Effect of Quality Systems on the Performance of Manufacturing System by Using Simulation

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***Abstract*— The simulation, modelling and analysis of manufacturing systems for performance improvement have become increasingly important during the last few decades. Abundant literature is available on the application of simulation in solving layout, materials handling, production control problems, line balancing, warehouse designs etc. It can also be used to measure performance of an existing plant as well as plants undergoing the introduction of new production philosophies. Simulation can quantify performance improvements. A relatively new application area of simulation is its incorporation into continuous improvement philosophies.**

The new requirements for enterprise flexibility, quality improvement, costs and throughput time reduction - cannot be achieved by using the traditional approaches. Manufacturing paradigms such as Just-in-Time (JIT), Total Quality Management (TQM), Total Productive Maintenance (TPM), Supply Chain Management (SCM) etc. has emerged to enhance business performance. Past research on these paradigms generally investigate the implementation and impact of these programs in isolation. The recent literature reports the discussion on joint implementation which is either conceptual or empirical surveys, favouring joint implementation of these paradigms The main objective of this study is to apply computer based simulation in JIT, TQM, TPM and SCM environment in a batch production manufacturing system. Various operating philosophies were developed and simulated using Design of Experiment (DoE) by implementing the related practices of different paradigms. The simulation exercise helps to quantify the key performance indicators. The effects of adopting these paradigms, in isolation and joint implementation, on manufacturing performance are investigated.

JIT, TQM, TPM and SCM represent alternate approaches to improve the effectiveness and efficiency of an organization's operations function. These paradigms have already been widely promoted worldwide. The vast literature is available on critical success factors and implementation. The empirical surveys, case studies and their impact on manufacturing performance are also widely investigated. Nevertheless, most of these publications opt for one of these paradigms as their central subject, and pay no or little attention to others. Quite often, the paradigm so opted is characterized as the major or only remedy for poor performance in manufacturing. However, none of these paradigms is self-sufficient and may not be powerful enough to deliver the improvements and innovations and address the problems and issues of organization as a whole that are required nowadays to insure the survival and growth of a firm. They are not mutually exclusive and inconsistent. On the contrary, they need complementary support and may reinforce mutually. They complement each other by reinforcing mutually, inducing side-effects in favour of other paradigm's, mutual simulation and exploitation of shared values. More researchers have begun to discuss the importance of complementary implementation and their effect on manufacturing programs. These researches on joint implementation includes JIT and TQM [1,3,9,10, 21]; TPM and TQM [11,12,13]; JIT, SCM and TQM [17,18]; JIT, TQM and TPM [2,4,19,20]; JIT and SCM [21,22]; TQM and SCM [23]; SCM and ERP [7,8,14,15,16,24] and TQM and ERP [25,26,27]. The sited authors and others have recognized that manufacturing competitiveness is based on foundation of integrating and overlapping practices, which forms the basis for pursuing superior performance in manufacturing. Linking one paradigm to another will enhance manufacturing performance.

***Index Terms*—JIT, TPM,TQM, SCM, DoE**

I. INTRODUCTION

Relationship among JIT, TQM, TPM and SCM

In Japan it is said that in order to be strong enough in manufacturing one has to have good brains which requires Total Quality Management (TQM), but one also needs to have strong muscles or, in other words, strong manufacturing capability which require Total Productive Maintenance (TPM). Moreover, one has to have a good nervous system to connect brain with muscles, which means just-in-time production. So, in manufacturing, one needs to have TQM, JIT and TPM. But, the organization can not work in isolation. It requires input in the form of quality material from various suppliers and is fulfilling the customer demand. SCM will help organization to interact with outside world along with manufacturing strategy. The relationship among JIT, TQM, TPM and SCM exist at a strategic level, and impacts business performance. The empirical surveys have also validated that if implemented complementarily (JIT-TQM-TPM [2, 3, 20] and JIT-TQM-SCM [17]), will enhance performance of manufacturing system.

