International Journal of Advanced Technology in Engineering and Science
Vol. No. 09, Issue No. 12, December 2021
www.ijates.com
ijates
ISSN 2348 - 7550

Brief Review on Manufacturing Flexibility and a Tangible Choice in Small Scale Industries

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ABSTRACT

This paper deals with the subject matter—manufacturing flexibility, Small Scale Industries (SSIs) and tangible choice from the perspective of production design, control and planning. Different types of manufacturing flexibility in production systems especially in small scale industries are discussed in brief in order to show which type of flexibility is more appropriate for rational consideration and in what way it is to be considered and applied for utility. The review of literature reveals that flexibility in a manufacturing system in SSIs has a viable and significant impact on its performance but this section in the context of manufacturing industries has hardly been explored by the researchers. There exists some gaps which necessitate further research works in this area of manufacturing.

Key words: Manufacturing flexibility, Small Scale Industries, Flexibility, FMS.

1. INTRODUCTION

This study reflects upon the existing literature on manufacturing flexibility and its implementation and their problems in small scale industries. Soni et al. (1990) have concluded that the advent of computer aided process planning, group technology, just-in-time production and other Computer Integrated Manufacturing (CIM) components have increased the degree of flexibility in machine scheduling, better utilisation of limited available resources, reduced manufacturing lead time and higher quality of finished products. Ranky (1985) states that such advances have enabled industries to develop flexible manufacturing cells, robotized work cells, flexible inspection cells, etc. This paper aims to provide a brief review of all the relevant studies in the past which were hardly explored by the academicians and practitioners working in this field of manufacturing. Further here different types of manufacturing systems are discussed that are available at all levels of manufacturing industries whether it is a large scaleindustry or small scale industry.

1.1. *Continuous Process Industries*

In this type of industry, the production process usually follows a specific set of sequences. These industries can be easily automated and process monitoring can be, and is generally, done by using computers. For example, oil refineries, chemical plants, food processing industries, etc. Continuous process industries mete out an optimum batch size for which their benefits are maximum. Mehra et al. (2007) in their study on simulation, based on an actual process industry with two batch size reductions, have observed that batch reduction is beneficial in continuousprocess industries. The same observation was also found to be true for discrete manufacturing.

1.2. *Mass Production Industries*

Lesser human interference and cost-effective operation are primary objectives in designing a production line. Automation can be either fixed or flexible. For example, manufacturing fasteners, integrated chips, auto-mobiles, electronic products, bicycles bearings, etc. use massproduction principle design.

Ford and its production engineers were eventually forced to follow the lead of General Motors (GM) into adapting flexible mass production. Hounshell traces in detail the story of the painful transition of the Ford to the newer technology of flexible mass production. Ford with model T had taken American mass production to its most extreme form.

1.3. *Batch Production (Discrete Manufacturing)*

Batch production method is the most widely used method in global manufacturing industries. It has small to medium size of batches and varieties of such products can be manufactured in a single shop. Therefore, work centres with broader specifications are recommended in discrete manufacturing. Moreover, loss of production time due to product changeover is pertinent to be considered. Jenny et al. (2019) have emphasized on the use of optimization-based control techniques for efficient energy management in discrete manufacturing systems.

Among all kinds of manufacturing systems batch production is most suited for adopting manufacturing flexibility. Flexible Manufacturing System (FMS) is most suitable for the mid volume and mid variety production systems as shown in the figure 1.

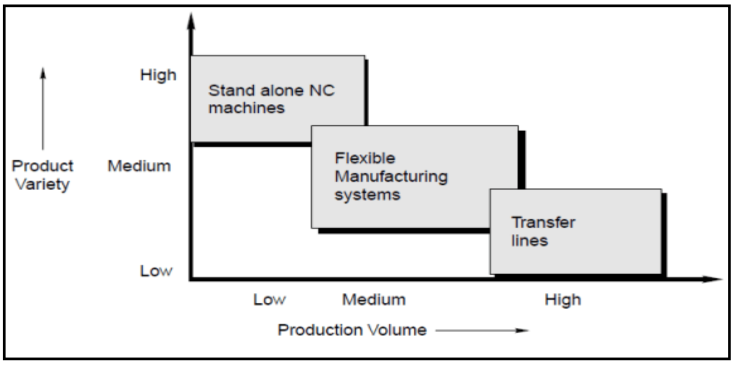

Figure 1. Application characteristics of FMS

2. MANUFACTURING SYSTEM LAYOUTS

Different types of layouts are there in manufacturing sector in large as well as small scale industries according to the arrangement of machine and the flow of parts. According to part flow and arrangement of machine, layouts of flexible manufacturing system are discussed below:

2.1. *In-line layout*

The machines and handling system are arranged in a straight line. Parts progress from one workstation to the next in a well-defined sequence with work always moves in one direction and with no back-flow as shown in Figure 2. A secondary handling system is provided at each workstation to separate most of the parts from the primary line.

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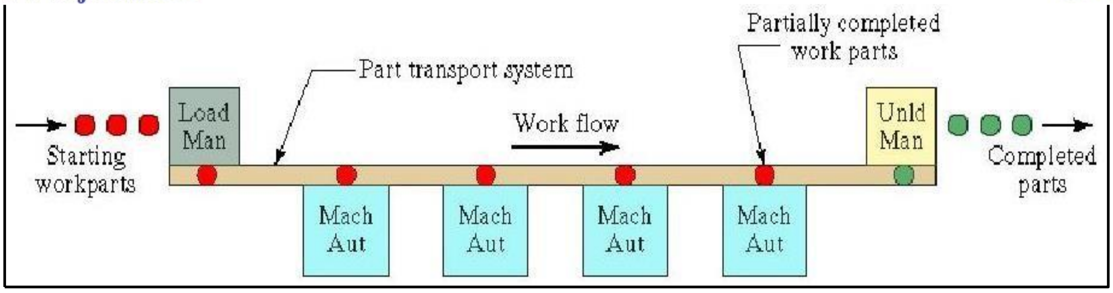

Figure 2. In-line layout

2.2. *Ladder layout*

This consists of a loop with rungs upon which workstations are located as shown in Figure 3. The rungs increase the number of possible ways of getting from one machine to the next, and obviate the need for a secondary material handling system. It reduces average travel distance and minimizes congestion in the handling system, thereby reducing transport time between stations.

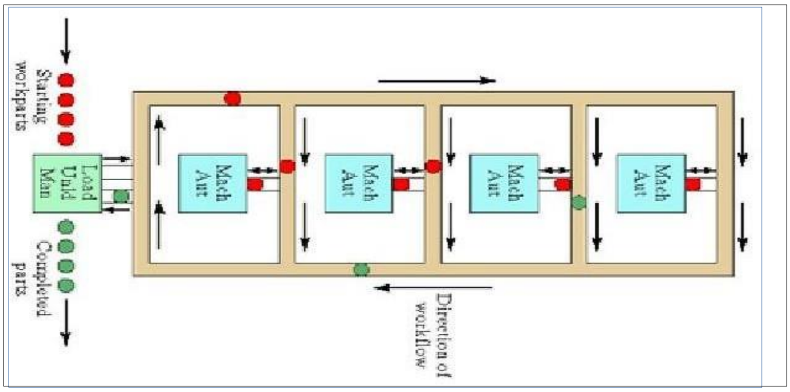

Figure 3. Ladder layout

2.3. *Loop layout*

Workstations are organized in a loop that is served by a looped parts handling system. Parts usually flow in one direction around the loop with the capability to stop and be transferred to any station as shown in Figure 4. Each station has secondary handling equipment so that part can be brought-to and transferred- from the station work head to the material handling loop. Load/unload stations are usually located at one end of the loop.

