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# REVIEW OF FLEXIBLE MANUFACTURING SYSTEM BASED ON MODELING AND SIMULATION

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***Abstract*—**This paper focused on the literature survey of the use of flexible manufacturing system design and operation problems on the basis of simulation tools and their methodology which have been widely used for manufacturing system design and analysis. During this period, simulation has been proving to be an extremely useful analysis and optimization tool, and many articles, papers, and conferences have focused directly on the topic. This paper presents a scenario the use of simulation tools and their methodology in flexible manufacturing system from a period 1982 to 2015.

***Keywords*—**Flexible manufacturing system (FMS), modeling, simulation, software.

## I. INTRODUCTION

In modern era manufacturing industries tremendously prefer flexible manufacturing system 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 labor 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 [1]. So, A FMS is a highly automated group technology machine cell, consisting of a group of processing workstations (four or more processing workstations) usually CNC machines often computer numerical control machine tools those are connected by the automated material handling (automated guided vehicle (AGVs) and conveyor) and storage and retrieve system, and controlled by a distributed computer system.

In today's world also focused on the business scenario of the market, response time to resolve the demand of the customer, it has the flexibility to change the market scenario, reducing the product and service cost to capture the market share in the manufacturing industry. But everything depends on the setup of the FMS and working capability of the entire system. So we focused in this paper on the evaluation of flexible manufacturing system analysis on the basis of the design and use of simulation

modeling tools. How the simulation, modeling and design of FMS change from early age to modern age according to the use of FMS tools software and methodology to solve the desired problem using the different setup of the flexible manufacturing system.

## II. GENERALIZED OF FLEXIBLE MANUFACTURING SYSTEM

The flexible manufacturing system (FMS) consisting of basically, Power station, Evacuation station, Milling machine ,Control equipment of milling machine, Lathe machine, Control equipment the lathe, robot.

Basically in a flexible manufacturing system, machines and robots are connected through distributed computer system with a master computer to run the entire system. Machines and robots have computer control to run the program. The robot is used for loading and unloading the parts in the system. The storage area or automated storage and retrieve system used for raw material and finished product in FMS. Typically conveyor or AGV is used for transport product/parts from one station to another station in FMS. These are the basic features of any flexible manufacturing system.

Fig. 1. Flexible manufacturing system (Faculty of Engineering Management and Technology, University of Oradea).

## III. PAPER REVIEW ON FMS MODELING SOFTWARE AND METHODOLOGY

We focused on the overview of a literature survey of the paper based on modeling and methodology according to the utilization of software from beginning of the use of flexible manufacturing system. How the application of software and methodology apply to developed the FMS system from early age to modern age. We review the paper according to 80's to 2000 which named early age and 2000 to 2015 which named modern age. Review of the mentioned article present below:

