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# A Modern Approach to Manufacturing Technology and Performance Analysis of a Flexible Manufacturing System

**Grace gautam[1], Zeeshan raza[2] and Dr. A.K Madan[3]**

(1,2,3) Research scholar, Department of mechanical engineering, Delhi technological university, Delhi

(4) Professor, Department of mechanical engineering, Delhi technological university, Delhi

## Abstract

The performance of a flexible manufacturing system (FMS) has a great impact on a manufacturing firm success and the analysis of FMS justifies the high investment cost behind it. As the competition in the global market is growing, manufacturing companies compete not only on product cost and quality but also in time to market. FMS as a highly automated system typically comprised of a set of processing workstations allowing in an integrated manner to react rapidly and economically to production-oriented aspects of an enterprise in order to cope significant changes in its operating environment. This paper analysed the performance of a FMS through manufacturing process modelling and simulation. The modelling of a manufacturing system enables to grasp quickly how the current system is working and to evaluate the proposed process changes before actual decision making, on the other hand, the simulation of the system supports the idea of virtual manufacturing and gives prompt response to the decision maker. Moreover, integration of system dynamic analysis with reliability estimation methods enable engineers to find the most unreliable places in a production process and supports the decision making for reliability improvement of a production system. In this paper elaboration of the graphic simulation model of FMS operation has been described, FMS model parameters have been estimated, and criteria have been defined based on requirements regarding system reliability. - Flexibility in manufacturing system is one of the most important issues of present scenario, to fulfill the desired customer’s requirement & getting low cost and high quality of product that enforced to adopting the flexible manufacturing system for various modern manufacturing enterprises. The basic of FMS is to convert & increases positivity throughout the manufacturing process for achieving higher productivity and best quality of product. Flexible manufacturing system consist of an integrated system of computerized numerically controlled

(CNC) machine tool, automated material handling system operating under the controlled computer , workstation, storage.

**Keywords**: Performance evaluation, FMS Modelling and Simulation, Reliability analysis, Computer Numerical Control, FMS Layout, Flexibility, Flexible Manufacturing System

## Introduction

Fierce competition at home and abroad Manufacturing market is always attracting business Rapid technological change, more demanding, Focus on the customer and shorten the product life cycle. Or The flexibility of the manufacturing company Competitiveness. Manufacturing system must be flexible Adapting to volatile demand, various product configurations, Effective launch of new products. flexible The Manufacturing System (FMS) provides these features as follows: With the involvement of programmable automation for editing Material handling. In addition, the proper function of z A system that manages product changes successfully It is necessary to guarantee the adjustment to the demand situation. It It leads to the best performance. Example: improvement Significant reductions in equipment utilization, setup time and work in process (WIP), throughput and lead times Number of times. Therefore, FMS and factor assessment You need to define and analyze that performance rating Get the optimum lead time and equipment recovery. Problems such as inventory reduction and market response time Flexibility to meet customer requirements and adapt to changing markets, reduce product costs, Many companies are almost obliged to switch to Flex, such as services to gain market share. Manufacturing System (FMS) as a viable means to meet the above requirements during production Consistently high quality and cost effective products. FMS is actually an automated set of numbers Controlled machine tool and material handling system capable of a wide range of manufacturing Operation by quick tool and command change. What should we be aware of when studying FMS "We have to be technology managers, not just technology users," said Peter Drucker. FMS We need to handle technologies that are well adapted to our environmental requirements.

## FLEXIBLE MANUFACTURING AND FLEXIBILITY

Flexibility is a property that allows a mixed mode manufacturing system to cope with some effort. The degree of variation in the part or product cycle. Production will not be interrupted by switching in the meantime. Models, and hence FMS, are called flexible because they can handle a wide variety of different data. Workplace parts style and production can be adjusted accordingly Changing demand patterns. Gives you the different kinds of flexibility that a manufacturing system has The following flexible production systems are usually Computer Numerical Control (CNC) Machine Tools, Link to each other through automated material handling and storage Control by a computer system integrated with the system. like that The system can handle a variety of different things Product family with the help of CNC machine tools, Loaded and unloaded by industrial robots.

### Machine Flexibility

It is the capability to adapt a given machine in the system to a wide range of production operations and part styles. The greater the range of operations and part styles the greater will be the machine flexibility. The various factors on which machine flexibility depends are:

Setup or changeover time

Ease with which part-programs can be downloaded to machines

Tool storage capacity of machines

Skill and versatility of workers in the systems

**Production Flexibility**

It is the range of part styles that can be produced on the systems. The range of part styles that can be produced by a manufacturing system at moderate cost and time is determined by the process envelope. It depends on following factors:

Machine flexibility of individual stations

Range of machine flexibilities of all stations in the system

**Product Flexibility**

It refers to ability to change over to a new set of products economically and quickly in response to the changing market requirements. The change over time includes the time for designing, planning, tooling, and fixturing of new products introduced in the manufacturing line-up. It depends upon following factors:

Relatedness of new part design with the existing part family

Off-line part program preparation

Machine flexibility

**Volume Flexibility**

It is the ability of the system to vary the production volumes of different products to accommodate changes in demand while remaining profitable. It can also be termed as capacity flexibility. Factors affecting the volume flexibility are:

Level of manual labour performing production

Amount invested in capital equipment

**BASIC COMPONENT OF FMS**

**Workstations**

In present day application these workstations are typically computer numerical control (CNC) machine tools that perform machining operation on families of parts. Flexible manufacturing systems are being designed with other type of processing equipnments including inspection stations, assembly works and sheet metal presses. The various workstations are

Machining centers

Load and unload stations

Assembly work stations

Inspection stations

Forging stations

**Automated Material Handling and Storage system**

The various automated material handling systems are used to transport work parts and subassembly parts between the processing stations, sometimes incorporating storage into function. The various functions of automated material handling and storage system are

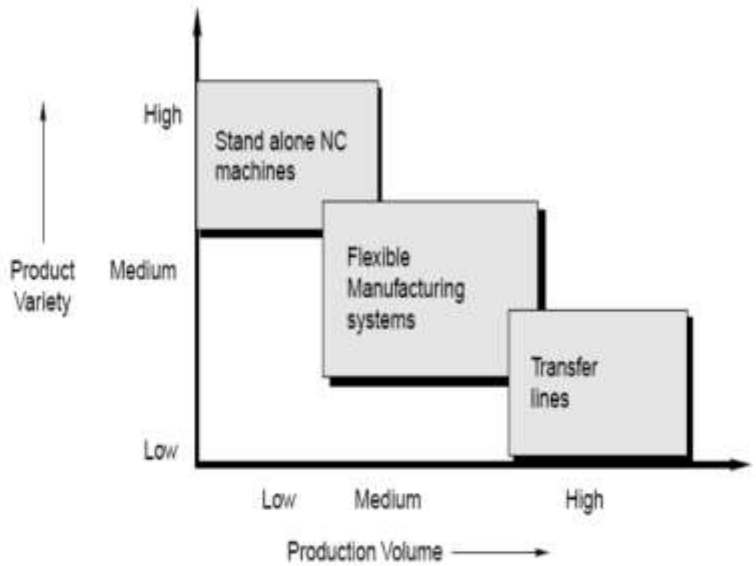
Random and independent movement of work parts between workstations

Handling of a variety of work part configurations

Temporary storage

Convenient access for loading and unloading of work parts

Compatible with computer control




**Computer Control System**

It is used to coordinate the activities of the processing stations and the material handling system in the FMS. The various functions of computer control system are:

Control of each work station

Distribution of control instruction to work station

Production control

Traffic control

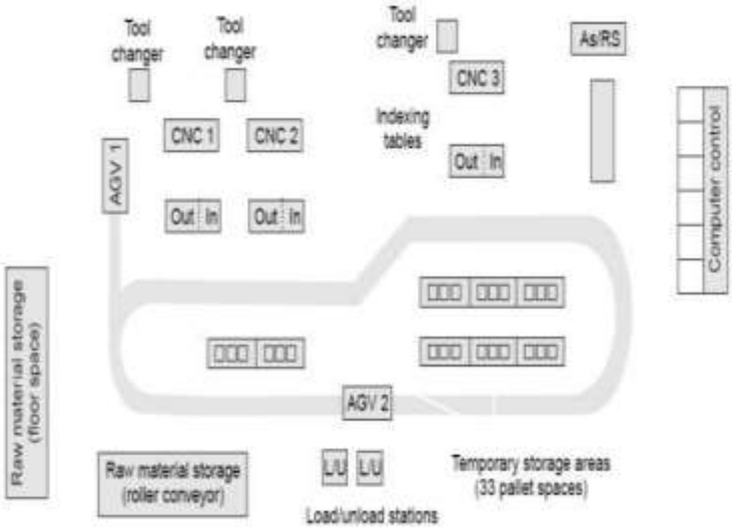
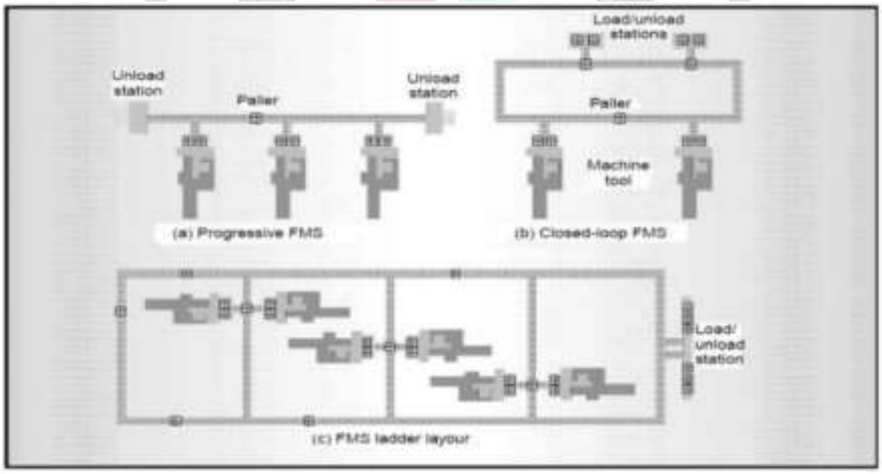