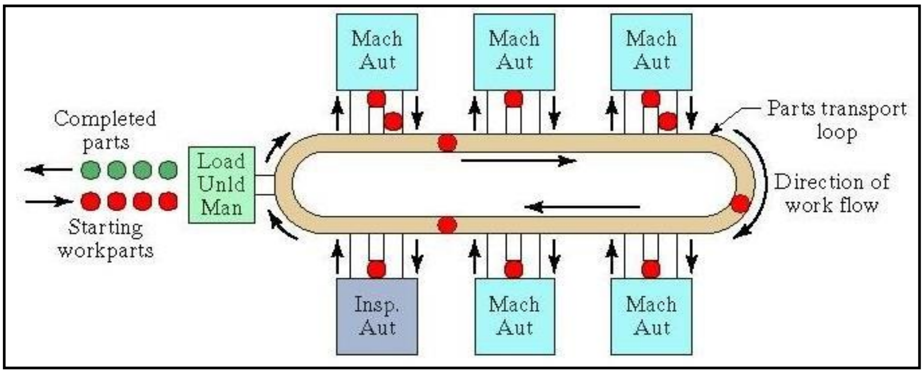

Figure 4. Loop Layout

International Journal of Advanced Technology in Engineering and Science
Vol. No. 09, Issue No. 12, December 2021
www.ijates.com
ijates
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2.4. *Open field layout*

It consists of multiple loops and ladders, and may include sidings also as shown in Figure 5. This layout is generally used to process a large family of parts, although the number of different machine types may be limited, and parts are usually routed to different workstations dependingon which one becomes available first.

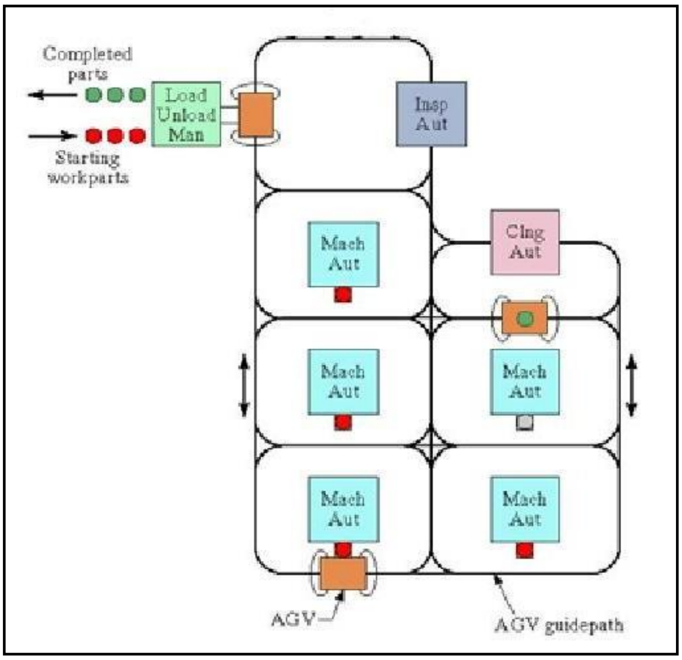

Figure 5. Open field layout

3. SMALL SCALE INDUSTRIES

Small scale industries SSI are stated as the small scale on the bases of their investment and their process of manufacturing and production that is done on a small scale level. The investment in SSIs is generally one time and are mostly on plant and machinery, that do not exceed 1 crore.

This class of industries is considered as sustenance of economy of a nation, which is having large work force. It is a labor intensive industry, so that it is helpful in generating employment opportunities. This also stabilizes and improve per-capita income of the country.

3.1. *Characteristics of SSIs*

Some important characteristics of SSI are as follows:

- It generally has a single owner.
- Its management rests with the owner/s so that the owner/s plays active role in the dayto day functions of the industry.
- It is a labor intensive, therefore limited technology is used.
- They are flexible and adaptable to a changing market environment.
- It caters the local/regional requirements because it works in a restricted area.
- It works on local and readily available resources.

3.2. *Objectives of SSIs*

The objectives of small scale industries are as follows:

- To create job opportunities for the population.
- To help in the development of economy in the rural areas of the country.
- To play an active role in reducing the regional economic imbalances.
- It improves the living standard for people in rural areas.

In view of the above characteristics and objectives of SSIs it is supposed to be a very important area for the development. As these industries works for small scale batch type production so that these are most suited to adopt the flexible manufacturing. For implementing FMS in this sector some strategic planning is required. Some of the researchers work on manufacturing design, control and planning that is briefly given in the next section.