II. APPLICATION OF SIMULATION IN ANALYSIS OF MANUFACTURING SYSTEM

Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system. Simulation is used in many contexts in order to gain insight into their functioning. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviours, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes. A computer simulation (or "sim") is an attempt to model a real-life or hypothetical situation on a computer so that it can be studied to see how the system works. By changing variables, pridiction may be made about

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the behaviour of the system. Modeling and Simulation is a discipline for developing a level of understanding of the interaction of the parts of a system, and of the system as a whole. The level of understanding which may be developed via this discipline is seldom achievable via any other discipline [61]. A system exists and operates in time and space and a model is a simplified representation of a system at some particular point in time or space intended to promote understanding of the real system.

III. Application of Simulation in Manufacturing

One of the largest application areas for simulation modeling is that of manufacturing systems, with the first uses dating back to at least the early 1960's. Manufacturing represents one of the most important applications of Simulation. This technique represents a valuable tool used by engineers when evaluating the effect of capital investment in equipments and physical facilities like factory plants, warehouses, and distribution centers. Simulation can be used to predict the performance of an existing or planned system and to compare alternative solutions for a particular design problem. The simulation, modelling and analysis of manufacturing systems for performance improvement have become increasingly important during the last few decades. Simulation has been used to investigate a wide variety of problematic areas in manufacturing. Abundant literature is available on the application of simulation in solving layout, materials handling, production control problems, line balancing, warehouse designs etc. Simulation is one of the most powerful analysis tools available to those responsible for the design and operation of complex manufacturing systems. It can be used to measure performance of an existing plant as well as plants undergoing the introduction of new production philosophies. Simulation can quantify performance improvements. A relatively new application area of simulation is its incorporation into continuous improvement philosophies.

The following are some of the specific issues that simulation is used to address in manufacturing:

The need for the quantity of equipment and personnel

· Number and type of machines for a particular objective

· Number, type, and physical arrangement of transporters, conveyors, and other support equipment (e.g., pallets and fixtures)

· Location and size of inventory buffers

· Evaluation of a change in product volume or mix

· Evaluation of the effect of a new piece of equipment on an existing manufacturing system

· Evaluation of capital investments

· Labor-requirements planning

Performance evaluation

· Throughput analysis

· Time-in-system analysis

· Bottleneck analysis

Evaluation of operational procedures

· Production scheduling

· Inventory policies

· Control strategies [e.g., for an automated guided vehicle system (AGVS)]

· Reliability analysis (e.g., effect of preventive maintenance)

· Quality-control policies

The most important reasons and advantages of simulation methodology for modeling manufacturing systems are that:

• Realistic models are possible; they are a practical approach to representing the important characteristics of a manufacturing system and may incorporate any complex interactions that exist between different variables;

• Options may be considered without direct system experimentation and alternative designs can be easily evaluated, independently of the real system

• A computer simulation models ability to directly address the performance measures typically used in a real system;

• Non-existent systems may be modeled;

• Visual output helps and assists the end-user in model development and validation;

• No advanced mathematics is required;

• Analytical methods are perceived to be unhelpful by management or may require over-simplification **[61].**

IV. Design of Experiments

The main objective of this study is to apply computer based simulation in JIT, TQM, TPM and SCM environment in a batch production manufacturing system. Various operating philosophies were developed and simulated using Design of Experiment (DoE) by implementing the related practices of different paradigms. The simulation exercise helps to quantify the key performance indicators. The effects of adopting these paradigms, in isolation and joint implementation, on manufacturing performance are investigated.

The no. of experiments and their combination is as shown in **table 1**

Run	JIT	TPM	TQM	SCM
BASE MODEL				
RUN-1	√			
RUN-2		√		
RUN-3			√	
RUN-4				√
RUN-5	√	√		
RUN-6	√		√	
RUN-7	√			√
RUN-8		√	√	
RUN-9		√		√
RUN-10			√	√
RUN-11	√	√	√	
RUN-12	√	√		√
RUN-13	√		√	√
RUN-14		√	√	√
RUN-15	√	√	√	√

Table 1: DoE for finding number of runs for the experimentation

V. Conversion of a Model

In order to incorporate the implementation of a particular paradigm (s), the respective practices are being implemented and accordingly changes were made in the model.