### *A. Simulation Technique Used In Early Age:*

The author presented the application of flexible production systems (FPS) using PN in car production; it's based on decomposition and structuring [2]. Mention that FMS as an integrated computer controlled facilities which continuously able to produce a variety of parts in medium size with use of CNC machine tools and automated material handling system [3]. In [4] developed a physical simulator to analyze the performance measurement of the system effectivity of an FMS. They used fixed parameters of the simulators operation included the processing sequence, part selection, the machine center selection, and the maximum queue length and the components in the FMS**.** In [5] used classical PN to model two manufacturing systems: a transfer line with three machines and two buffers, and an FMS with three machines and two part types which based on a systematic bottom-up modeling approach. Abdin discussed the high-level programming language Q-GERT for simulation fundamental structure of Flexible manufacturing system model in design issue. A major task was to evaluate the design issues such as the effect of the dispatching rules for sequencing of jobs, determine the number of pallets limit and conveyor speed [6]. Alla represented colure PNs to model the same car productions system [7]. They used discrete event system to model the flexible manufacturing system [8]. Balbo focused on system behavior of the complex model by using two techniques stochastic Petri nets and queueing network for hierarchical modeling to evaluate the overall model [9]. Used PNs for modeling FMS and compare the flexibility in the system [10]**.** Henneke studied the overall system performance of FMS parameters using the ANOVA analysis to evaluate the FMS parameters such as part selection rules, machine selection rules, and machine queue capacity. They tried to investigate the effect of the part selection and machine selection rules and machine queue capacities on the overall performance of an FMS. They also used the six performance criteria to evaluate the FMS performance. The Waller-Duncan Bayes LSD helps to test for the significant differences between the individual means which perform multiple comparisons of system performance means generated by various treatments in a flexible manufacturing system. The study represented a substantial step in the improvement of flexible manufacturing system performance [11]. They described a heuristic based EST simulation-based scheduling algorithm for the performance evaluation of Batch Job Shop Flexible Manufacturing Systems (BJSFMS) to evaluate the performance of Maximum Makespan and Average Machine Utilization [12]**.** The author proposed a two-level heuristic algorithm to solve the loading problem in an FMS with variable production ratios. The results of simulation case study have been compared with the simulation package SIMFACTORY with satisfactory [13]. Stotts explained that the flexibility of the flexible manufacturing system which results comes from a combination of factors those are physical characters, information integrity, and the decision of operations and practice of management [14]. Al-Jaar review the classical and extended Petri nets for time analysis, and Binary Timed Petri Nets used to design and modeling of Flexible Manufacturing Systems logical structure [15]. The author presented advantages of using generalized stochastic Petri nets for modeling and analysis of complex manufacturing systems [16]. Petri nets used to model the flexible manufacturing system using two workstations and a robot as an input and output stations to simulate the system [17]. Zhou presented two-stage modeling approach combined with stochastic Petri nets together with fuzzy for the model and analyzed the performance of two resource sharing and deadlock-free manufacturing systems [18]. Zhou focused on resource sharing problems in flexible manufacturing system by the use of PNs with proposed hybrid synthesis approach [19]. Zhou described modeling of a flexible manufacturing system (FMS) with shared resources also automatic transport system using Colored-Timed Extended Petri nets to analyze the system [20]. Zhou presented deterministic timed Petri nets to model flexible manufacturing cell to compute the cycle time [21]. Brussel used colored Petri nets to model the automated guided vehicle (AGV) networks in a flexible manufacturing system [22]. The author used Petri net to synthesize theory for modeling shared-resource automated manufacturing systems (AMS). This theory helps to construct the net model by using bottom –up and modular composition approaches [23]. Yan used extended stochastic high-level evaluation Petri nets for modeling and analysis of flexible manufacturing system to find dynamic rescheduling [24]**.** Wang focused on modeling and analysis of dynamic behavior of automated manufacturing systems (AMS) using colored time object oriented PNs [25]. Zimmermann modeled manufacturing system using colored stochastic Petri nets. The structure of a manufacturing system and the work plans can be modeled separately [26]. Kim developed virtual manufacturing system for flexible manufacturing system using QUEST/IGRIP software to model product, process and facility using object-oriented paradigm [27].

