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A Highly Efficient and Optimised Simulation Based Multi objective Decision-Making for FMS Control

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Abstract:

Optimized and efficient decision-making systems is the burning topic of research in modern manufacturing industry. The aforesaid statement is validated by the fact that the limitations of traditional decision-making system compresses the length and breadth of multi-objective decision-system application in FMS. The bright area of FMS with more complexity in control and reduced simpler configuration plays a vital role in decision-making domain. The decision-making process consists of various activities such as collection of data from shop floor; appealing the decision-making activity; evaluation of alternatives and finally execution of best decisions. While studying and identifying a suitable decision-making approach the key critical factors such as decision automation levels, routing flexibility levels and control strategies are also considered. This paper investigates the cordial relation between the system ideality and process response time with various prospective of decision-making approaches responsible for shop-floor control of FMS. These cases are implemented to a real-time FMS problem and it is solved using ARENA simulation tool. ARENA is a simulation software that is used to calculate the industrial problems by creating a virtual shop floor environment. This proposed topology is being validated in real time solution of FMS problems with and without implementation of decision system in ARENA simulation tool. The real-time FMS problem is considered under the case of full routing flexibility. Finally, the comparative analysis of the results is done graphically and conclusion is drawn.

Keywords: -FMS, Decision-making, ARENA, Routing flexibility, Control strategies.

I. INTRODUCTION

This fast-shifting securities industry has resulted in the demand of versatile product variety which resulted in the need for more flexible and changeable manufacturing environment. Due to continuous modification in the taste of the customer the requirement of product type changes as a consequence of which the product variety needs to be exchanged. In decree to induce alterations in the product variety the manufacturing organizations require to be more active and elastic. This can be accomplished by the utilization of highly automated machines like that of CNCs and automated material handling equipment like robots, conveyor belts and AGVs giving rise to a highly-automated manufacturing environment for processing of components. Moreover, there is need of a proper management of design, planning, scheduling and command of such automated manufacturing systems for its proper working. The invention of such arrangements should be such that on that point should be a proper coordination between the planning phase along with the material and resource flow systems. Hence a demand of manufacturing system is there which should be highly flexible and along with that there should be a proper integration between all the resources present in the scheme to insure smooth flow of decisions in and among the manufacturing environment. The answer to this problem rests in the implementation of a highly flexible arrangement which is usually known as Flexible Manufacturing Systems (FMS). An FMS can be specified as a collection of CNC machines interlinked by an automated material-treatment system such as conveyor belts and robots designed for fabricating parts in mid volume and mid variety production range. The FMS serve as a technique to automate the batch production process. FMS works on the principle of group technology (GT) layout. GT is a technology where the parts are divided into certain part family depending on their operational and design similarities and the machine those are require for manufacturing of such parts are grouped together. Generally, batch production process uses such type of layout for manufacturing of components. FMS are the systems which uses highly flexible and automated machines to automate GT layout in order to manufacture parts in the batch production range.

Fig.1 shows in detail the entire setup of the Flexible Manufacturing Systems (FMS) with 6 machines and an ASRS system. The conveyer belts are utilized for transportation of jobs from machines to machines inside the organization. The robots that are shown are the pick and place type used for material handling of jobs from the conveyor to the machines. The cars used are generally CNC machines due to its highly automated and flexible performance. There are places often used for temporary storage of parts before and after the machines which can be referred to as buffer storage. Such storage is kept to maintain a continuity in part flow. Hence, from this system, it can clearly be summarized that the FMS are automated systems that have high complexity in its pattern and configuration and consists of extremely flexible machine for processing of jobs that are integrated with one another by various material handling equipment like AGVs, conveyors, robots, etc.