4. FMS DESIGN, PLANNING, CONTROL AND AUTOMATION

FMS design and implementation require the knowledge of operations research concepts and problem-solving techniques. Stecke (1985) precisely defines the problems to be encountered in FMS Design, Planning, Control and Automation. FMS Design involves determining the optimum number of machine tools of each type, the capacity of material handling system and buffer size. FMS planning problems require determination of category of parts which can be simulatneously machined, groups of machine tools, pallets and fixtures assignment to part types and precious cutting tools in a tool magazine. FMS Control requires determination of the optimal input sequence of parts and the optimal sequence of machine tool for the given part mix. FMS Automation includes monitoring of the system to ensure that the quality and due dates are taken care of.

4.1. *FMS Design*

Parsaei and Wilhelm (1989) have noted that the most widely recognised important steps in advanced modern manufacturing systems are planning, justification and actual implementation. Jones and Thornley (1962) describe designing to be a very complicated intellectual human activity. Bayazit (1990) compares scientific method and design method while explaining their importance in the work of a designer. Mathematical and operations research techniques of simulation, queueing theory and mathematical programming are some of the basic tools required for designing an FMS system.

Florescu and Barabas (2020) have presented a material flow design methodology for FMS so that an optimal process design in an advanced manufacturing system is obtained. Technical and economic parameters for each processing and transport capacity can be optimized by the use of dedicated analysis and simulation software.

The sub-components of FMS Design, i.e., process design and analysis and simulation, are efficiently executed in the presence of proper documentation. Documentation can be primarily stated to be an information processing mechanism. Wulff et al. (2000) emphasize the role of defensive documentation as it not only serves the purpose of information processing but also redistributes work and responsibility among project members. Therefore, documentation is a principal activity and it must be properly dealt with by being readily available (inspectable andcomputable) and by being concise thus preventing information over-load.

4.2. *FMS Planning*

After the Flexible Manufacturing System has been designed and simulated, the means for actual implementation are secured. This stage is called Strategic Manufacturing Planning or simply Manufacturing Planning. Manufacturing planning takes into account the varieties and sequence of processes, the quality and the facilities available to implement the plan in hand.

Papke-Shields et al. (2006) discusses the evolution of planning processes from a non-rational adaptive mode towards a more rational adaptive mode. Papke-Shields et al. (2006) states that the planning processes vary between the two extremes of “focusing on adaptability” first and “focusing on rationality” first. Over the passage of time, computers are seen to be increasingly used to automate the process plan. This is called Computer Aided Process Planning (CAPP). Niebel extrapolated the use of computers in decision making for process planning in 1965. Leo Kumar (2019) explains the two major types of CAPP—variant approach and generative approach. Variant approach requires expert to categorize parts and then in accordance with path similarity within a part family Group Technology (GT) is used. However, in generative approach (a.k.a. intelligent approach) the process plan is executed in accordance with the geometry information, design logic and algorithms.

Chau et al. (2021) states that there are five important factors to study quality. Customer focus is the most weighted factor whereas quality of information technology, quality of process integration and leadership are important but lesser weighted factors impacting quality. Chau et al. (2021) observes that supplier quality management has negligible effect.

4.3. FMS Control

Post-designing and planning of FMS the next step is to ensure control of manufacturing process, which includes- WEB ordering and shipping, scheduling, shop floor and material procurement.

SSIs and also MSIs require relatively smaller inventories and desire faster shop floor to market delivery. The commercial utilisation of WEB ordering and shipping, a sub-set of information technology, allows to create a feedback loop between production line and supply channel. Viswanadham (2000) talks about Order-to-Delivery (ODP) process (a.k.a. Order-to-Cash process (OCP) as an important business process in which as soon as the buyer makes an order the necessary cash is generated for the seller at the final sales transaction. It is pertinent to notethat flexibility can be enhanced by approaching real-time techniques.

