



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119

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GRAPH THEORY MODELING USING PETRI NET

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Science degree in Mathematics (B.Sc., Mathematics)

by

A.VARSHA (38060014)

APRIL 2021



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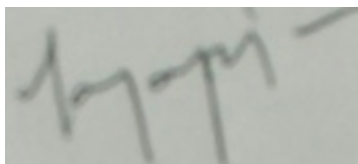
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DEPARTMENT OF MATHEMATICS

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **VARSHA.A (REG.NO.38060014)** who carried out the project entitled **"GRAPH THEORY MODELING USING PETRI NET"** under our supervision from **JANUARY 2021** to **APRIL 2021**.



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External Guide (if Applicable)

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(Dr. M.NIRMALA)

Head of the Department

(Name in Capital letters with Seal & Signature)

Submitted for Viva voce Examination held

on_____

Internal Examiner External Examiner

DECLARATION

I **VARSHA A (38060014)** hereby declare that the Project Report entitled
“**GRAPH THEORY MODELING USING PETRI NET**” done by me under
the guidance of **Dr.J.JAYAPRIYA** (internal)_____ (External)
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submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering / Technology degree in **MATHEMATICS**.

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SIGNATURE OF THE CANDIDATE

A. Varsha .

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ABSTRACT

Graph theory can be applied to research field ranging from computer vision to transportation planning. Petri net are mathematical object which can be demonstrated by live Graphic element such as place and transition. They are competent in formalizing and solving issues in graph theory. Specifically petri net model of flow networks and corresponding residual Network was introduced . Based on the proposed model the way finding a maximum flow for a Given network was presented.FMS system using a petri net based approach has been in practice in industries for long years.This paper illustrates the modeling and performances analysis of FMS.

KEYWORDS:

- GRAPH THEORY
- PETRI NET
- NETWORK
- FLEXIBILITY
- FLEXIBLE MANUFACTURING SYSTEM (FMS) ,

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CHAPTER - 1

1. INTRODUCTION:

Over the last few years, manufacturing industries largely prefer flexible manufacturing system (FMS) because of its high quality of product at low cost, low amount of stock, low manufacturing lead time, high competitiveness, and quick response to the customer demands and low labour cost. It has the capability to manufacture a wide variety of product with higher productivity. A flexible manufacturing system (FMS) is a decision-making system, a discrete-event system and consists of variable machines, automatic transport system and produce a different variety of products in job flow process, and also reduce production cost by share resources. The sudden changes in the machine or increasing and decreasing the production suddenly will result in the damage of the system. It is difficult to predict the behaviour of Manufacturing systems without modeling, analyzing, and control techniques.

Hence several techniques have been designed to describe the behavior of the manufacturing systems. One of which is petri nets .Petri Nets (PN) are most powerful graphical and mathematical tool for modeling and analyzing concurrent ,parallel ,simultaneous ,synchronous ,distributed and resource storing system. It is a formal model of information flow. The concepts and techniques of petri nets are being developed in a search for natural simple, and powerful methods for analyzing the flow of information. It is their simplicity and ability to model sequential execution, concurrency, conflict, synchronization and merging like situations which makes them suitable to model FMS. The outline of petri net is given below.

1.1. INTRODUCTION TO PETRI NET:

1.1.1. HISTORY:

The doctoral dissertation of Carl Adam Petri in 1962 discussed the basis for a theory of communication between synchronous components of a computer system.

Petri net particularly concerned with describing the causal relationships between events. This work thus began the development of Petri nets into the large body of research and development existing today. Initially, many researchers studied Petri nets with respect to theories and applications. The use and study of the Petri nets have spread, and many research projects and conferences on Petri nets have come to our attention. Further, the research areas of Petri nets have spread and have expanded to depth in theory and width in application on the basis of the mathematical as well as the graphical tool. Recently, many authors who have entered the research of Petri nets have provided not only suitable platforms in the areas of modelling and design of concurrent systems, information systems, manufacturing systems, and performance analysis, but also their own experience and understanding of various extended models and applications. Also an excellent society has been established for sharing new research results with other researchers who are concerned about the field of Petri nets.

1.1.2. PETRI NET GRAPH:

More theoretical work on Petri nets is based on the formal definition of Petri net structures. However, a graphical representation of a Petri net structure is much more useful for illustrating the concepts of the Petri net.

Definition: A Petri net structure, C is a four-tuple $C=(P, T, I, O)$, $P=\{p_1, p_2, \dots, p_n\}$ is a finite set of places, $n \geq 0$. $T=\{t_1, t_2, \dots, t_m\}$ is a finite set of transitions, $m \geq 0$. The set of places and the set of transitions are disjoint, $P \cap T = \emptyset$. $I: T \rightarrow P^*$ is the input function, a mapping from transitions to bags of places. $O: T \rightarrow P^\infty$ is the output function, a mapping from transitions to bags of places. Fig1.1 shows a simple petri net graph.