Fig. 2.2 Flexible Manufacturing System

## TYPES OF FMS LAYOUT

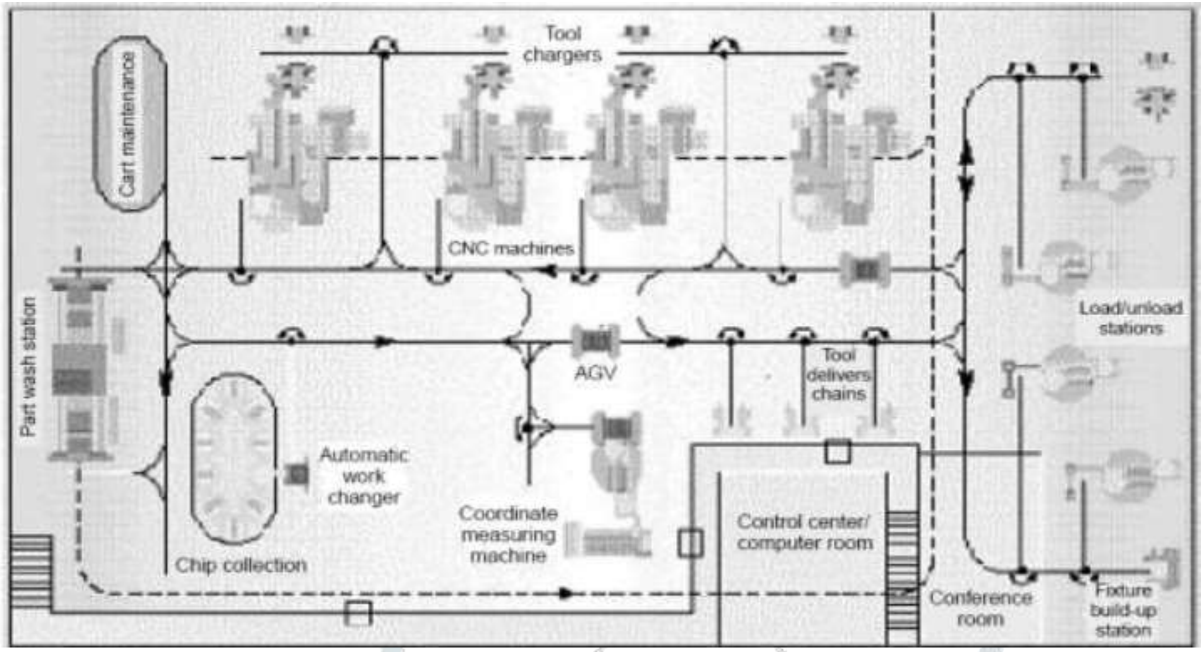
### Loop type

The basic loop configuration is as shown in Fig. 3The part usually moves in one directional around the loop, with the capability to stop and be transferred to any station. The loading and unloading station is typically located at one end of the loop.