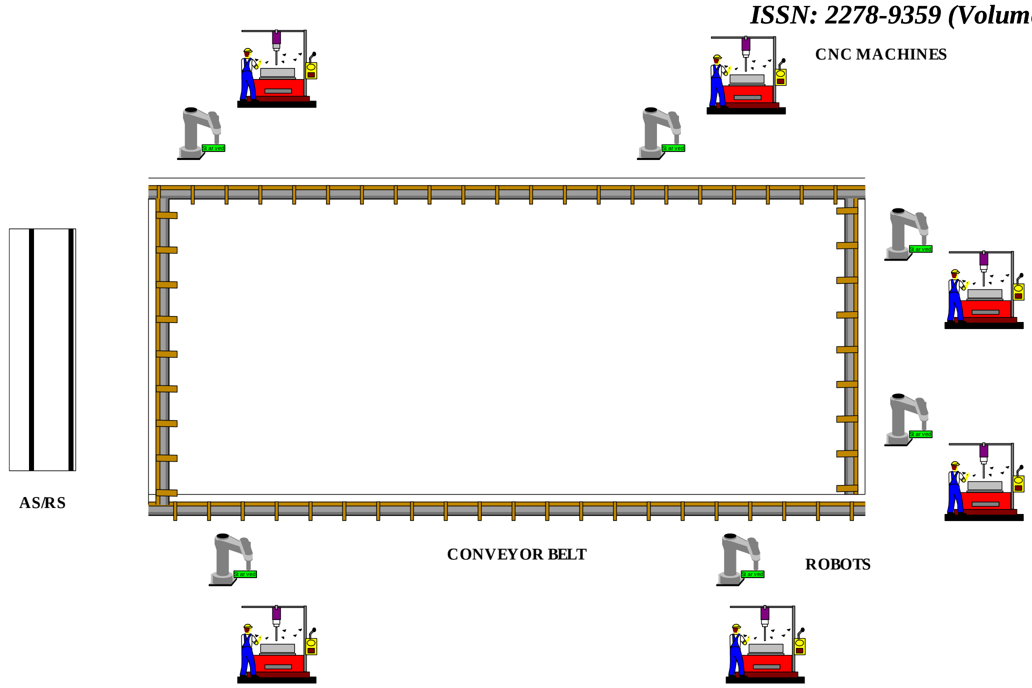

Fig. 1 FMS setup with CNC machines and material handling equipment.

It is apparent from the fact that the FMS are highly automated systems possessing a high complexity in design and form. Hence a proper scheduling and dispatching methodology needs to be adopted for allocation of jobs to the pool of machines. Thither are many uncertainties and disturbances occurring on the workshop floor as a reason of which the scheduling of FMS becomes quite a challenging undertaking. Effective scheduling can be acted by taking the appropriate decision at the appropriate time and its performance at the needed time. These conclusions can be denoted to ascertain judgement regarding the choice of the sequencing or dispatching rule to be applied, the job, loading sequence and certain methodologies to be swept up to tackle the events of emergencies in the shop floor like urgent job arrivals, machine breakdown and tool breakdown. Hence this entire process can be termed as the decision-making in FMS. The decision-making involves several operations like a collection of shop floor data, appealing the decision-making activity, evaluation of all the available alternative and finally the implementation of the best decision plan. Some quantity of time is required for these actions to hold home. Reaction time can be limited as the time that is needed for the entire decision-making process to be carried out. Decision-making is a time dependent process. The entire decision-making activity is an occasion of time only the details of which are studied in the decision analysis section of this report.

This paper consists of the various possible approaches that can be outlined in the decision-making process and the implementation of the same to a real-time FMS problem. The real-time problem in FMS refers to such problem which is learned from the shop floor environment where the problems like rush job orders, car breakdowns, tool breakdowns are encountered very frequently. Assuming the entire operation in such a job environment is truly a real hard undertaking. Hence, as a result of which the decision-making process finds a nifty application for such type of troubles. The decision taken should be concrete and thorough as a result of which the entire procedure can be optimized. The several cases of decision making approaches that are used are real time decision making, proactive decision- making, reactive decision-making and pre-active decision-making. Founded on these approaches different cases in decision-making are generated and the figuring is done for the results using ARENA simulation tools. The trouble is worked out by using these decision approaches and without using it and ultimately the results are compared to determine the outcome of decision-making on the performance of FMS. Hybrid AI techniques like Genetic Algorithm (GA) is applied to this decision-making process on FMS problem and the solutions found are compared with the one found using ARENA simulation software. Lastly, the graphical interpretation is done for the terminations.

Section 1 of this paper deal with the brief introduction to the decision-making used to control the real-time problem in FMS environment. Section 2 consists of the review of literature in brief stating the gap that draws from the literature and based on which objective of the inquiry is framed. Section 3 consists of the background and motivation behind the study. It also deals with the problem statement that is developed based on the research objective and motivation. Section 4 deals with the detailed methodology adopted to resolve the trouble. Here in this chapter different approaches of the decision-making are considered in detail and based it on various situations are generated which final implementation of the situations is caused with the FMS problem. Section 5 contains the results and discussion that are launch by employing the methodology that is taken. The solutions found are properly broken down and graphical interpretation is done for the results and finally the section 6 deals with the conclusion and the future scope of the work which is made based on the answers.