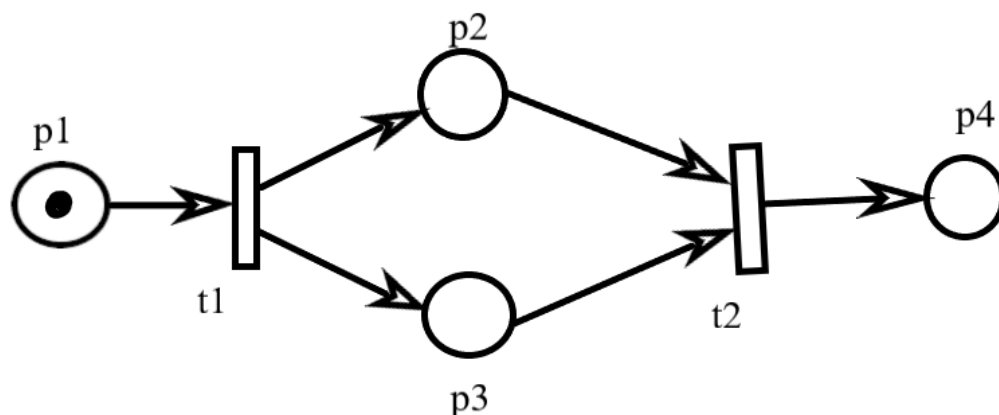


Fig.1.1 Simple Petri Net Graph

Petri nets are bipartite directed graphs, in which there are two types of vertices known as places and transitions. The places are represented by hollow circle and transitions are represented by vertical bar. Places usually represent a state of the system, conditions or a resource and transitions represent events. A token is a small solid dot (or solid circle), presence of token in a place means the condition represented by the place is satisfied or a resource represented by the place is available. Places are connected to transitions by directed arcs and they represent input and output function.

A firing of transition indicate occurrence of an event represented by it and transition is said to be enabled for firing, if all the input places of a transition are having tokens in them, in other words an event can occur only if all the conditions are satisfied or all the resources required for an event are available.

1.1.3. Types of Petri Nets:

- *Coloured Petri nets*: Developed in the late 1970s. Represent attributes of these objects, the Petri net model is extended with colour or typed tokens. Tokens often represent objects (e.g. resources, goods, humans) in the modeled system. Transitions use the values of the consumed tokens to determine the values of the produced tokens. A transition describes the relation between the values of the „input token“. Ordinary Petri nets An ordinary type of Petri net modelling, graph uses circles to represent places and bars to represent transitions (events). Input-output relationships are represented by directed arcs between places and transitions. Black dots inside a circle or place called tokens. Tokens reside at a place when it is active. Tokens flow through the „net“ depending on the present marking of the net. The marking of Petri net is contained in a vector dimension n , where „ n “ is the number of places and each value of the vector corresponds to the number of tokens in the corresponding places, when there is a token in each of the input places of a transition, that transition is enabled to fire. If the weights on each of the arcs between places and transitions are equal to one, then the transition fires by removing a token from each of its input places and by placing a token in each of its output places. In this type of Petri net one token is removed or added when a transition fires.

- Weighted Petri nets: This type allows the original Petri net to add or remove multiple tokens when a transition fires. The edges are number of tokens. If there is no label, then the default value is 1.
- Time extended Petri nets: First developed in the mid 1970s. For real systems it is often important to describe the temporal behaviour of the system, i.e. we need to model durations and delays. There are three basic ways to introduce time into the Petri net. Time can be associated with: Places Transitions Token
Petri nets are in the Timed Petri net model: In this model, time duration is associated with each transition. There are many other extensions to Petri nets that consider time. The firing rules in this model are that the transition must fire as soon as it is enabled, and firing a transition takes fixed, finite amount of time. The notation of instantaneous firing of transition is not preserved in the Time Petri net model.

CHAPTER - 2

LITERATURE SURVEY:

- Browne et al., 1984 defines FMS as an integrated computer-controlled system with automated material handling devices and CNC machine-tools and which can be used to simultaneously process a medium-sized volume of a variety of parts.
- Chan et al. (2007) presented a simulation study using Taguchi's method analysis of physical and operating parameters of the flexible manufacturing system along with flexibility. An approach is developed to study the impact of variations in the physical and operating parameters of an FMS and to identify the level of these variations. The physical and operating parameters of alternative resources may influence the system's performance with the changing levels of flexibility and operational control parameters such as scheduling rules. The results of simulation study shows that expected benefits may not be present when routing flexibility (RF) levels are increased with presence of the variations in physical and operating parameters. The increase in RF level becomes counterproductive under such environment when variations are above certain limits. It may be useful for decision maker to distinguish the level of flexibility up to which it can be gainfully increased under the presence of variations.

- Sarker et al. (1994) have presented a detailed classification for the types of manufacturing related flexibility as follows: routing flexibility (RF), machine, flexibility, process flexibility, expansion flexibility, job flexibility, design flexibility, material handling flexibility, setup time flexibility, and volume flexibility.
- Buitenhek et al. (2002) described that the design of these systems is an important issue of the expensive components of FMS. The design of FMS requires both the physical and the control aspects. Physical aspects includes the issues such as types and numbers of machines, material handling systems, processing times on a machine, machine setting time, tool changing time, transportation time, loading, unloading time, etc. and for the control aspects, the design involves defining the scheduling rules or algorithms that defines the way the system is to be operated.
- Gupta and Buzacott (1989) explained that the flexibility does not come from the abilities of machine alone; in fact flexibility is the result of a combination of factors like physical characteristics, operating decisions, information integration, and management practice. Flexibility is critical in providing the effectiveness to manufacturing system under different operating conditions.
- Bennett et al. (1992) identifies the factors crucial to the development of efficient flexible production systems, namely: effective integration of subsystems, development of appropriate controls and performance measures, compatibility between production system design and organization structure, and argues that the flexibility cannot be potentially exploited if its objectives are not defined and considered at design stage.
- Kumar et al. (2003) used an ant colony optimization approach for scheduling of FMS for a given level of flexibility.
- Wang and Yen (2001) considered the transportation times in automated material handling system for simulation study of dispatching rule performance.
- Chan (2001) used the simulation under Taguchi method to study the effect of RF on an FMS. Bruccoleri et al. (2003) suggested the simulation as a tool for defining the configuration of an FMS or a complex system.
- Shnits et al. (2004) used simulation of operating system as a decision support tool for controlling the flexible system to exploit flexibility.

