 - 0.310 No of Carts_3 - 0.073 No of Carts_4 + 0.0 Velocity of Carts_60 - 0.272 Velocity of Carts_65 - 0.337 Velocity of Carts_70

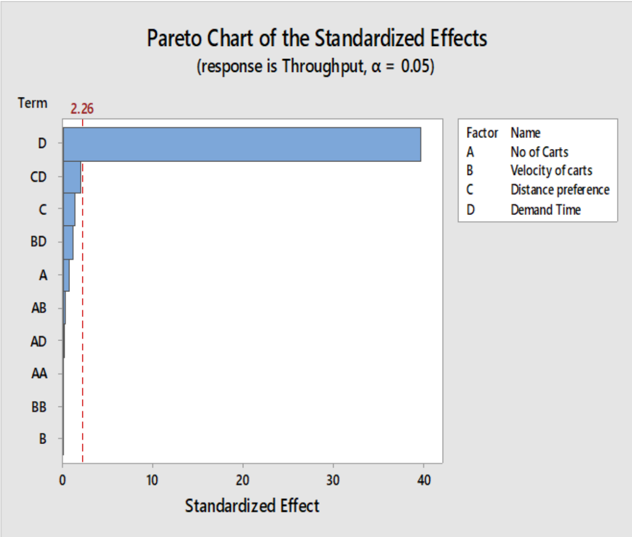

Fig5: Effects of combinations on the throughput

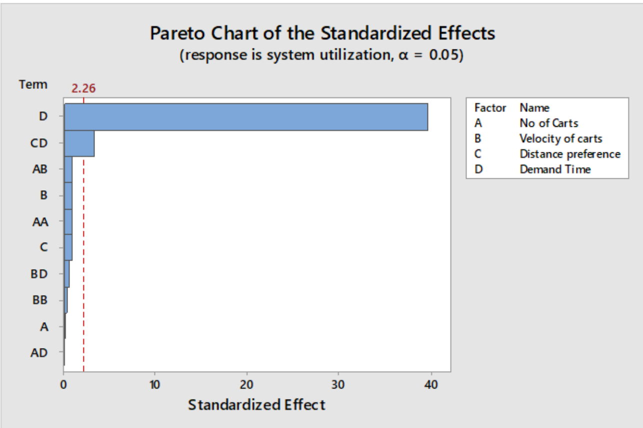

Fig 6: Effects of combinations on the system utilization

IV. CONCLUSION

The parametric optimization on the responses throughput and system utilization is attempted in this work using Taguchi for experiment design, ANOVA for parametric contribution and Response surface analysis for combinational contribution.

- The major parameter effecting the both throughput and system utilization is demand time. The larger the demand time lesser are the responses.
- The following contribution is through distance preference. According to literature and the present work smaller the distance more is the increase in the response. The other two responses are almost negligible.
- The combination effect on the responses shows the mixed behavior for response in different manner. For throughput distance preference X demand time is the major effective combination followed by no. of carts X velocity of carts. The remaining interactions can be neglected.
- The best possible combination for maximum responses is distance preference – small, demand time – 10, no. of carts – 4 and velocity of carts – 70. The regression models for optimized parameters to obtain better responses are generated.