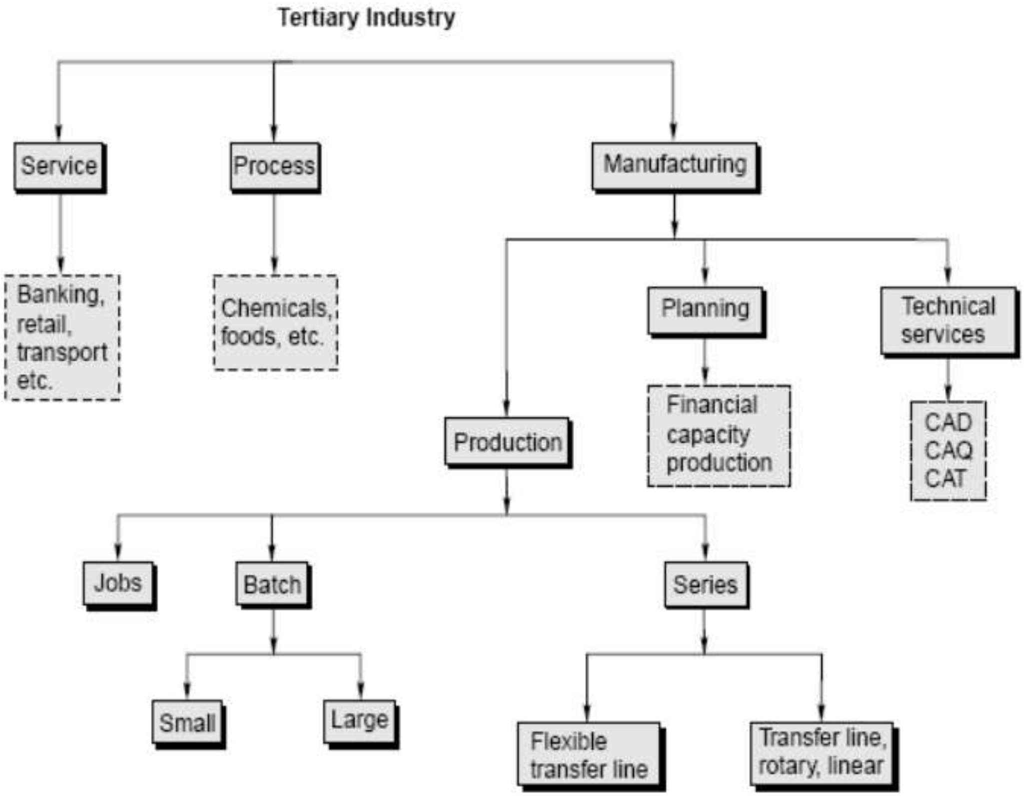
**Open field type**

The configuration of the open field is shown in fig. 3.1(d). The loading and unloading station is typically located at the same end. The part will go through all the substations, such as CNC machines , coordinate measuring and wash station by the help of AGV"S from one substation to another.




**APPLICATION OF FMS**

FMS technology is most broadly applied in machining process. Furthermore, it is applicable in metal press working, forging, and assembly, mostly used in mid-volume and midvariety production [5, 6]. From the applications of FMS certain number of benefits can be derived such as: higher machine utilization, fewer machines (less resources), reduced factory floor space, increased responsiveness to changes, reduction in inventory requirements, shortened manufacturing lead times, curtailed direct labour requirements and greater labour productivity, and possibility for unattended production.




**System Modelling and Reliability**

Activity analysis and activity modeling are one An important element of system research. Usually difficult Understand and remember all the information that should be The system is known because of the large amount of data, Complex and confusing. Integrated Definition (IDEF) On the other hand, a graphical approach to system description IDEF0 is a diagrammatic technique for displaying components Parts, interrelationships between them, and how they fit together Hierarchical structure. IDEF0 is used to apply a structured one How to better understand how to improve manufacturing Productivity IDEF0 model can provide a way Collect, organize and document system information. Due to the increasing complexity of modern engineering The concept of system, reliability has become very Key elements in overall system design Novelty of integrated system rationalization tools System modeling, simulation, And reliability estimates. All analysis will be implemented Based on IDEF0 modeling. Selected for this study FMS is modeled by the IDEF0 method followed by ASIS simulation analysis, with bottlenecks. Use of FMS processes or components. We also conducted a TOBE simulation analysis. Identify the impact of the change and ultimately its reliability An analysis was performed to verify the stability of the FMS.

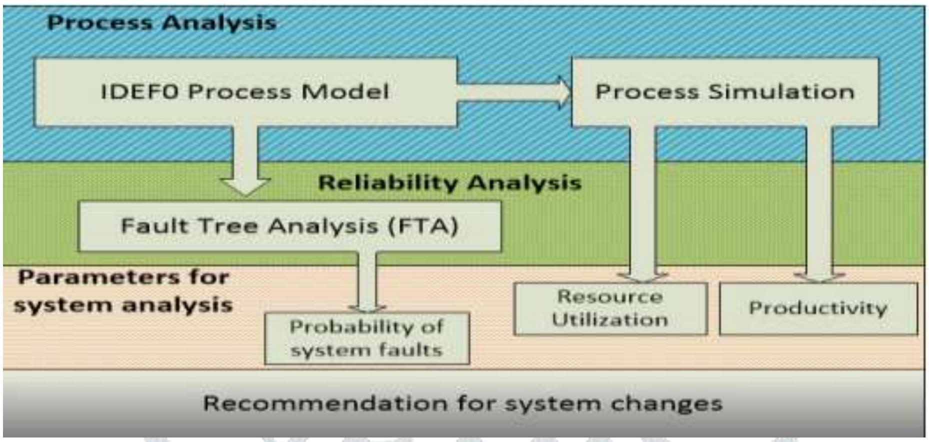
## Methodology

This paper proposes a technique for generating fault trees. From the process model. Both ways are possible The hierarchical structure of IDEF0 and FTA is the same. Or The defined mechanism of the system is The process from IDEF0 methodModels is Probability of failure of each mechanism of the system Join the process. You can enter information At the stage of defining system parameters. Everyone Change the operating parameters of the system to be changed Unpredictable errors can occur after that performance. Therefore, it is necessary to evaluate the reliability of the system. All changes. Probability is required for all lowest level events Associated with her. It can calculate the probability of Occurrence of top-level events. According to the axiom of Probability, probability of high-level events occurring You can decide as follows:

For AND events: P(A B) P(A)u P(B)

For OR events: P(A B) P(A)

The overall model for the analysis of a flexible manufacturing system is shown in Fig. 1. The authors follow the same modelling schema, starting from process model, followed by process simulation and reliability analysis. Authors have evaluated the parameters through simulation and discuss the improvement recommendations in the following sections.