The scheduling and control of manufacturing processes in FMS has been an important research area. Wu and Wysk (1989) suggest that scheduling should not be planned too much ahead of time, rather a dispatching rule should be determined just before the implementation for each short period of time, i.e., in regard to the dynamic status of the system. Erol et al. (2012) observes that using negotiation/bidding mechanism between agents in a multi-agent based system generates better or comparable schedules, for the control of Automated Guided Vehicles (AGVs), in comparison to those obtained with static optimisation algorithms and dispatching rules. Phanden et al. (2013) propose four main models to help integrate the existing planning and scheduling departments from the “mean tardiness” and “makespan” viewpoints, which are: process plan selection module, scheduling module, schedule analysis module and process plan modification module. Başak and Albayrak (2015) observe that quick cell configuration and efficient operation of cells in FMS can be done using Petri Net (PN) model. Başak and Albayrak (2015) have based their findings on the use of Object-Oriented Petri Nets (OOPNs) approach and modelling the system as a Time Market Graph (TMG). Such a performance evaluation problem can be reduced to a simple Linear Programming (LP) problem having n constraints and m-n+1 variables;

'm' represents the number of places in TMG and 'n'represents number of transitions in TMG.

Alfieri et al. (2012) explain the necessity of a detailed schedule for the manufacturing processes, absence of this may affect the feasibility of material requirement planning. Tzafestas and Kapsiotis (1994) state that in case of an autonomous manufacturing/supply chain each sub- suppliers in the hierarchy of intermediate supplier incurs some costs and adds some delay in material procurement. Tzafestas and Kapsiotis (1994) present a numerical method solution byexamining three possible scenarios.

Shop floor consists of an actual schedule comprising of alternative processes which are to be performed on alternative machines for the production of each part. The supervisors/first-line managers help in formalisation of shop floor and also help in strengthening the structural factors. Delbridge and Lowe (1997) describe the social importance of supervisors due to their ability to ensure process flexibility that relies o informality while bringing together multiple teams. Newer developments such as Internet of Things (IoT), Artificial Intelligence (AI), cloud computing and big data have facilitated convergence of physical and virtual shop floor. Tao et al. (2017) present a categorisation of evolution into stages on the basis of degree of convergence, which is shown

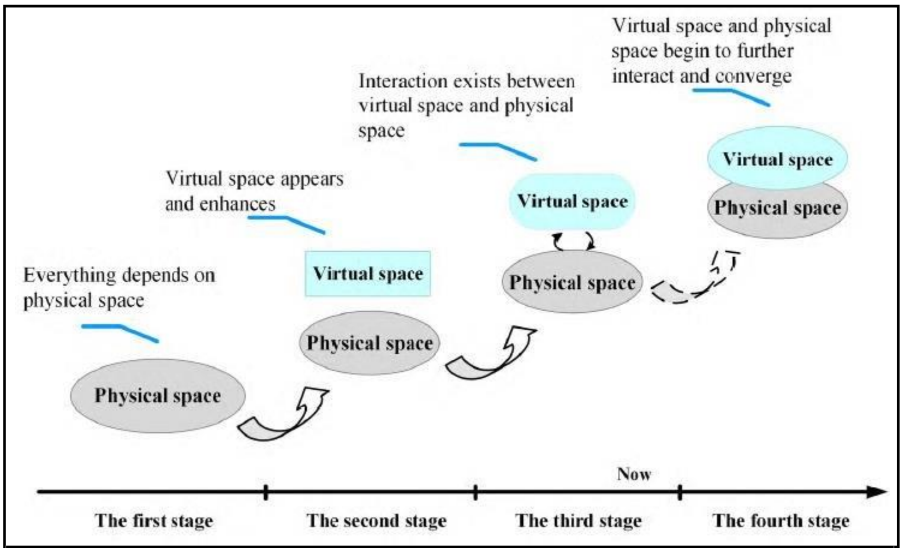

Figure 6. The Evolution Process of Shop Floor

in figure 6.

4.4. *FMS Automation*

The last section or the final department is factory automation, which finally implements the actual plan, comprises of automated material handling, assembly automation, inspection test and material processing.

Kusiak (2018) reviews the importance of the six pillar of smart manufacturing- manufacturing processes, materials procurement, scheduling data, predictive engineering, sustainability & resource sharing and networking in automated material handling and supply chain management. A passive material handling strategy may incur delay between the arrival of trolley and completion of job on a machine which may lead to increased total non value-added energy consumption. Wang et al. (2020) explain that how the application of Cyber Physical System (CPS) to manufacturing resources (machines and trolleys) increases traceability and controllability in manufacturing. Wang et al. (2020) propose the use of digital-twin model for timely analysis of performance parameters and then using the obtained data to design a proactive material handling model for the allocation of smart trolleys optimally.