- Tüysüz and Kahraman (2009) presented an approach for modeling and analysis of time critical, dynamic and complex systems using stochastic Petri nets together with fuzzy sets.
- Santarek and Buseif (1998) introduced a method and tools for the design of automated manufacturing systems and their sequential controllers. The high level system design specification was developed using Structured Analysis and Design Technique (SADT) method and Design: IDEF software package. The interface is based on a number of transformation rules from an IDEF0 specification into a Petri net. Petri net is used to determine if the manufacturing system will operate in the desired manner. Petri nets are proven tools enabling analysis of concurrent processes performed with the use of shared resources (machines, equipment, operators, etc.). SADT: IDEF0 represents activity oriented modeling approach. IDEF0 representation of a manufacturing system consists of an ordered set of boxes representing activities performed by the system. The activity may be a decision-making, information conversion, or material conversion activity. The inputs are those items which are transformed by the activity; the output is the result of the activity. The conditions and rules describing the manner in which the activity is performed are represented by control arrows. The mechanism represents resources (machines, computers, operators, etc.) used when performing the activity. IDEF0 was found to be a powerful descriptive tool that offers a number of features which make it easy to apply and easy to understand. It allows for a top down step refinement, using a graphical representation with few constructs and simple rules. IDEF0 is able to modify the existing system by adding a new constrains (machine, buffer, robot, etc.) without any essential change in the existing model. Standard PN's do not include any time concept. Therefore, with a standard PN it is possible to describe only the logical structure of systems, and not their time evolution.
- Viswanadham et al. (1990) investigated the use of Petri net (PN) models in the prevention and avoidance of deadlocks in flexible manufacturing systems. For deadlock prevention, a reachability graph of a Petri net model of the given FMS is used, whereas for deadlock avoidance, Petri net-based on-line controller is proposed. Deadlock handling can take two forms: deadlock prevention in which deadlocks are eliminated by static resource allocation policies and deadlock avoidance in which dynamic policies are employed to avert deadlocks just in time.

- Tavana (2008) used Petri nets (PNs) for dynamic process modeling of the emergency management system at a nuclear power plant. PNs with their graphical and precise nature and their firm mathematical foundation are useful in reducing the number of false evacuations at the plant. Process models are widely used for decomposing organizational complexities, adapting best business practices, identifying process weaknesses, training end-users, and designing business blueprints.
- As a graphical tool, PNs provide a visual medium for a modeler to describe a complex system. As a mathematical tool, PN models can be represented by linear algebraic equations, creating the possibility for the formal analysis of the model (Zurawski and Zhou, 1994). Mathematical properties of PN can be classified into structural properties that depend on the net structure and behavioral properties that depend on the initial and subsequent markings. As a graphical tool, PNs are used to enhance communications and produce accurate and complete specifications while the mathematical properties of PNs are used to detect deadlock, overflow, and irreversible situations. Performance evaluation is also possible through mathematical analysis of the model using stochastic timed PNs. One of the strengths of PNs is their broad based applicability to a wide range of systems. Timed PNs are those in which places or transitions have time durations in their activities (Liu et al., 2007). Stochastic PNs include the ability to model randomness in a situation, and also allow for time as an element in the PN (Murata, 1989, Lee et al., 2001). Colored PNs allow the user and developer to witness the changes in places and transitions through the application of color-specific tokens, and movement through the system can be represented through the changes in colors (Chen et al., 2001). Fuzzy PNs are used to model fuzzy rule-based reasoning to handle uncertain and imprecise information (Huang et al., 2008, Li and Lara-Rosano, 2000).
- Sun and Fu (1994) proposed a systematic method to construct a timed place Petri-net model for modeling an FMS which is as an automatic Petri-net generator, with a graphic user interface, through which a user can input the system information of a practical FMS, such as the number of automated guided vehicles (AGVs), the number of machines, and their geometric relationship, as well as process flows of parts to be processed. This generator will then use the above information to generate the corresponding Petri-net model.

- Venkateswaran and Bhat (2006) reviews the difficulties in evolution of modeling the system, design of a controller and then their implementation using a programmable logic controller to a discrete event system. A model for investigating the development of an algorithm for fuzzy logic controller for supervisory control of a discrete event system is described. Such an algorithm is helpful to efficiently maintain an optimum throughput and energy requirements of the drives. This results in concise representation and handling of uncertainty in discrete event systems.
- Kovačić et al. (2001) presented a concept to implement computer integrated tool for design and simulation of flexible manufacturing systems (FMS). A methodology is described for setting an FMS configuration that supports automatic generation of a matrix-based FMS description and consequently, enables effective off-site design and simulation of the FMS by using virtual reality models and web-related technologies. An integrated control system is presented for the intelligent processing of the acquired sensor data, graphically oriented setup of the FMS and dynamically linked automated multilevel control of FMS system.
- Delgadillo and Llano (2006) introduced a Petri net-based integrated approach, for simultaneously modeling and scheduling manufacturing systems. A prototype that simulates the execution of the production plan, and implements priority dispatching rules to solve the eventual conflicts, is presented. Such an application was tested in a complex flexible job shop-type system. Scheduling is a difficult task in most manufacturing settings due to the complexity of the system. Hence there is a requirement of powerful tools that can handle both modeling and optimization.
- Nandkeolyar and Christy (1989) interfaced a computer simulation model of an FMS with the Hooke–Jeeves algorithm to search an optimum design without full factorial experimentation. Some modifications of the HJ algorithm are carried out to accommodate the stochastic nature of computer simulation. The inter-relationships between FMS components are not well understood. Consequently, it has not been possible to develop closed form analytic models of FMSs. So, computer simulation has been extensively applied to study their performance.
- Modelling and Scheduling of a FMS (Sawik, 1990) 6 m/cs and 4 part types to find detailed operation scheduling in FMS. A hierarchical decision approach is used. Scheduling is Determined by decomposing problem into 4 sub-problems. In first, part types are divided into subsets/ batches for Simultaneous processing. Then,