REFERENCES

1. Aggoune, R., H. A. Mahdi, and M. Portman. 2001. "Genetic Algorithm for the Flow Shop Scheduling Problem with Availability Constraints." IEEE International Conference on Systems, Man, and Cybernetics 4: 2546–2551.
2. Altıparmak, F., B. Dengiz, and A. Smith. 2000. "An Evolutionary Approach for Reliability Optimization in Fixed Topology Computer Networks." Transactions on Operational Research 12 (1–2): 57–75.
3. Bagheri, A., M. Zandieh, I. Mahdavi, and M. Yazdani. 2010. "An Artificial Immune Algorithm for the Flexible Job-shop Scheduling Problem." Future Generation Computer Systems 26 (4): 533–541.
4. Blum, C., and A. Roli. 2003. "Metaheuristics in Combinatorial Optimization." ACM Computing Surveys 35 (3): 268–308.
5. Ceran, G. 2006. "Solving Hybrid Flow Shop Scheduling Problems by Using Data Mining and Genetic Algorithm." Master's thesis, Selcuk University.
6. Chan, F. T. S., and H. K. Chan. 2004. "A Comprehensive Survey and Future Trend of Simulation Study on FMS Scheduling." Journal of Intelligent Manufacturing 15: 87–102.
7. Chan, F. T. S., S. Chung, and P. Chan. 2005. "An Introduction of Dominant Genes in Genetic Algorithm for Scheduling of FMS." In Proceedings of the IEEE International Symposium on Intelligent Control.
8. Limassol, Cyprus. Chaudhry, I. 2012. "A Genetic Algorithm Approach for Process Planning and Scheduling in Job Shop Environment." In Proceedings of the World Congress on Engineering, Vol. III. London: WCE.
9. Cheng, B. W., and C. L. Chang. 2007. "A Study on Flow Shop Scheduling Problem Combining Taguchi Experimental Design and Genetic Algorithm." Expert Systems with Applications 32: 415–421.
10. Cheng, E., and G. Wang. 2000. "Single Machine Scheduling with Learning Effect Considerations." Annals of Operations Research98: 273–290.
11. Chiang, T. C., and L. C. Fu. 2004. "Solving the FMS Scheduling Problem by Critical Ratio-based Heuristics and the Genetic Algorithm." IEEE International Conference on Robotics and Automation 3: 3131–3336.
12. Choua, Fuh-Der, and Ching-En Lee. 1999. "Two-machine Flowshop Scheduling with Bicriteria Problem." Computers & Industrial Engineering 36 (3): 549–564.
13. Chryssolouris, G. 2006. Manufacturing Systems: Theory and Practice. 2nd ed. New York: Springer-Verlag.
14. Chryssolouris, G., and V. Subramaniam. 2001. "Dynamic Scheduling of Manufacturing Job Shops Using Genetic Algorithms." Journal of Intelligent Manufacturing 12 (3): 281–293.
15. Davidson, M. J., K. Balasubramanian, and G. Tagore. 2008. "Experimental Investigation on Flow-forming of AA6061 Alloy a Taguchi Approach." Journal of Materials Processing Technology 200: 283–287.
16. Doğdu, N., Ş. Onural, and B. Cerit. 2004. "A Study of Optimal Scheduling of Flexible Manufacturing Systems." Nigde University Journal of Engineering Sciences 8 (1): 31–39.
17. Du Plessis, B. J., and G. H. De Villiers. 2007. "The Application of the Taguchi Method in the Evaluation of Mechanical Flotation in Waste Activated Sludge Thickening." Resources, Conservation and Recycling 50: 202–210.
18. Engin, O. 2001. "To Increase the Performance of Flow-shop Scheduling Problems Solving with Genetic Algorithms: A Parameter Optimization." PhD dissertation, Istanbul Technical University.
19. Garey, M. R., D. S. Johnson, and R. Sethi. 1976. "The Complexity of Flowshop and Jobshop Scheduling." Mathematics of Operations Research 1 (2): 117–129.
20. Gen, M., J. Gao, and L. Lin. 2009. "Multistage-based Genetic Algorithm for Flexible Job-shop Scheduling Problem." Studies in Computational Intelligence 187: 183–196. doi:10.1007/978-3-540-95978-6_13.
21. Glover, F. 1986. "Future Paths for Integer Programming and Links to Artificial Intelligence." Computers & Operational Research 13 (5): 533–549.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

AUTHORS PROFILE

Manu G is a Faculty Member in the department of Mechanical Engineering at SJCIT. His qualifications include a Bachelors degree from BMSCE and Master degree from UVCE. His research works in the field of Flexible manufacturing systems; he has several publications at national and international level, and he had membership at IIF & IIE.

Dr. Vijay Kumar M is a Professor and Head of the department, Industrial Engineering and Management. His qualifications include a Bachelors degree from Bangalore University, Master degree from Kuvempu University and PhD from VTU. He also has industrial experience at EMVEE, Bangalore. He has several publications at national and international level. Membership at several bodies.