One of the most widely used type of assembly cells known as hybrid assembly cells are based on Human-Robot Collaboration (HRC) framework. HRC can be defined as a framework providing for co-existence of human and robots in the same cell and sharing tasks as per their capabilities. Therefore, hybrid assembly cells have more degree of automation and are much better at execution of collaborative tasks than manual assembly cells. Tsarouchi et al. (2017) present a preliminary design of a hybrid assembly cell for the case of a manual assembly cell in an automotive industry. Guo et al. (2020) explain that how the introduction of digital twin model, IoT, smart gateway, web 3D and industrial wearable technologies in fixed-position assembly islands reduces the uncertainty and complexity in resource (workers, equipments and materials) allocation. Fixed-position assembly islands are widely used in the assembly of fragile products and heavy equipment industries.

Inspection Test focuses on deciding the optimum time for inspection test so as to prevent unnecessary defect detections and thereby preventing re-planning and restarting of the manufacturing process and as a result preventing unnecessary delay. Post-inspection the defective pieces are either repaired, if feasible, or else discarded. The time to repair the defective parts and the time taken to obtain the required number of acceptable parts/products (cumulatively known as 'makespan' time) should be as less as possible.

5. CONCLUSION

The purpose of this brief review is to develop a perspective of understanding of the working of SSIs, its importance in the economic growth of a nation and the design, control and planning requirements of a manufacturing system to enable flexibility. Research papers were collected from the journals focused on design, control and planning of FMS. Most of the SSIs (as well as MSIs) hesitate to adopt the wider prospect of FMS due to the presence of cheap labour in developing countries and the expensive pay-roll of FMS skilled engineers. Apart from these difficulties the following shortcomings may be noted:

1. Diverse approaches taken by researchers have reduced the effectiveness of documentation.
2. Simulation offers a method to optimise the FMS for desired parameters but requires experienced and skilled leadership in case of unexpected situations/failures of certain parts.
3. Finding a balanced approach between the extremes of 'rationality' and 'adaptability' is of key importance.
4. Real-time quality inspection and real-time feedback is still to be achieved to greatly minimise the loss of material and time.
5. Critically evaluated and detailed schedule is required to enable feasibility of the production plan itself as well as to enable effective use of AGVs and Automatic Storage/Retrieval System (AS/RS) in material procurement and such.
6. Physical and Virtual shop floor convergence can be said to be still in the third stage.

It is seen that most of the research works and findings in the field of flexibility was done on large scale industries in which high quality skills/technology and capital are involved. The review of theoretical and empirical works reveals that an integrated framework to assess manufacturing flexibility and performance of SSIs is largely missing in the existing literature.Therefore, there is a need to explore this type of industries.

6. DISCUSSION

Research works need to be pursued to further optimise cost-effectiveness of FMS so that it canbe utilised in SSIs.

Complexity of using AGVs and AS/RS are still a challenge in SSIs. Furthermore, a lesser diverse (or a more unified) approach should be derived by the researchers to increase the effectiveness of documentation and thereby allowing a wider scope and easier implementation of FMS in all types of industries. FMS is a growing concept which has the potential to provide more feasible solutions to manufacturing industries. Additionally, evolution of convergence to the fourth stage can bring ground-breaking results to existing problems of manufacturing process.

REFERENCES

[1]. Soni, R. G., Parsaei, H. R., & Liles, D. H. (1990) A methodology for evaluating computer integrated manufacturing technologies, *Computers & Industrial Engineering*, *19*(1-4), 210-214.

[2]. Ranky, P. G. (1985) FMS in CIM (flexible manufacturing systems in computer integrated manufacturing), *Robotica*, *3*(4), 205-214.

[3]. Mehra, S., Inman, R. A., & Tuite, G. (2006) A simulation-based comparison of batch sizes in a continuous processing industry, *Production Planning & Control*, *17*(1), 54-66.

[4]. Diaz Castañeda, J. L., & Ocampo-Martínez, C. (2019) Energy efficiency in discrete-manufacturing systems: insights, trends, and control strategies, *Journal of manufacturing systems*, *52*(Part A), 131-145.