m/c loading is done. Then, part i/p seq is determined followed by scheduling of operations and sequencing the operations assigned to each m/c Presents an integer Programming formulation of scheduling in FMS. Based on algorithms for each decision stage an optimum schedule is Constructed. Can work for both online and offline scheduling.

- A new method of FMS Scheduling using Optimisation and simulation FMSBreak and Build Model- A multi-objective optimisation and simulation technique the problem is solved in 3 Stages of BBM – In building stage, an optimum schedule was Built using heuristics. In Breaking Stage was used to determine break-even point using break even analysis. In the rebuilding stage, the most proper schedule is selected using simulation.
- A review of Machine Learning in Dynamic Scheduling of FMS Considers a general FMS and compares the performance on the basis of literature Review. Dynamic scheduling of FMS by means of Dispatching Rules Based on Machine Learning. 2 approaches are used - first a rule is selected by simulating a set of dispatching rules; second, based on Knowledge Base, best rule is identified. A classification of general Scheduling approaches is done. Two ways of dynamically modifying the dispatching rules are used to show their Improvement upon static case. Paper lists the generalized shortcomings of KBS
Real time scheduling mechanism for a FMS: using simulation and dispatching rules (Jeong and Kim, 1998) 6 HMC, 2 L/UL stations, a w/p stocker that can store up to 150 pallets with the assumption that Processing times and due dates are known. It is used to develop a scheduling strategy to measure the difference between actual and estimated performances A simulation-based real-time scheduling mechanism in which job dispatching rules vary dynamically based on information from discrete event simulation that is used for evaluating a set of candidate Dispatching rules. Rules are selected by simulating the system from the time of rule selection until the end of the Planning horizon, but the selected rule is used until another rule is selected. Performance of the dispatching rules is compared in terms of mean flow times and mean tardiness. Stress was laid on the computation time which was found to be less than 45sec for a Dynamic model.
- MC involves two performance dimensions that are productivity and customization ability; for a MC strategy to be economically feasible, providers should build

competitiveness on the two dimensions simultaneously. Then, technology is the major enabler to overcome that cost-variety trade-off; adopting advanced manufacturing and information technologies such as CNC, FMS, and Internet will potentially lead to simultaneous improvements in the two MC performance dimensions. It is economically sustainable, MC strategies usually require the access to a broad, diversified range of markets and customers; hence, the actual effect of technology adoption on productivity and customization performance will be moderated by the market scope of the firm.

CHAPTER - 3

3. FLEXIBLE MANUFACTURING SYSTEMS (FMS):

3.1 INTRODUCTION:

In the middle of the 1960s, market competition became more intense. During 1960 to 1970 *cost* was the primary concern. Later *quality* became a priority. As the market became more and more complex, *speed of delivery* became something customer also needed. A new strategy was formulated: *Customizability*. The companies have to adapt to the environment in which they operate, to be more *flexible* in their operations and to satisfy different market segments (customizability). Thus the innovation of FMS became related to the effort of gaining competitive advantage.

First of all, FMS is a manufacturing technology. Secondly, FMS is a philosophy. "System" is the key word. Philosophically, FMS incorporates a system view of manufacturing. The buzz word for today's manufacturer is "agility". An agile manufacturer is one who is the fastest to the market, operates with the lowest total cost and has the greatest ability to "delight" its customers. FMS is simply one way that manufacturers are able to achieve this agility.

An MIT study on competitiveness pointed out that American companies spent twice as much on product innovation as they did on process innovation. Germans and Japanese did just the opposite. In studying FMS, we need to keep in mind what

Peter Drucker said: "We must become managers of technology not merely users of technology".

Since FMS is a technology, well adjusted to the environmental needs, we have to manage it successfully.

3.2 FLEXIBILITY CONCEPT. DIFFERENT APPROACHES:

Today *flexibility* means to produce reasonably priced customized products of high quality that can be quickly delivered to customers. Different approaches to flexibility and their meanings are shown Table 3.1

Approach	Flexibility meaning
Manufacturing	• The capability of producing different parts without major retooling • A measure of how fast the company converts its process (es) from making an old line of products to produce a new product • The ability to change a production schedule, to modify a part, or to handle multiple parts
Operational	• The ability to efficiently produce highly customized and unique products
Customer	• The ability to exploit various dimension of speed of delivery
Strategic	• The ability of a company to offer a wide variety of

	products to its customers
Capacity	• The ability to rapidly increase or decrease production levels or to shift capacity quickly from one product or service to another

Table :3.1

3.3WHAT IS FLEXIBILITY IN MANUFACTURING? :

While variations abound in what specifically constitutes flexibility, there is a general consensus about the core elements. There are three levels of manufacturing flexibility.