VI. RESULTS AND DISCUSSION

First, the simulation model of ordinary batch production manufacturing system was developed by using WITNESS package and the system was simulated. The stated key drivers were introduced to convert the base model of ordinary batch production manufacturing system to replicate a particular paradigm. The simulation was performed over a period of 480 minutes considering 6 working days and a shift of 8 hours as the average of 3 simulation runs. Design of Experiment (DoE) was used to determine the number of scenarios for joint implementation. The results obtained are tabulated in **table 2**

KPIs → / Simulation Run ↓	Break down Time (%)	Machine Utilisation (%busy)	Setup Time	Avg. WIP(No. of parts)	Rejection (%)	Cost Per Part (Rs)	Throughput Capacity (Part)
Base Model	2.41	52.21	0.9125	69.29	6.8	3328	238
JIT	1.84	32.76	0.663	46.32	6.15	3075	248
TQM	1.41	49.68	1.05	66.5	1.72	3069	294
TPM	0.87	60.47	1.11	79.18	5.9	3147	265
SCM	2.43	58.41	1.1	48.44	5.45	3093	262
JIT+TQM	1.13	27.82	**0.615**	41.35	1.73	3120	279
JIT+TPM	0.66	33.81	0.67	45.78	6.34	3107	253
JIT+SCM	2.14	36.14	0.75	51.47	6.33	3128	263
TQM+TPM	0.76	49.65	0.73	66.23	1.72	3083	295
TQM+SCM	1.47	54.24	1.19	45.1	1.66	3039	299
TPM+SCM	0.89	58.18	1.1	48.36	6.31	3095	270
JIT+TQM+TPM	0.25	29.28	0.635	42.48	1.75	3061	298
TQM+TPM+SCM	0.71	54.36	1.08	44.98	1.66	3042	301
JIT+TPM+SCM	0.34	37.75	0.75	50.61	5.23	3079	291
JIT+TQM+SCM	0.35	29.63	0.69	50.18	2.5	3052	303
JIT+TQM+TPM+SCM	0.29	29.56	0.653	50.16	2.29	3055	303

VII. RESULT HISTOGRAMS

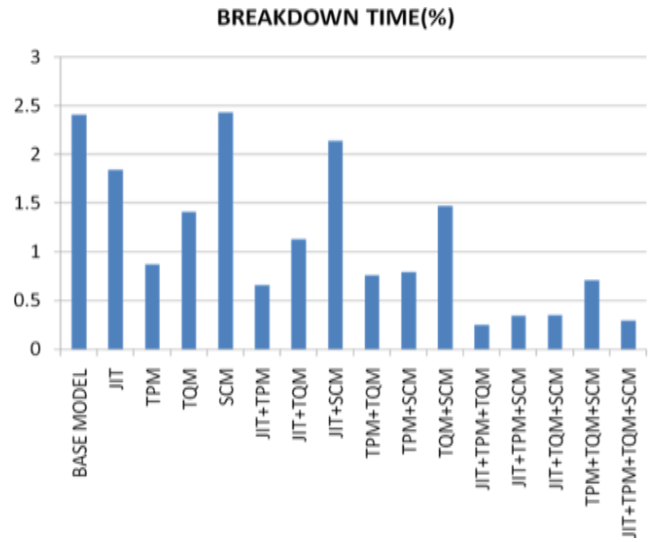

Fig 1 Effect on breakdown time (% of total production time)

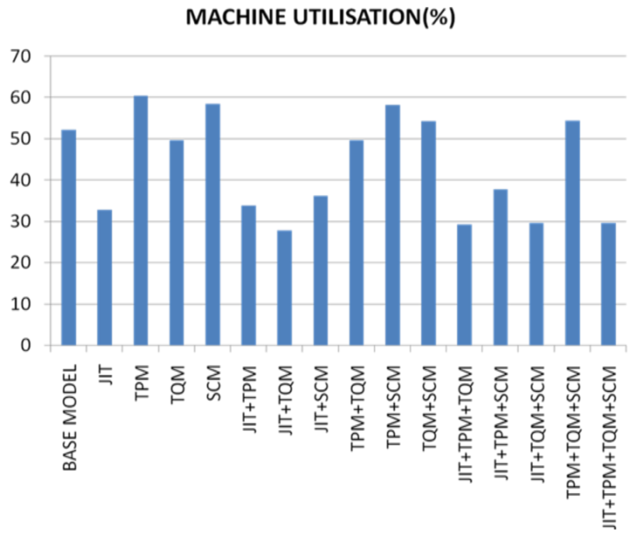

Fig 2 Effect on machine utilization (% busy)