II. LITERATURE REVIEW

Design of FMS is a really a very complicated task and rather very difficult. [1] in their research work performed the overall design implementation of FMS and calculated the overall utilization, no of workstations, the bottleneck station, no. of busy servers and overall FMS efficiency using analytical bottleneck model techniques and Rank order clustering (ROC) algorithm. The results so obtained were compared with the conventional manufacturing conditions and accordingly the effectiveness of FMS is concluded. FMS planning and designing issues are very much important to know the capacity of the system. [2] has clearly outlined the design, planning, scheduling and control problems of FMS. The author defined the entire design process in two phases i.e. initial specification decisions and subsequent implementation decisions. The initial specification decisions can be referred to as like the determination of range of family that can be produced, the no of machine tools and robots required, outlining the flexibility types, specifying the material handling capability, etc. The implementation decisions can be referred to as layout type determination, determination of the no. of pallets and fixtures, pallets and fixtures design. The FMS scheduling problems can be stated as the determination of optimal sequence of the part types, development of appropriate scheduling methods and prioritization of parts when several parts are waiting to be processed. Finally, the control problems are policy determination for proper handling of machine tools and other breakdowns, finished goods inspection, process monitoring and tool life monitoring activities. [3] proposed a heuristic algorithm to solve two major planning problems i.e. part type selection and machine loading problems. System constraints, information regarding related parts, machines and tool magazines are considered to generate solution in a limited space. The aforesaid algorithm has been tested and compared with the results which is obtained by solving the two planning problems separately. The test indicated that the algorithm is very efficient and practical to solve the FMS planning problems.

There are many amounts of literatures available on FMS process planning and scheduling. One of them is by [4] that focused on the integration of process and production planning for the control of FMS. The outcomes of the process planning are like workpiece selection, determination of processing operations, optimal sequence determination, appropriate machine tool selection, cutting tools and fixtures selection and machining conditions determination. Some constraints faced under the FMS environments are also outlined like that the tool magazines capacity, buffer storage capacity for pallets, multiple fixtures problem and the cutting tools availability. Certain types of flexibility dimensions are also classified like action versus state, system versus machine level, range versus response type, static versus dynamic, Potential versus actual and Short, medium versus long term. The process planning as focused in this paper are classified as nonlinear, closed loop and distributed process planning. The preplanning phase i.e. done before process planning deals with the generation of the offline activity at the initial stages, the pairing planning phase matches the part operations with the machine capacities and the final planning deals with the setup, tools and fixture preparation along with the generation of the NC programs. [5] focused on an integrated scheme for the process planning and scheduling of FMS. The paper described in detail the flow diagram of the process planning for FMS. Initially there will be production order where the details about part types, part type production quantity, number of pallets and multiple process plans for each part type are mentioned. Then at the Process plan selection module the total production time for multiple parts is computed and the 4 process plans for each part type is selected using shortest total processing time criteria and some priority are assigned to these plans that are arranged in decreasing order. The shortlisted plans are stored in a process plan database and the best process plan is retrieved from it. Then after using scheduling module part selection and machine selection for selected part is done based on the selected process plan. If the next required alternative machine in unavailable the next best process plan is selected according to the currently followed process plans. Finally, it is implanted in the manufacturing system and the current shop floor status is monitored continuously and necessary changes are made in the process plans allocation depending on the shop floor status.

Conventional scheduling contains a good amount of literature. The literature by [6] outlined a survey of dynamic scheduling in manufacturing systems. The literature focused on the dynamic scheduling problem which has considered a number of real time events and its effects that can be broadly classified as resource related and job related. The dynamic scheduling that has been classified as completely reactive, predictive reactive and robust proactive scheduling. Various rescheduling strategies are also outlined that are used to tackle real time events. [7] presented an article on flow shop scheduling research. In that paper, they have introduced impact of NP completeness concept and the selection criterion which uses Johnsons algorithm for minimization of make span and flow time. A review paper by [8] stressed on the job shop schedules used in industries which are made to work in a very stochastic environment. The authors have stated that a deviation occurs in a predictive schedule when any machine breakdown, urgent job arrivals, power failure, misplaced parts occurred. In such situation, the solution is to completely reschedule the system which is very time consuming. Hence schedule recovery techniques are used to tackle such problem and the authors in their paper explored different such techniques and as such robust plan was prepared.