(a) Basic flexibilities

- *Machine flexibility* - the ease with which a machine can process various operations
- *Material handling flexibility* - a measure of the ease with which different part types can be transported and properly positioned at the various machine tools in a system
- *Operation flexibility* - a measure of the ease with which alternative operation sequences can be used for processing a part type

(b) System flexibilities

- *Volume flexibility* - a measure of a system's capability to be operated profitably at different volumes of the existing part types
- *Expansion flexibility* - the ability to build a system and expand it incrementally
- *Routing flexibility* - a measure of the alternative paths that a part can effectively follow through a system for a given process plan

- *Process flexibility* - a measure of the volume of the set of part types that a system can produce without incurring any setup
- *Product flexibility* - the volume of the set of part types that can be manufactured in a system with minor setup

(c) Aggregate flexibilities

- *Program flexibility* - the ability of a system to run for reasonably long periods without external intervention
- *Production flexibility* - the volume of the set of part types that a system can produce without major investment in capital equipment
- *Market flexibility* - the ability of a system to efficiently adapt to changing market conditions

3.4 SEEKING BENEFITS ON FLEXIBILITY:

Today's manufacturing strategy is to seek benefits from flexibility. This is only feasible when a production system is under complete control of FMS technology. Having in mind the *Process- Product Matrix* you may realize that for an industry it is possible to reach for high flexibility by making innovative technical and organizational efforts. See the Volvo's process structure that makes cars on movable pallets, rather than an assembly line. The process gains in flexibility. Also, the Volvo system has more flexibility because it uses multi-skill operators who are not paced by a mechanical line.

So we may search for benefits from flexibility on moving to the job shop structures.

Actually, the need is for *flexible processes* to permit rapid low cost switching from one product line to another. This is possible with *flexible workers* whose multiple skills would develop the ability to switch easily from one kind of task to another.

As main resources, flexible processes and flexible workers would create *flexible plants* as plants which can adapt to changes in real time, using movable equipment, knockdown walls and easily accessible and re-routable utilities.

3.5 FMS- AN EXAMPLE OF TECHNOLOGY AND AN ALTERNATIVE LAYOUT:

The idea of an FMS was proposed in England (1960s) under the name "System 24", a flexible machining system that could operate without human operators 24 hours a day under computer control. From the beginning the emphasis was on *automation* rather than the "reorganization of workflow".

Early FMSs were large and very complex, consisting of dozens of Computer Numerical Controlled machines (CNC) and sophisticate material handling systems. They were very automated, very expensive and controlled by incredibly complex software. There were only a limited number of industries that could afford investing in a traditional FMS as described above. Currently, the trend in FMS is toward small versions of the traditional FMS, called flexible manufacturing cells (FMC). Today two or more CNC machines are considered a *flexible cell* and two ore more cells are considered a flexible manufacturing system.

Thus, a **Flexible Manufacturing System** (FMS) consists of several machine tools along with part and tool handling devices such as robots, arranged so that it can handle any family of parts for which it has been designed and developed.

3.6 DIFFERENT FMSs LEVELS ARE:

- *Flexible Manufacturing Module* (FMM). Example : a NC machine, a pallet changer and a part buffer;
- *Flexible Manufacturing (Assembly) Cell* (F(M/A)C). Example : Four FMMs and an AGV(automated guided vehicle);
- *Flexible Manufacturing Group* (FMG). Example : Two FMCs, a FMM and two AGVs which will transport parts from a Part Loading area, through machines, to a Part Unloading Area;

- *Flexible Production Systems (FPS)*. Example : A FMG and a FAC, two AGVs, an Automated Tool Storage, and an Automated Part/assembly Storage;
- *Flexible Manufacturing Line (FML)*. Example : multiple stations in a line layout and AGVs.

3.7 ADVANTAGES AND DISADVANTAGES OF FMSS IMPLEMENTATION:

3.7.1 Advantages

- Faster, lower- cost changes from one part to another which will improve capital utilization
- Lower direct labour cost, due to the reduction in number of workers
- Reduced inventory, due to the planning and programming precision
- Consistent and better quality, due to the automated control
- Lower cost/unit of output, due to the greater productivity using the same number of workers
- Savings from the indirect labor, from reduced errors, rework, repairs and rejects

3.7.2 Disadvantages

- Limited ability to adapt to changes in product or product mix (ex. machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible in a given FMS)
- Substantial pre-planning activity
- Expensive, costing millions of dollars
- Technological problems of exact component positioning and precise timing necessary to process a component
- Sophisticated manufacturing systems

FMSs complexity and cost are reasons for their slow acceptance by industry. In most of the cases FMCs are favoured.

CHAPTER - 4

4. STRUCTURE OF FMS:

The structure of FMS is generally created according to request of manufacturing technology concrete type of part. This is the way to place single production station. Based on hypothetical FMS in which is exchange, loading – unloading station linked to other production stations. It consists of the manipulation equipment MZ, two compensating tanks for input VZ1 - output VZ2 of parts and the storage of pallets with unfinished and finished products S1 and S2. FMS is a functional production unit (one plant). The single production stations are designed as modules with own control system. The integrating element is AGVS with transportation moving along linear path covering material flow between modules. Potential problems happened in described FMS and a model of the Petri net is designed for an exchange station. The exchange station realizes through manipulating equipment pallet delivery with unfinished parts from storage to the compensating tank on the output. Then it lifts a pallet with finished parts out of the compensating tank on the input, replaces the pallet and loads it into the storage – it is shown on Figure 4.1.

4.1A MODEL OF PETRI NET

A spot S1 has got passive marks modeling pallets. Marks in spots S1 are replaceable only in combination with active marks assigned to the place MZ. The mark MZ models manipulation equipment, transportation system for operating with pallets. In the spot GU there are designed passive marks generating a type of task an exchange of pallet. Transition t_1 allowed because of 3 parts going into it. They take 3 tokens which moves to place M_1 and then by the transition t_2 into the place M_2 after period and OP declaring the length of manipulating process.