*B. Simulation Technique Used In Modern Age:*

In [28] considered the transportation times in automated material handling system for simulation study of dispatching rule performance. Petri nets used to model manufacturing systems by two-phase optimization method [29]. Abdallah confessed that manufacturing systems modeling in deadlock-free scheduling problem is suitable to use by PNs is a comparison to mathematical programming approaches [30]. In [31] - [32] used reachability graph of PN reduction model of an FMS for optimal deadlock prevention policy to find the optimal solution. Bruccoleri suggested the simulation as a tool for defining the configuration of an FMS or a complex system [33]. Chen proposed colored Petri nets to model the FMS using object-oriented method for evaluation of dynamic tool allocation and performance of the modeling [34]. Kumar used an ant colony optimization approach for scheduling of FMS for a given level of flexibility [35]. In [36] used a simulation of operating system as a decision support tool for controlling the flexible system to exploit flexibility. In [37] determined the effect of operation flexibility and dispatching rules on flexible manufacturing system using simulation software SIMPROCESS. Abou-Ali discussed planned and unplanned FMS through simulation model to study the effect of dispatching rules [38]. In [39] focused on modeling of networked manufacturing systems and control system architecture using hybrid PN approach. Chan used Taguchi method analysis in a flexible manufacturing system for simulation with flexibility. And also the system performance depend on changing flexibility and operational control parameters such as scheduling rules. The result of simulation study show that expected benefits may not be present when routing flexibility (RF) levels is increased in the 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 [40]. Stochastic Petri nets approach together with fuzzy sets used to model and analysis the complex and dynamic system [41]. In [42] discussed the Multi-Objective Non-Linear Programming (MONLP) and Evolution Strategy (ES) simulation systematic approach for the flexible manufacturing system design and analysis with an automated guided vehicle system to improve the operating performance of FMS with AGVs. Design parameters of the system defined by MONLP through regression analysis and multi-factorial. ES basically used for verifying each parameter for simulation-based optimization. In [43] Used stochastic Petri nets with fuzzy logic to model and analysis the flexible manufacturing cell. In [44] Pouyan described an extended version of knitting synthesis technique in flexible manufacturing system as a real life example. PN model was synthesized by an extension version of the knitting synthesis technique for modeling, analysis, and control of concurrent asynchronous distributed systems. They called it well- behaved Petri net system. It is provided guaranteed result to operate cyclic fashion, stable and deadlock-free. In [45] Auto Mod software used to simulate different framework of FMS system using RFID data**.** In [46] Copik focused on the analysis of production systems with the use of Petri nets. This paper deals with the state of design analysis, calculation of the reachability and firing sequence for every reachable state from initial to required state by use of Petri nets. They described two stage in production system 1) modeled Petri nets. 2) Actual model production line. They analyzed reachability state of the production process, production cost, production time and the performance of production system by using Petri nets. Another important aspect of this paper is minimizing human intervention in the production process. In [47] focused on the design of scheduling problems of a Flexible manufacturing system (FMS) using timed place Petri nets (TPPN). El-Tamimi focused on a performance measure of flexible manufacturing system by the use of simulation because mathematical programming approaches are difficult to solve the complex system. For measuring and analysis of the performance, they implement Petri nets. The system has been modeled using AweSim i.e. Visual Slam software. They used bottleneck technique to compare and verification of the required results [48]**.** In [49] CPN Tools used to model and simulate flexible manufacturing cell and fuzzy system based on Matlab for rule base system for decision making in the system**.** In [50] focused on a combination of flexible alternate machines and flexible alternative operations sequences in flexible manufacturing system to obtain the full routing flexibility, used ARENA simulation software to model and simulate the FMS to observe the various effects of the factors in the system. In [51] used high-level Petri nets to model automated flexible manufacturing system to an analysis shop floor scheduling problem**.** In [52] Kumar mentioned, Flexsim software is used to modeling, analysis and performance measure for flexible manufacturing system.

## IV. UTILIZATION OF MODELING SOFTWARE IN FLEXIBLE MANUFACTURING SYSTEM

Simulation is a powerful tool to analyze and optimize manufacturing system for the purpose of design, modeling and ongoing performance. Simulation of an entire manufacturing system involves identification of organization machines, robots, the layout of the system, also involving multiple processes in the system. There is such model assist with scheduling and routing in a flexible manufacturing system. Model a flexible manufacturing system to identify the initial data for the system. There are number of workstations, number and type of tools, Number and type of conveyors, conveyor speed, type of industrial robots, automated storage and retrieved system for the raw materials and finishing parts, number and type of parts, routing of the system, technological operations of the parts, duration of the

processing time for parts and machines in the system, priority rules for the parts and machine are required to construct the flexible manufacturing model. The simulation software has the ability to construct the required model and analysis the system performance. For flexible manufacturing system or discrete event system software are used to modeling and simulate the system to generate the desired results using different criteria. From 1960's to till now lots of software use in manufacturing system to find the solution without the investment of much money and waste of time before implementing in a real system. Below in the figures we show the physical view of the software.

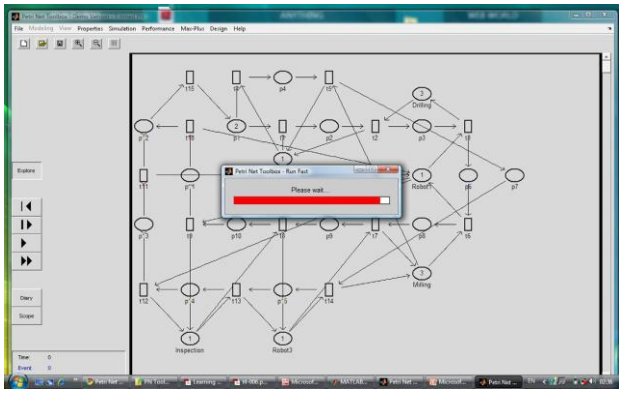

Fig. 2. Petri net model of FMS using MATLAB Petri net toolbox [48].