Disturbances and uncertainties are the common problems which are faced by the shop floor engineers during the execution of planned schedules. Our main aim is to design a robust schedule which can restrain those disturbances. [9] outlined the production disturbances problem in manufacturing systems. Various conditions like upstream and downstream are studied and the nature of the disturbance propagation was analysed. Finally, they defined their recovery time and robustness was measured which was used for optimizing reactive and proactive control strategies. Another literature by [10] outlined the effects of uncertainties on supply chain management that may pose an adverse impact to dynamic systems. A dynamic system model of supply chain was presented which can be used for disruptive event management under full load states of manufacturing systems.

Scheduling of FMS is a very complex and difficult task as there are many disturbances which occur when implementing the process. Such disturbances can be new job arrival, machine breakdown, tool failure, controller failure of the system amongst all. There is a significant amount of literatures available on FMS scheduling but till now no dedicated and accurate method is found out for this process. Some of such works are stated in this short survey. [11] has given an overview of different planning and scheduling problems. Some of such problems the author had described are selection problem, loading problems, WIP problems, part scheduling and allocation problems, dispatching problems, layout problems and costing and investment problems. The author had clearly distinguished between the planning and scheduling problem i.e. according to him the planning problems refers to grouping of machine tools, allocating pallets and fixtures, the tool magazine capacity, etc., whereas the scheduling problem includes optimal input sequence determination of parts and that of machine tools. Work on dynamic scheduling was done by [12] in which the authors have suggested two level control hierarchy. The higher level determined a dominant decision criteria and scheduling rules based on the actual shop floor status while the lower level used simulation for scheduling rule determination. The authors have developed a mechanism which works on dynamic scheduling principle and enabled FMS to adjust with volatile working environment. [13] focused on the development of a distributed implementable in real time scheduling rule as a result of which the closed loop system would be stable. Various computing relations are presented for determining process parameters which are suitable for planning purposes. [14] stated that the FMS scheduling problems faced the drawbacks like modelling and complexity. The authors proposed a finite automata (FA) theory to develop a modelling formalism and an accompanying scheduling algorithm for control and scheduling FMS with resource constraints. The mentioned process is fully automatic and requires least human intervention. An FA model has been generated and that was used to decompose complex scheduling problems into smaller one and finally a heuristic algorithm like GA was used to schedule these generated processes. The paper by [15] concluded that the GA (Genetic Algorithm) performance offers better results of objective functions after the applications of several primitive and deterministic approaches on the sample with varying complexities. The paper also outlines several primitive and deterministic techniques i.e. the priority scheduling and dispatching rules that can be used like SIOT, LIOT, SPT, LPT, SRPT, LRPT, SR, LR, SV and LV in detail. The mathematical expression along with the process that is followed in the shop floor for all rules are stated in the detail and the job sequences along with the results that are found by implementing these rules are calculated and shown. The research paper stressed on the detailed methodology used by the GA out of which one is search approach where the new solutions will be generated by using the various genetic operators like selection, crossover and mutation. The result found using the GA finally is compared with the one found using these priority rules.

Decision making process is one of the important considerations in FMS which is responsible for its shop floor control. It’s because of the fact that the FMS are systems with high flexibility that can process a variety of jobs in different machines; the decision-making process becomes a very complicated and difficult task in FMS environments. Certain literatures are available on the decision making of FMS. [16] has considered the importance of time and used this preemptive approach to implement the real-time decision making in FMS. These operational rules can be changed according to the output quantity of the FMS. Additionally, based performance criteria were also considered in that developed algorithm as several decision makers are unlikely to consider several criteria of equimportance. [17] has stated that the decision-making process consists of various activities such as collection of information for decision making; appealing the decision-making activity; invoking the decision; evaluation of alternatives and finally implementation of decision. Their research work consists of the effect of response time variation towards the performance parameters of FMS like make span performance, routing flexibility, mean flow time, etc. were studied. The various decision-making approaches are mentioned in this paper. Six different situations based on the above approaches of decision making were outlined. Such situations were simulated using various computer simulation tools and results were obtained by varying the response time. Finally, the graphical representation of this above study is done and accordingly results were displayed.