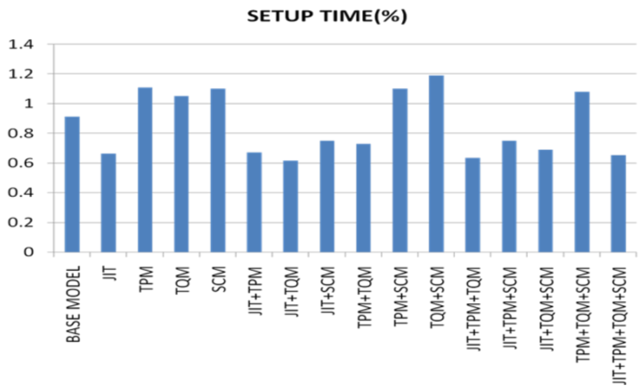

Fig 3 Effect on setup time

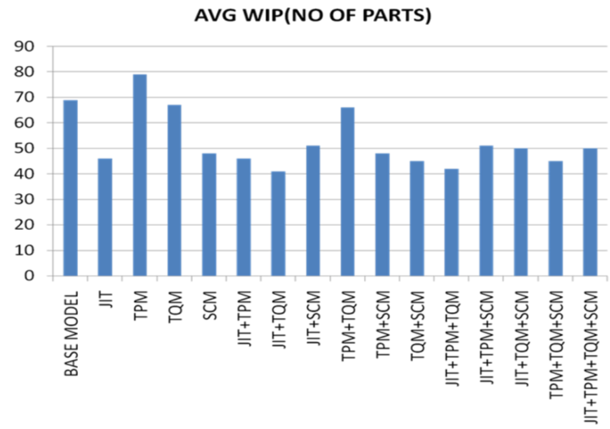

Fig 4 Effect on average WIP

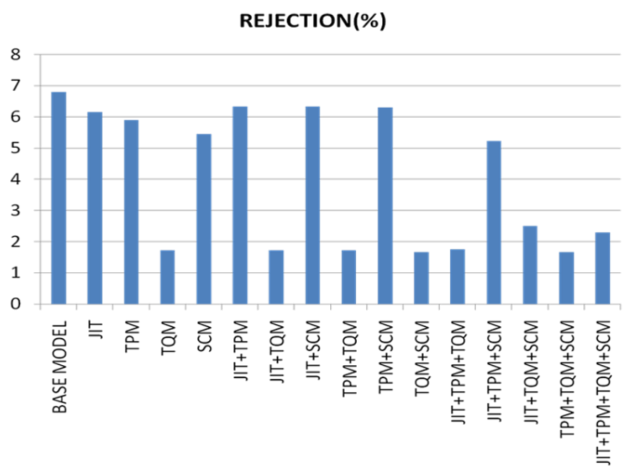

Fig 5 Effect on % rejection

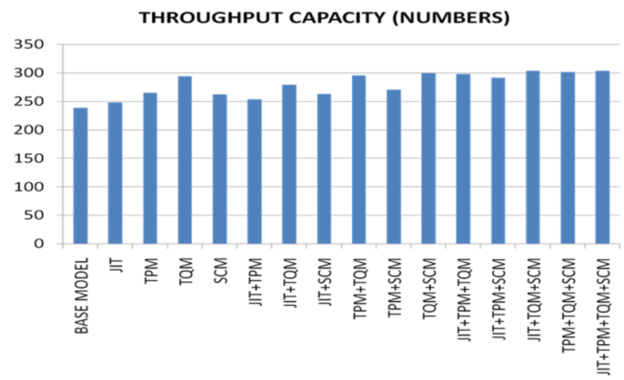

Fig 6 Effect on throughput capacity

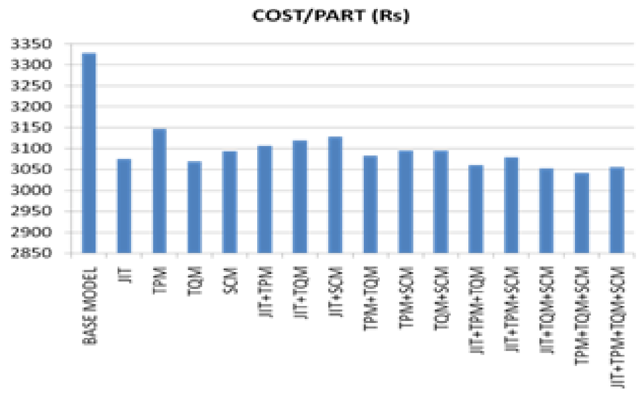

Fig 7 Effect on cost pr part

VIII. Discussion

The % breakdown time is maximum for the base model. As we convert the push system into pull and additionally implement the TQM and TPM (i.e. JIT +TQM+TPM) the breakdown time is minimum (0.25 %). The TPM has huge impact on breakdown time as compare to implementation of other paradigms. When TPM alone is implemented, the breakdown time is 0.87 % which improves when implemented along with JIT and TQM.

Machine Utilization (%busy) for the base model is 52.21 %. It means that the system is idle for about 50% of time. When JIT+TQM is implemented, it is minimum (27.82) and is maximum for TPM (60.47). For JIT machine utilization is minimum (32.2) as compared to BASE MODEL. It means that the machine capacity is freed so as to take up additional production.

The setup Time (%) is minimum for JIT+TQM (0.61) while it is maximum for TPM and SCM (1.1) and for JIT is (0.66). Thus by implementing the JIT + TQM, there is drastic reduction in set-up time. The reduction in set-up time is a necessary requirement of JIT and is done through continuous improvement to develop new SMED's.

Inventory reduction is a big challenge to the companies. Avg. WIP (No. of part) for JIT (46.32) is minimum as compared to BASE MODEL (69.29). The WI has reduced as we convert the push system in to pull. There is further reduction in WIP for JIT+TQM (41.35).

The rejection (%) is minimum for TQM (1.72) as compared to BASE MODEL (6.8). It is lowest for TQM+TPM+SCM (1.66). By implementing TQM, the processes are in the control and the supplier's development helps in reducing the rejections. The machining rejections are reduced by TPM and in transit damages are reduced by SCM by providing the right quantity.

The throughput capacity is highest for JIT+ TQM+TPM+SCM (303) and for JIT+ TQM+ SCM. For the base model, it is lowest (238). As some improvement initiative is implemented, it affects the throughput capacity positively. The cost of production is highest for base model (3328) and is lowest for JIT+ TPM+ SCM (3042).