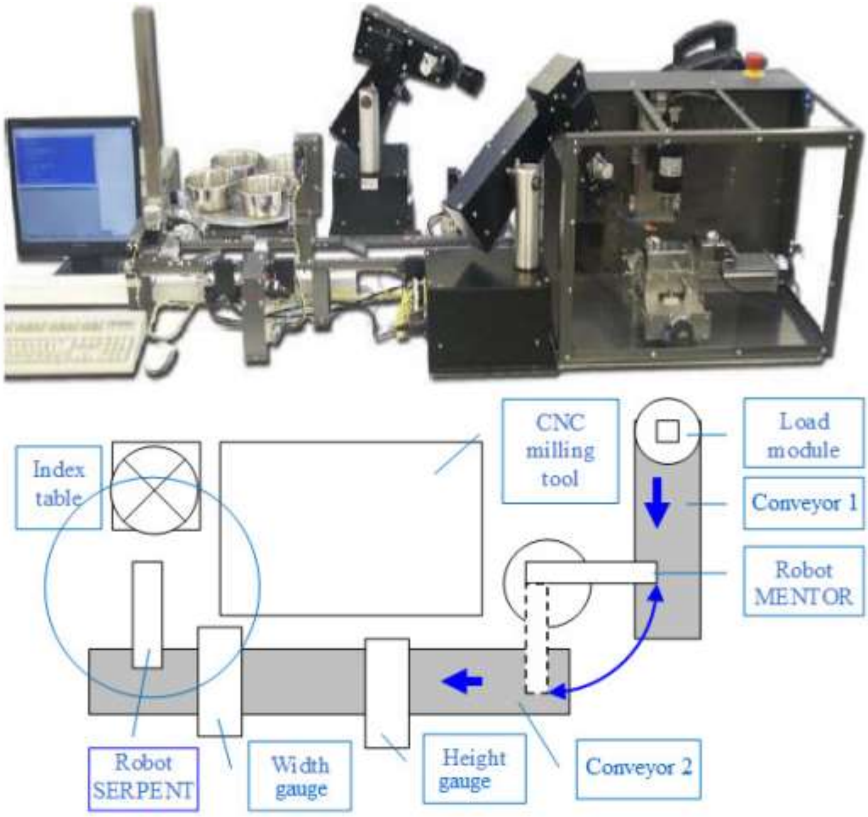



**Analysis of FMS processes**

There are usually two types of problems or challenges This should be taken into account when analyzing FMS. beginning, Design challenges addressing FMS selection Addresses components, and secondly, operational issues Usage aspect of FMS. This study FMS operational research and process simulation Performed to evaluate the performance of the proposed changes And its impact on other parameters. In the meantime Identify FMS bottlenecks.

**Configuration of the system**

There are many different configurations of FMS, however authors focus on an exemplary FMS consisting of a CNC milling machine, two conveyors and two robotic arms. Such configuration can be found in various cases of automated production industry .This kind of configuration simplifies material-handling control, better understanding of operations, enhanced strategic focus and flexibility. In general, it leads to simplified operations and simplified scheduling logic in particular Conveyors are equipped with sensors, which secure the positions of moving work part. FMS consists of interdependent parts that work together to perform a required functions.




**Modelling of the process**

The model presented in the current work describes the selected model FMS process flow, its control method, work content The tasks and functions it performs, and the results it produces. The current model is being developed for process analysis. Improvement and update or replacement Manufacturing system. In recent studies, the author uses IDEF0 A modeling method to describe a manufacturing system. Or Top-level diagram of the current process with a mechanism The ones involved are shown in Figure 4. The node tree diagram (NTD) for the entire process is as follows: Introduced in Figure 5.