The transitions t_3 take a red color token to MZ and other two to VZ2 also transition t_4 takes VZ1 and transition t_5 carries 3 tokens which moves to play M₃ and then by the transition t_6 into the places M₄ after period OP declaring the length of manipulating process and stimulation ends with transition t_7 when active mark returns token red into M₂ and green into GU with finished task in spot S2 and GU is prepared against to generate task this cycle could start to repeat.

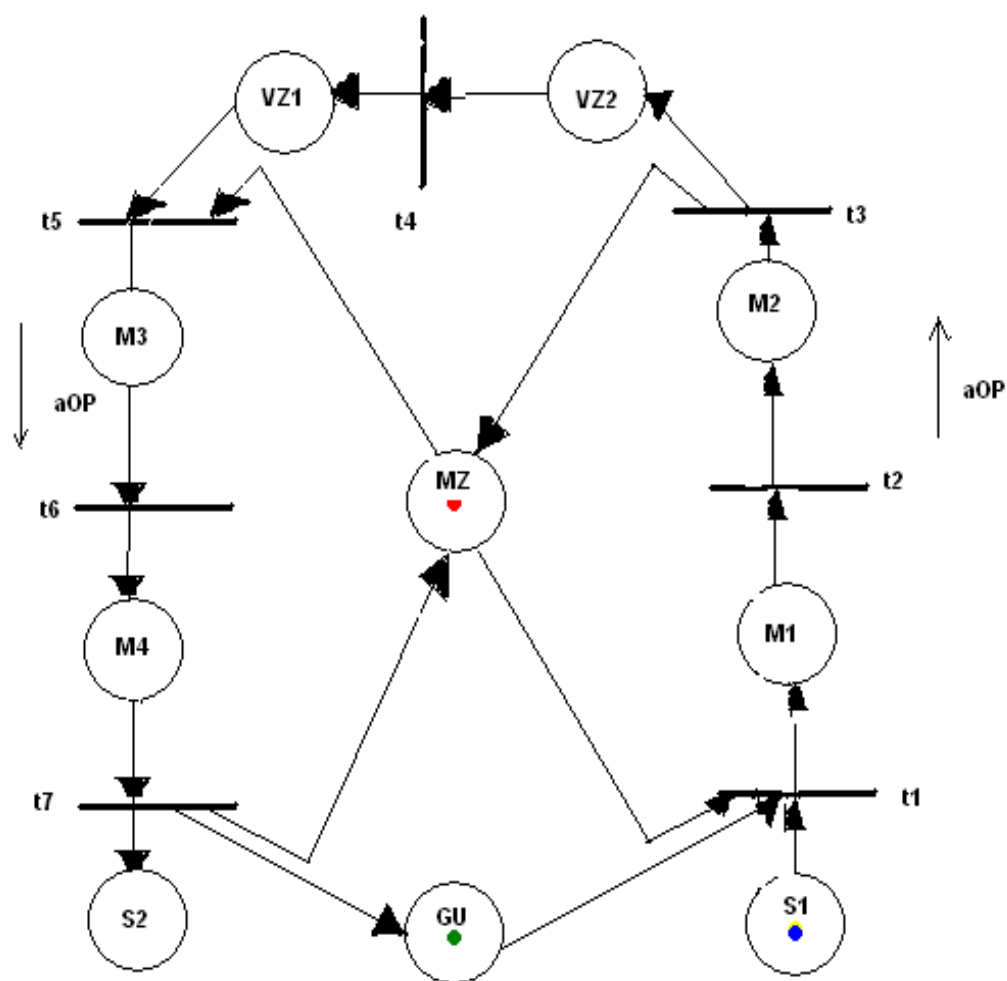


Figure:4.1A Model Of Petri Net

4.2 COMPUTERIZED SIMULATION

The program Visual Object Net++ using following values from table 4.2 simulated designed model of Petri net. – 1 case. Program Visual Object Net++ is able to create a graph of utilization of any place Petri net. The graph showing the process of utilization of manipulation equipment by the manipulation with pallet is on Figure4.2 and on Figure4.3. is the percent of utilization.

Definition of places, transitions and activities in Petri net Table 4.1.

Definition of Petri net	
Places	
Identifiers	Definition - description
VZ1	The compensating tank on the input
VZ2	The compensating tank on the output
GU	Generation of the task
MZ	Power supply of manipulation equipment
S1	Storage of pallets with unfinished parts
S2	Storage of pallets with finished parts
M1	Start of manipulation with pallet – unfinished parts
M2	End of manipulation with pallet – unfinished parts
M3	Start of manipulation with pallet – finished parts
M4	End of manipulation with pallet – finished parts
Transitions	
t1	Lifting of pallet out of S1
t2	Manipulating with a pallet
t3	Transfer of a pallet to the VZ2, return red color token to MZ

Time in seconds	t ₁	t ₂	t ₃	t ₄	t ₅	t ₆	t ₇
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t ₄	Conveyance
t ₅	Lifting of pallet out of VZ1
t ₆	Manipulating with a pallet
t ₇	Transfer of a pallet to the S2, return green color token to GU
Activities	
Avz	Time of a pallet exchange
aOP	Time of manipulation

Table: 4.1

Table: 4.2

In the case, that an exchange station is linked to the whole production system, we have to consider other input values. We assume there are 10 parts on the pallet and to finish one piece takes 135 seconds. According to it manipulation equipment lifts out of the storage a pallet with unfinished parts at the time when previous load is finished - after 1350 seconds. This way t₁=1350 seconds, table 4.2 – 2 case.