From these above papers on decision making techniques it was found out that the simulation was done at different levels of routing flexibility i.e. by varying the RF at various levels the different parameters were studied. Hence the routing flexibility has a significant effect on FMS performance. [18] studied the different levels of RF on FMS and concluded the effects of RF on different system criteria i.e. makespan, lead time and machine utilization. [19] has outlined the concept of full routing flexibility which refers to the combination of flexible alternative machines along with the flexible alternative operation sequences. The literature concentrates on the effects of RF on the operational control of FMS like part entry selection, alternate operation selection and alternate route selection.

[20] proposed a real-time methodology for minimizing the mean flow time in FMS under the conditions of full routing flexibility in FMS. A simulation methodology is adopted for minimizing the mean flow time among the alternate routes by using a simulation tool ARENA. A model is designed using various blocks using the ARENA simulation software. The various blocks are the boxes of different sizes that represent different logic. At the end, the boxes are connected using the connector lines which show the flow of entities through the system. Finally, performance parameters i.e. the mean flow time and the machine utilization is calculated and the conclusions are drawn accordingly. The findings from the study as seen in ARENA stated that for part 2 the waiting time and the WIP is maximum while for part 1 it is minimum, while the machine utilization for machine 2 is maximum amongst all other machines for a 4 machine, 3-part type model which when simulated for 100 parts.

III. BACKGROUND AND MOTIVATION

This section deals with the detailed analysis of a real-time problem and the framing of the problem resulting in the generation of a problem statement. The primary aim of the developing such type of trouble lies in the motivation that was the primary reason behind conducting this inquiry. The primary fact of undergoing such research lies in the fact that outlines the troubles confronted by most of the low to medium scale industries. The industries that lack automation in their manufacturing facilities faced serious problem relating to the client demands, lead time and machine use. The primary cause behind such type of problems lies in the improper implementation and employment of manufacturing systems and improper selection of the machines to process the jobs. It occurs due to the wrong utilization and selection of resources, lack of proper process planning, gaps in data flow and lack of trained personnel. The answer to such problems lies in the automating the resources and installation of such machines which will be extremely flexible and user friendly to operate and by investing in such a manufacturing system where there will be consolidation among the various resources such that a tranquil flow of information will take space in such organizations. In order to incorporate the several resources between a manufacturing system, there should be a proper selection of the material handling equipment like that of conveyors, robots, AGVs, etc. which can be managed with the implementation of FMS. This research study centered on the implementation of FMS to these industries by submitting an FMS problem similar to the situations faced by these industries and simulation of its solutions for the real-time FMS problems and reasoning out the issue on them. The problem statement is composed in accordance with the problem environment. The problem environment is of a simple FMS environment where some jobs are to be delegated to a pool of machines in such a fashion that the objective functions are optimized. The surroundings are well accommodated for a batch production process where the parts are to be constructed for a mid- variety and mid variety production range. The berth is projected as if it is a real-time problem where there are hazards of several types of uncertainties that are running in the shop floor like urgent job arrivals, machine breakdown, etc. The FMS problem statement just makes an imprint of the virtual FMS environment where the jobs come and start loading in the machines that is answered by implementing any proactive decision- making approaches and about emergency conditions like urgent job arrivals are also met. Certain reactive decision-making approach is employed to tackle such cases. After framing of the problem certain assumptions are formed which are common for FMS problems. 80 % of such assumptions are advisable for real time problem in industries, but not more than that.

A. Problem Statement;

A FMS consists of 11 jobs and 6 machines which are distributed in three stations as S1 which consists of 2 machines, S2 with 2 machines and S3 with 2 machines respectively. Two AGVs are there for material handling and a load/unload station is there. The details about the number of operations for each job are shown below: - J1= 3 operations, J2= 3 operations, J3= 4 operations, J4= 4 operations, J5= 5 operations, J6= 5 operations, J7= 2 operations, J8= 3 operations, J9= 2 operations, J10= 2 operations and J11= 2 operations. The various decision-making approaches are implemented and the mean flow time, mean job waiting time and average utilization is calculated. There are also certain emergency cases of urgent job arrival J12 with 2 operations after the completion of 100 minutes. The reactive decision making is gone through to keep the alterations. The details about the number of operations along with their processing time is shown in Table I. With acknowledgment to the Table I. The TPT stands for the total processing time, which is a sum total of all the processing times for a particular job. The dimensions of all the times are in proceedings as noted before. The shift time is taken to be 8 hours, i.e. 480 minutes.