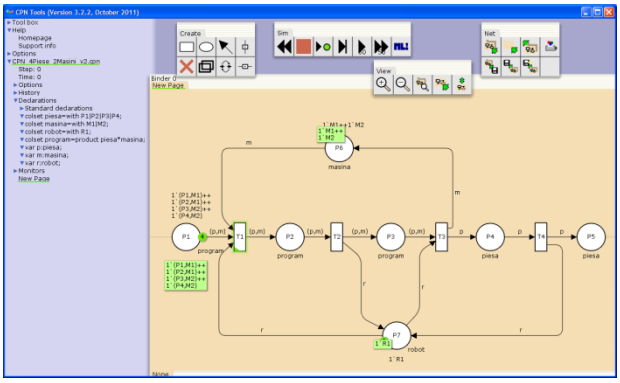

Fig. 3. CPN tools used to model flexible manufacturing Cell [53].

There is software list mentioned below in the table:

TABLE I
LIST OF SOFTWARE

| Name of software | Descriptions | Advantages |
|---|---|---|
| ARENA | Arena Simulation Software is the Discrete Event Simulation Software. | System modeling. Builds an experiment model by placing modules (boxes of different shapes) that represent processes or logic. |
| Auto Mod | Simulation of production and logistics systems. | Graphical simulation for complex manufacturing system and material handling systems analysis. It also designed for detailed analysis of operations and flows. |
| Visual SLAM AweSim | Network or flow diagram. | Simulation project, build a network, sub-network, discrete event, and continuous models. |
| Matlab Petri net tool box | Simulation, analysis and design of discrete event systems based on Petri Net models. | Graphical editor, behavioral analysis, place and transition computation, time-dependent properties, simulation and analysis of max-plus algebra, design depend on parameterized models. |
| CPN tools | Graphical modeling of colored Petri nets. | Editing, simulating, and analyzing Colored Petri nets. |
| TINA | Toolbox for timed Petri Nets. | Extensions as an inhibitor and read arcs, priorities or Time Petri Nets. |
| CPN-AMI | Tools suitable for Petri net modeling and verification. | Modeling, simulation, model checking and computation of structural properties. |
| GreatSPN | Qualitative and quantitative analysis of Petri nets. | Design and analysis to evaluate the performance of stochastic Petri net. |
| Romeo | Toolbox for T-Time Petri nets. | Able to analysis performance for T-Time Petri nets and scheduling. |
| Snoopy | Design and animate hierarchical graphs among others Petri nets. | The tools used to the simulation of stochastic/continuous Petri nets/timed Petri nets/hybrid Petri nets extended Petri nets, animation of place/transition Petri nets. |
| SimHPN | A tool used to develop for simulation. | Simulation, analysis and synthesis of systems modeled with Hybrid PNs. |
| Delphi simulation software | Modeling of the flexible manufacturing system. | Object oriented functional networks in FMS. Provides structure, functionality and behavior in the system. |
| Artifex PN software tool | Powerful modeling and simulation environment are supporting the design of discrete event systems. | Fast Simulation, Structural Analysis, Advanced Performance Analysis, Graphical Editor, Token Game Animation, Petri net supported. |
| FlexSim | the powerful analysis tool | Make intelligent decisions in the design and operation of a system. |
| QUEST | Modeling and simulation tools for manufacturing system. | Its helps to build object-oriented modeling with language based behavior. Also system analysis and capable of outputs results for discrete event system. |
| SIM PROCESS | A hierarchical modeling tool that combines process mapping, Object-oriented Modeling, discrete-event simulation and Costing. | Graphical "drag-and-drop" model development, Process optimization, Realistic estimates of activity, resource, and production costs, Visualization of process dynamics and bottlenecks. |

## V. CONCLUSION

Survey of this paper based on used of simulation software in the field of the flexible manufacturing system. We try to identify the application of software and design approach in a flexible manufacturing system. From 1982 to 2015, the application of software and techniques we discussed in a short way through this paper. It is observed that lots of paper and articles based on modeling and optimization because the papers are to develop the system in a realistic way in the industries. From this study we concluded that Visual SLAM AweSim and CPN tools are mostly used to solve FMS, and other discrete events systems modeling problems. For future studies we decided to use CPNtools and Matlab Petri Net Toolbox because these are suitable for academic purposes and can be linked with other modules like for example Fuzzy logic or Neural Nets, thus satisfying research demands.

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