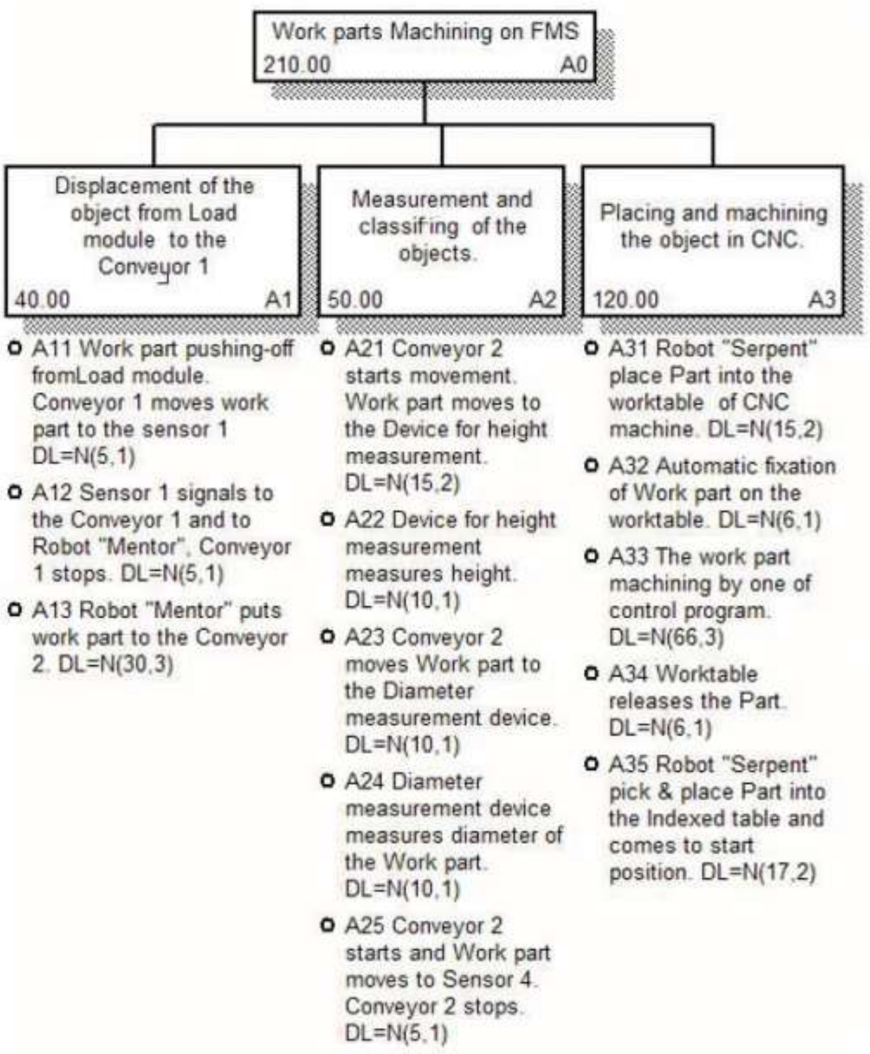



Fig. 5. Common process Node Tree Diagram

The processes are numbered and Provides process leaf activity (prefix A) With the deviation given by the persistence logic (DL) Normal distribution (N): DL = N (duration in seconds, Deviation in seconds). The processing time for all activities has not changed Some types of workpieces, except for processing time. Or Processing time is different from A33 activity. Diameter (D) = 25 mm and D = 28mm was not the same. The longest processing time is Used for process analysis when machining D = 28mm. System duty cycle and timing diagram The process is shown in Figure 6.

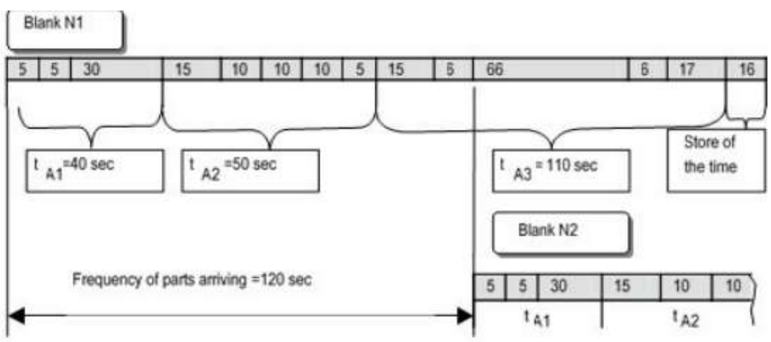
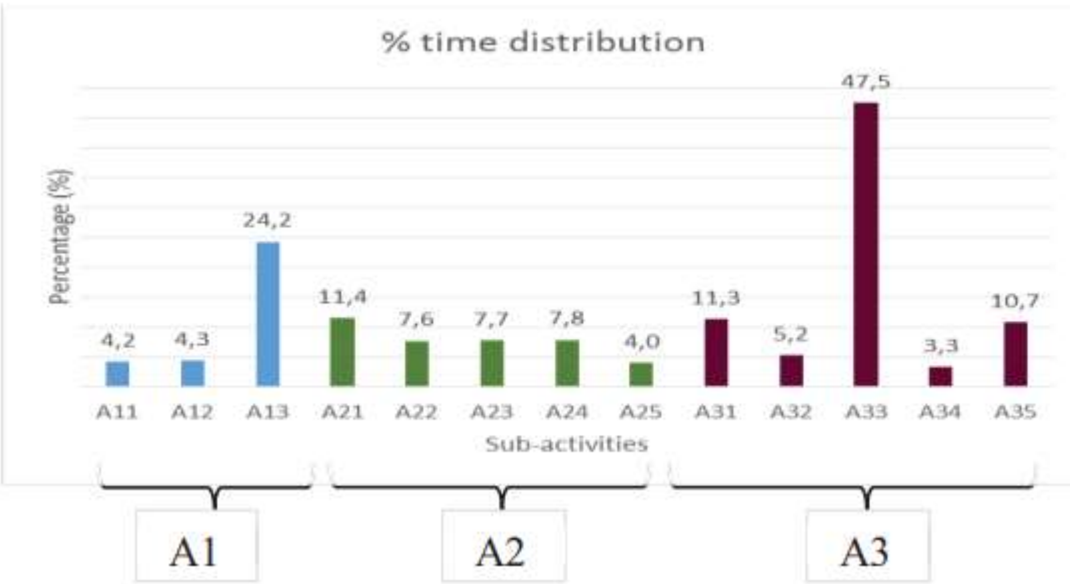