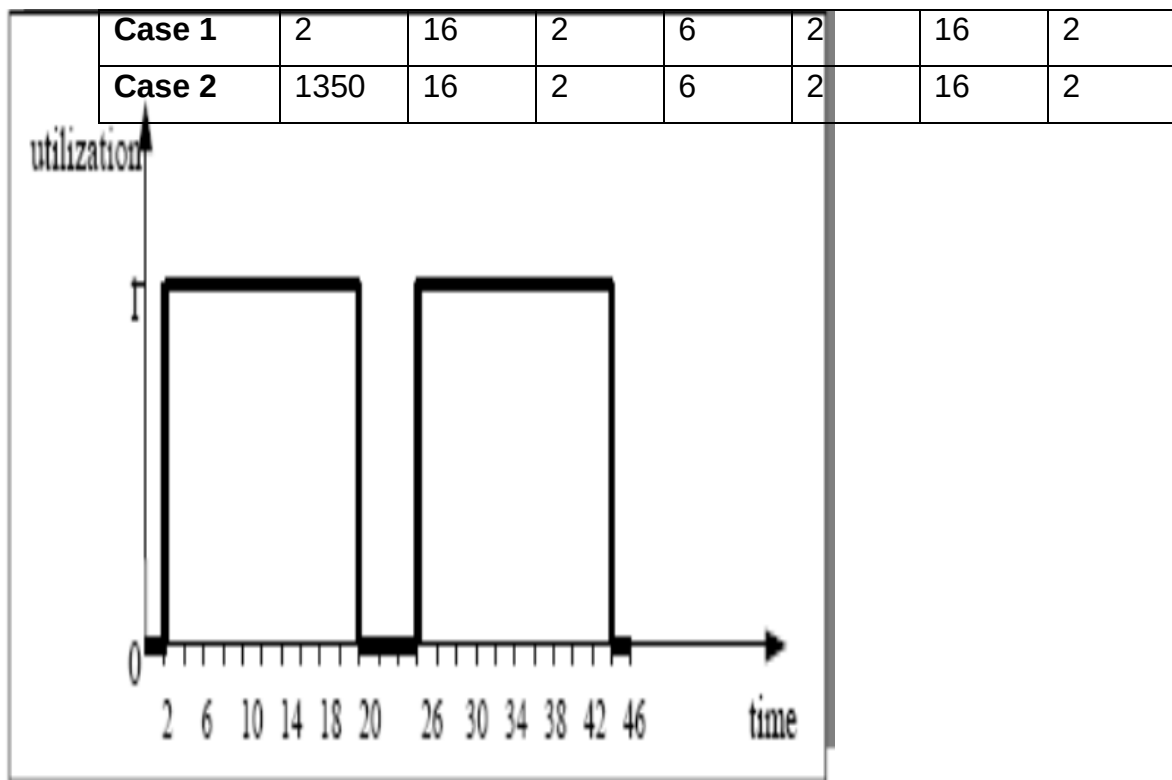


Figure:4.2 The Process Of Utilization Of Manipulation Equipment

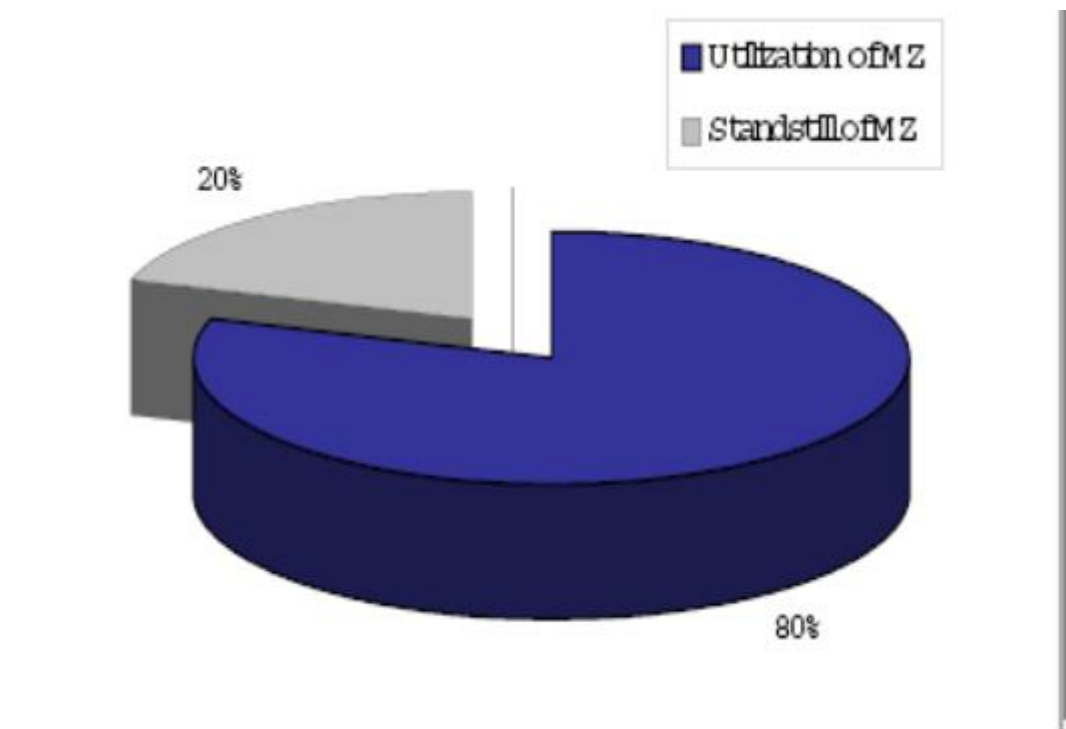


Figure: 4.3 The Utilization Of Manipulation Equipment

The graph shows that manipulation equipment waits first 1350 seconds to finish previous load and after that starts the single process of manipulation in the exchange station. All this cycle repeats depending upon a number of pallets. The graph showing the process of utilization of manipulation equipment is on Figure 4.2 and on Figure 4.4 there is its .