The Fig.2 shows the layout of the virtual FMS shop floor consisting of two AGVs. The line diagram on which the AGVs are represented shows the path that is to be followed by the AGVs for the transport of the jobs from station to station. There are 6 machines which are divided into three stations and before each station there is a material handling robot for loading and unloading of the jobs. There is the provision of an Automated storage and retrieval system (AS/RS) that acts as an automated inventory for jobs storage. A load and unload station there to load and unload the jobs coming to and from the AS/RS. The mannequin is created by using ARENA software. The jobs are allocated to the machines based on the various decision-making approaches and the consequences are calculated for this system using ARENA software. The total shift time to be accepted to solve and simulate the problem is 8 hours.

Table I Shows The Details About Various Jobs And The Processing Time For Each Of Them. All The Values Are In Minutes.

JOBS	TOTAL OPS.	1	2	3	4	5	TOTAL PROCESSING TIME
J1	3	40	50	60			150
J2	3	40	55	54			149
J3	4	60	45	48	45		198
J4	4	40	50	50	40		180
J5	5	40	45	45	65	50	245
J6	5	35	45	55	55	52	243
J7	2	70	75				145
J8	3	95	90	75			260
J9	2	75	80				155
J10	2	85	90				175
J11	2	100	85				185
J12	2	88	80				168

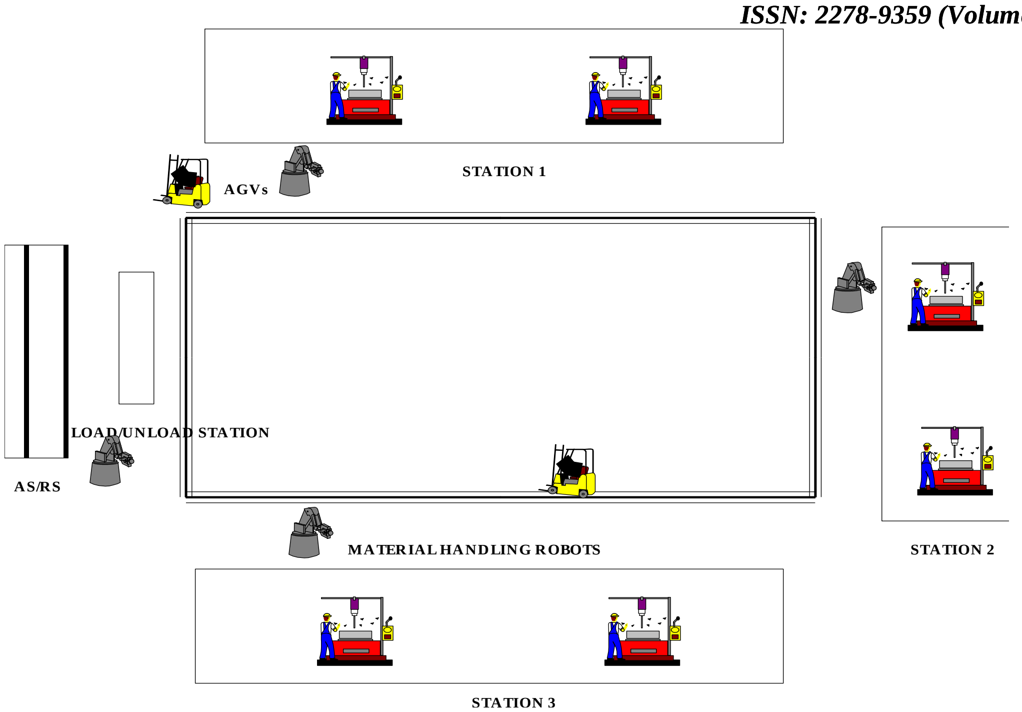

Fig. 2 The schematic layout of a virtual FMS environment as studied in the problem.

Drawing up the objective functions;

Owing to the high capital investment in installing an FMS it is naturally expected by the management or owner to attain an optimal machine utilization and current time. This can well be accomplished by taking minimization of MFT, minimization of MJWT. of the parts and maximization of machine utilization. Hence our aim is to reduce MFT, JWT and maximize machine utilization of the arrangement as a consequence of which the objectives can be achieved easily. Now formulating objective functions for decision making based on the stated aims: -

Min MFT

s.t.

$Q > 0, n > 0$

Min MJWT

s.t.

$w > 0, n > 0$

Max U

s.t.