Fig. 6 Time graph of process

**Simulation of the process**

The main goal of process change is to increase FMS productivity by decreasing the cycle time of the process. The aim of simulation is to depict the impact of changes and to validate the current study scenario. The simulation results provide useful information about the operation of studied FMS in general, and for CNC milling machine in particular. In this work only the mechanical parts of FMS were considered. The dynamic analysis of the process allows determining the behaviour of the system under different initial inputs by performing the repeated experiments within the process. Previous study concluded that the main benefit of using the simulation for manufacturing system allows manager and engineer to obtain a system-wide view of the effect of local changes in the manufacturing system. The modelling of a system enables to grasp quickly how a current system is working and to evaluate the proposed process changes before decision-making

Time allocation for each function is shown in the simulation results graph, see Fig. 7. The chart shows that function A33 (work part machining time proportion) should be decreased for more efficient FMS operation and productivity increment.




The summary report of the simulation shows that 9 parts were produced during 20 minutes of operation, Fig. 8 demonstrates the utilization of FMS objects (components).

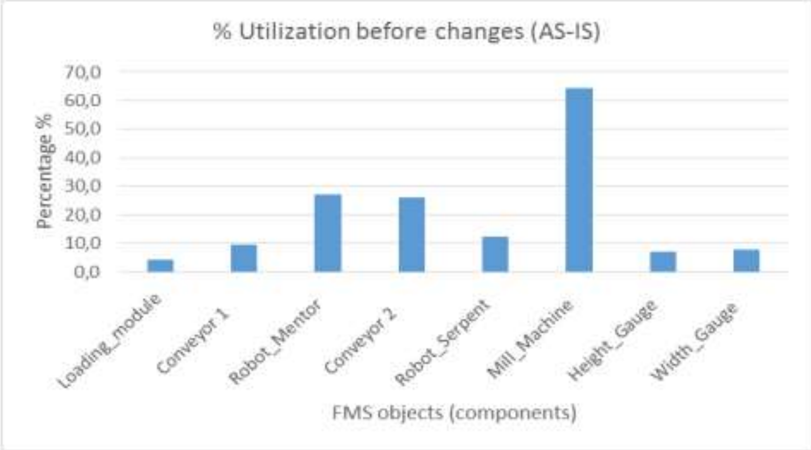



Fig. 8. Loading (utilization) of FMS objects

## Enhancing FMS productivity

After studied current (AS-IS) model scenario, simulation on existing parameters, authors have discovered the parameters that should be changed to achieve higher throughput of FMS. The experiments were carried out on the same base model, thus each time only one argument of the system varied.

From the Table 2 it is noticeable that the machining of same length with different types of end mill resulted in reduction of machine processing time.

| Parameters | *AS-IS (S18)* | *TO-BE (MS45)* |
|---|---|---|
| Cycle time (sec) | 120 | 100 |
| Release blank from load module | 12 | 16 |
| Collect part to indexed table | 9 | 12 |
| ***Usage of FMS objects (%) for interval 20 minutes*** | | |
| CNC Milling tool | 64.3 | 15.1 |
| Robot «Mentor» | 27.1 | 33.6 |
| Robot «Serpent» | 12.4 | 16.2 |
| Conveyor 1 | 9.6 | 12.0 |
| Conveyor 2 | 26.2 | 34.2 |
| High measurement device | 7.0 | 11.2 |
| Diameter measurement device | 7.6 | 11.4 |
| Load module | 4.4 | 5.8 |
| ***% change of the cycle time = 16.6 (% reduction in time)*** | | |
| ***Cutting tool (min)*** | | |
| Stability of tool | 20 | 45 |
| ***Lead time division (%)*** | | |
| Operation time | 36.56 | 35.16 |
| Moving time | 62.77 | 60.90 |
| Waiting time | 0.65 | 3.92 |

Reduction in the machining time with the changes of cutting tool also changed the cycle time of the whole process. The changes were taken into the account in simulation model as well and the following results were obtained in 20 minutes' time duration. The results of simulation are shown in Fig. 9 and the timing of respective components of the FMS also effected by different tools as shown in Fig. 10.