[5]. Stecke, K. E. (1985) Design, planning, scheduling, and control problems of flexible manufacturing systems, *Annals of Operations research*, *3*(1), 1-12.

[6]. Parsaei, H. R., & Wilhelm, M. R. (1989) A justification methodology for automated manufacturing technologies, *Computers & industrial engineering*, *16*(3), 363-373.

[7]. Jones, C. and Thornley, D.G. (1962) *Conference on Systematic and Intuitive Methods in Engineering, Industrial Design, Architecture and Communications*.

[8]. Bayazit, N. (1990) Development of a knowledge acquisition model for computer aided design,

[9]. *International Conference on Engineering Design (ICED), 2, 1024-1031.*

[10]. Florescu, A., & Barabas, S. A. (2020) Modeling and simulation of a flexible manufacturing system— A basic component of industry 4.0, *Applied Sciences*, *10*(22), 8300.

[11]. Wulff, I. A., Rasmussen, B., & Westgaard, R. H. (2000) Documentation in large-scale engineering design: information processing and defensive mechanisms to generate information overload, *International Journal of Industrial Ergonomics*, *25*(3), 295-310.

[12]. Papke-Shields, K. E., Malhotra, M. K., & Grover, V. (2006) Evolution in the strategic manufacturing planning process of organizations, *Journal of Operations Management*, *24*(5), 421-439.

[13]. Leo Kumar, S. P. (2019) Knowledge-based expert system in manufacturing planning: state-of-the-art review, *International Journal of Production Research*, *57*(15-16), 4766-4790.

[14]. Chau, K. Y., Tang, Y. M., Liu, X., Ip, Y. K., & Tao, Y. (2021) Investigation of critical success factors for improving supply chain quality management in manufacturing, *Enterprise Information Systems*, 1-20.

[15]. Viswanadham N. (2000) Order-to-Delivery Process, *Analysis of Manufacturing Enterprises*, 12, 183- 211.

[16]. Wu, S. Y. D., & Wysk, R. A. (1989) An application of discrete-event simulation to on-line control and scheduling in flexible manufacturing, *The International Journal of Production Research*, *27*(9), 1603-1623.

[17]. Erol, R., Sahin, C., Baykasoglu, A., & Kaplanoglu, V. (2012) A multi-agent based approach to dynamic scheduling of machines and automated guided vehicles in manufacturing systems, *Applied*

soft computing, *12*(6), 1720-1732.

[18]. Phanden, R. K., Jain, A., & Verma, R. (2013) An approach for integration of process planning and scheduling, *International journal of computer integrated manufacturing*, *26*(4), 284-302.

[19]. Başak, Ö., & Albayrak, Y. E. (2015) Petri net based decision system modeling in real-time scheduling and control of flexible automotive manufacturing systems, *Computers & Industrial Engineering*, *86*, 116-126.

[20]. Alfieri, A., Tolio, T., & Urgo, M. (2012) A project scheduling approach to production and material requirement planning in Manufacturing-to-Order environments, *Journal of Intelligent Manufacturing*, *23*(3), 575-585.

[21]. Tzafestas, S., & Kapsiotis, G. (1994) Coordinated control of manufacturing/supply chains using multi-level techniques, *Computer integrated manufacturing systems*, *7*(3), 206-212.

[22]. Delbridge, R., & Lowe, J. (1997) Manufacturing Control: Supervisory systems on the new shop floor, *Sociology*, *31*(3), 409-426.

[23]. Tao, F., Zhang, M., Cheng, J., & Qi, Q. (2017) Digital twin workshop: a new paradigm for future workshop, *Computer Integrated Manufacturing Systems*, *23*(1), 1-9.

[24]. Kusiak, A. (2018) Smart manufacturing, *International Journal of Production Research*, *56*(1-2), 508- 517.

[25]. Wang, W., Zhang, Y., & Zhong, R. Y. (2020) A proactive material handling method for CPS enabled shop-floor, *Robotics and computer-integrated manufacturing*, *61*.

[26]. Tsarouchi, P., Matthaiakis, A. S., Makris, S., & Chryssolouris, G. (2017) On a human-robot collaboration in an assembly cell, *International Journal of Computer Integrated Manufacturing*, *30*(6), 580-589.