The results shows that he implementation of these paradigms improves the effectiveness and efficiency of an organization's operations function. Each paradigm copes with the issue of improving the overall performance, based on a particular viewpoint and logic, which originated a rich set of practices and tools to be applied. From the results, it appears that there is no single paradigm which is able to improve the overall performance indicators. The implementation of one paradigm in conjunction with other helps to improve the performance. The existing manufacturing management and improvement literature suggests that these approaches offer complimentary output, which forms the basis for pursuing superior overall performance in manufacturing. The result shows the effect of implementing a particular paradigm in isolation and joint implementation. The results of the simulation study endorse the need of joint implementation of synergistic implementation for enhancement of overall performance of manufacturing industry.

IX. CONCLUSION

From the simulation experimentation it can be concluded that

1. The manufacturing performance can be improved by implementing on or the other paradigm.

2. Each paradigm does improve the performance, but has impact only on certain indicator.

3. The joint implementation of two paradigms is better than implementation of a single paradigm.

4. The overall performance further improves if additional paradigms are implemented.

5. The % breakdown time is lower, machine utilization (%busy) is higher, and setup time (%) is lowest for JIT + TPM + TQM. Ag. WIP rejection (%) is lowest for TPM+TQM+SCM. Throughput capacity is highest for JIT+TQM+SCM. The cost is lowest for JIT+TPM+TQM+SCM.

6. The closer observation shows that there is very negligible difference in the performance indicators of JIT + TPM + TQM and JIT+TPM+TQM+SCM. While JIT+TPM+TQM+SCM improves other performance indicators as well.

7. The results of the simulation study endorse the need of joint implementation of JIT+TPM+TQM+SCM for enhancement of overall performance of manufacturing industry.

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