High-speed steel S18-0, 9 parts produced

Inserts from hard alloy S6, 11 parts produced

End mills, hard alloy MS45 & NI45, 12 parts produced

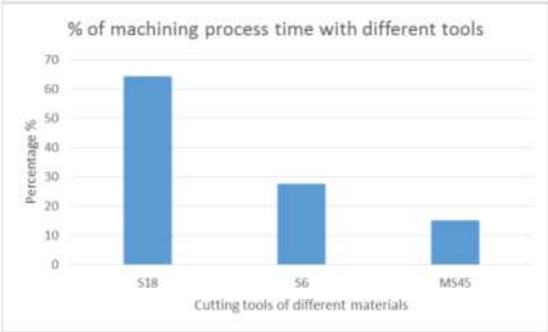



Fig. 9. Comparison of simulation results: altered types of cutting tools

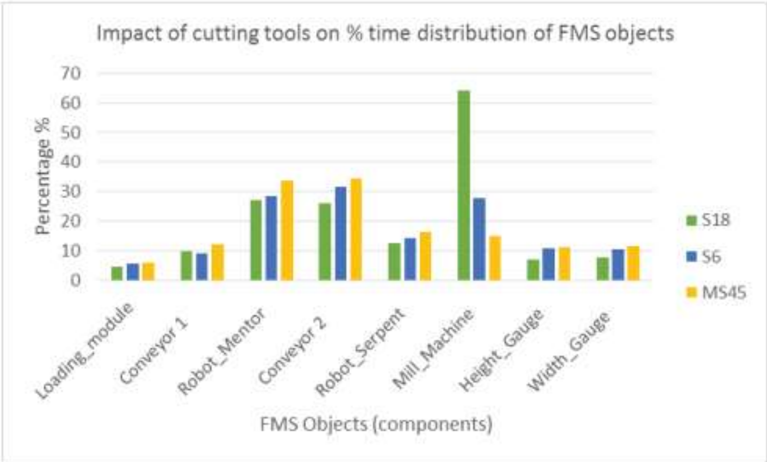
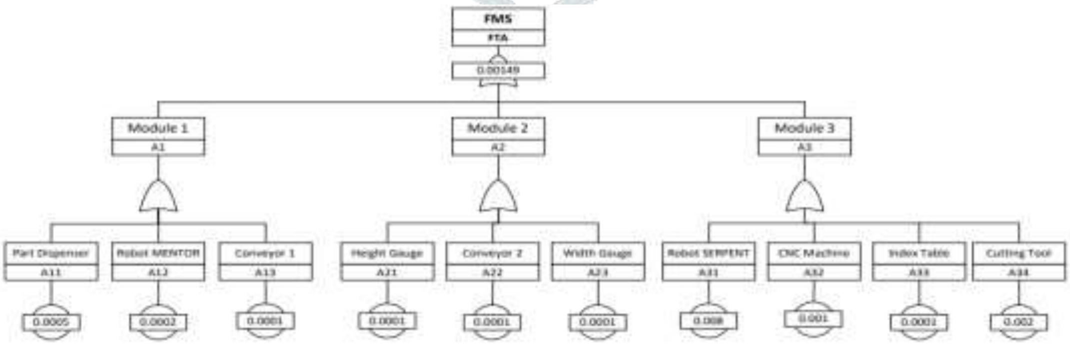



Fig. 10. Impact of cutting tools on the whole FMS components

**Reliability model of the FMS**




Successful results for the calculation of probability of faults can be achieved if all the mechanisms of a model have the same structure which was used in the FTA, in chosen modelling mechanism structure and FTA have resemblance. In the proposed automated technique to generate fault trees have been used capabilities of a modelling system. Models are enriched with information about probability of faults for every mechanism of a system, which took part in the process. The information can be entered to leaf level of diagram (A11-A34 see Table 3) at the stage of definition of parameters of the system. Probability of fault in high level could be defined by FTA calculation mechanism.

| Mechanism | Level | Activity | Probability of fault |
|---|---|---|---|
| FMS | A-0 | A0 | $149x10^{-5}$ |
| Module1 | A0 | A1 | $85x10^{-5}$ |
| Module2 | A0 | A2 | $45x10^{-5}$ |
| Module3 | A0 | A3 | $11.1x10^{-5}$ |
| Parts Dispenser | A1 | A11 | 0.0005 |
| Conveyer 1 | A1 | A12 | 0.0001 |
| Robot Mentor | A1 | A13 | 0.0002 |
| Conveyer 2 | A2 | A21 | 0.0001 |
| Height Gauge | A2 | A22 | 0.0001 |
| Width Gauge | A2 | A23 | 0.0001 |
| Robot Serpent | A3 | A31 | 0.008 |
| Cutting tool | A3 | A32 | 0.002 |
| CNC Mill | A3 | A33 | 0.001 |
| Indexed Table | A3 | A34 | 0.0001 |

## CONCLUSION

In the current business scenario and competitive environment among various manufacturing enterprises in order to achieve higher productivity & high quality product at low cost as per market demand, the FMS is efficient and effective tool in respect of their merits and applications. The FMS further create challenge to futuristic view of innovation for newer manufacturing technology.

In this study, the performance of a FMS was evaluated with the help of the IDEF0 modelling technique and the manufacturing simulation. The bottlenecks were found out, corresponding changes were proposed for the improvement in throughput time and the changes were simulated for comparison. The current process of FMS was improved by considering an efficient cutting tool that leads to the reduction in throughput time and increment of productivity. Furthermore, the paper was presented a generic model for conducting the overall process analysis of a system and also described how the reliability analysis of a FMS could be carried out. A procedure was suggested to generate the fault trees commonly used for the reliability analysis, which is supported by IDFE0 technique. The suggested techniques can be applied in the manufacturing industry to enhance the performance of a FMS.

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