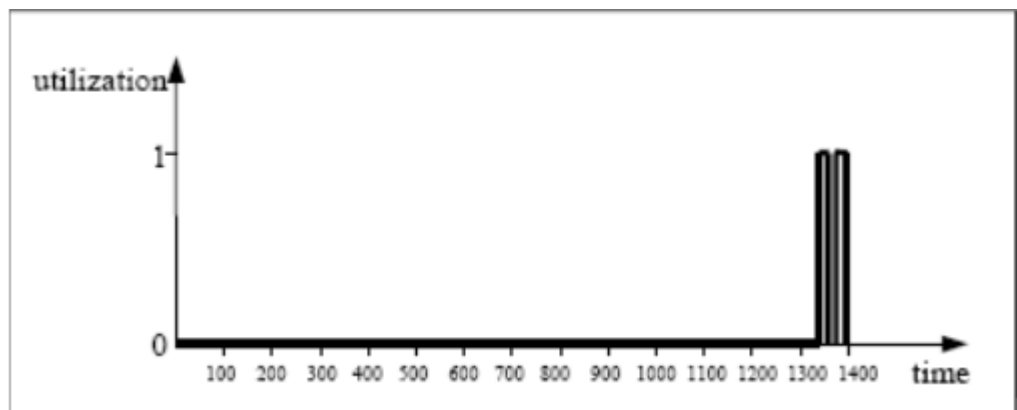


Figure: 4.4 The Process Of Utilization Of Manipulation Equipment

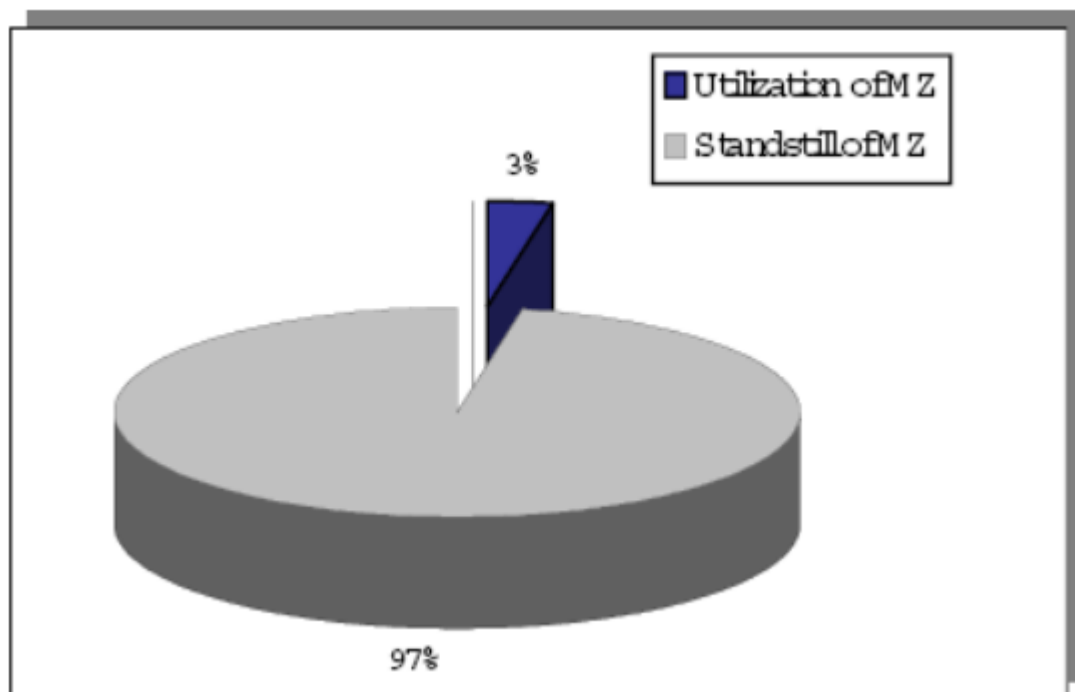


Figure: 4.5 The Utilization Of Manipulation Equipment

The graph on Figure 4.3 and Figure 4.5. Shows in the first case the exchange station working as an independent unit where is significantly higher utilization of manipulation equipment than in second case where the exchange station is linked to other subsystems and utilization of manipulation equipment is too small I. The obtained results enable us to assess if optimization created manipulating cycles is on the required level.

CHAPTER - 5

5. RESULT AND CONCLUSION:

Application of Petri net to practical FMS is a very important area in order to develop modern manufacturing control systems. This paper illustrates on Flexible manufacturing system using petri net based model. The common introduction to how the system can be modeled using Petri net is given. FMS performance depends on various input factors which include material supply, handling the material and transportation , production etc,.

CHAPTER - 6

6. CONCLUSIONS:

The simulation of manipulating cycles of FMS is the suitable mean at their optimization. The application of the formatted Petri Net into the simulation program (for example Visual Object Net++) can be discovered the percent usage of manipulating equipment and then assess the possibilities of the another optimization.

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