$t > 0, T > 0$

Nomenclature;
MFT: - Mean Flow Time
MJWT: - Mean waiting time of job
U: - Mean utilization
Q= Processing time
n= No. of jobs
w = waiting time of job
l= lateness
t= operating hours
T= shift hours

Calculating the objective functions;
MFT= Ci / n where Ci= Total flow time
MJWT= W/ n where W= Total job waiting time
U= t/T

Certain assumptions which are taken as follows: -

- All the machines can treat all types of jobs, i.e. the arrangement is fully elastic.
- The sum of time required for processing the job in each machine is equal.
- All job is unity.
- There is no delay in raw materials.
- Each part order has only one part type with individual due date for each part.
- At a time, only one part order will be executed on each machine.
- All the processing time is deterministic and preselected.
- Each part type is processed by a predetermined sequence.
- One AGV can carry only one part at a time.

Hence, from the objective functions, it is very well understood that this is a multi-objective optimization problem out of which the two objectives are minimized and one is maximizing function. The process is solved by using ARENA software. The summarized procedure to be embraced for the problem is shown as under.

B. Summarized Procedure;

The routine to be succeeded on using the ARENA software is as follows: -

1. Initially the decision is to be adopted regarding the methodology that is to be adopted for processing the jobs in the machines. It can be explained that as all the machines are flexible in treating all the types of the jobs the decision requires to be taken regarding job processing which will be done operation wise i.e. allocating a task to a machine for its one operation and for next operation of the job to the next car or job wise i.e. all the operations for a job are processed in one machine and finally the job gets out as finished product. The problem is solved and the results are simulated using both the methodology and accordingly the decision is taken.
2. Then after the priority decisions regarding the job allocation to the machines are considered based on various proactive decision approaches at the input buffer to the machine.
3. The tasks are processed at the machines.
4. At the output buffer to the machines certain emergency level decision (if any) is taken like urgent job arrivals, tool failure, etc. Certain reactive decision-making approaches are employed to tackle such cases of modifications. Such type of cases is encountered in dynamic scheduling problem.
5. Ultimately, the objective function values are estimated and the optimized output is set up.
6. The same trouble is solved again and the objective functions are found out, but without applying any such decision-making technique. Here in this case the jobs are administered to the machines randomly, i.e. without using any priority sequencing rules.
7. The problem is solved for one more time by considering certain response time entailed in decision-making in order to observe the effect of the response time on the performance parameters of FMS. Response time is the time taken by the decision maker to take decisions.

9. The answers are finally plotted graphically and comparison is created between them.
10. The determination is made accordingly.

IV. METHODOLOGY

This section deals with the detailed methodology that is adopted to solve this real-time FMS problem. The trouble that is acquired for study is of an FMS environment where the various decision-making approached are used to solve the problems. As mentioned in the previous chapter the problem is worked out using both the decision-making approaches as well as without using these approaches and finally the results are compared. Before going through the various decision-making approaches to a real-time problem, the theory behind such process needs to be experienced.

This theory behind the decision-making process that is needed for the proper discernment of the procedure is examined here in particular. The decision-making process as identified earlier is a very difficult activity and it calls for a diversity of projects. The total procedure of decision-making involves taking the right decision at the correct time for the proper shop floor control of the FMS. As FMS are highly flexible systems the (RF) Routing Flexibility, value of the systems decides the degree of flexibility of the FMS. When the value of RF is 1 it means only one alternative machine is available other than the automobile where the task is already loaded for processing the task. If the value is 2 then 2 more alternative machines are available other than the automobile where the task is already loaded for processing the job and so along. When RF is full means, it indicates that all the jobs can be sworn out in all the machines, i.e. all the machines are equally flexible to serve all sorts of work. Here in our problem we have regarded the outcome of decision making under the event of full routing flexibility of FMS. As referred to in Fig.3 the entire decision- making flow diagram is outlined. The initial pace is the real-time decision which depends on the dynamic scheduling problem like making sudden changes in Master production schedule (MPS). The following step is proactive decision making that is answered in the planning stage. Here in this step the decision is required whether to swear out the job by viewing all the operations separately or by acquiring all the operations as a whole for a single task. It too dispenses with the appropriate machine and tool selection decisions as per the business demand. Then at the machine input buffer the decisions regarding the allocation of the tasks to the machines is managed. Certain sequencing rules are followed for that like FCFS, SPT, etc. for the job allocation to the machines and accordingly the sequencing decisions are required. This phase is named as a proactive sequencing decision phase. Then later the job is allocated to the machines where the processing of character takes place.

At the output buffer to the machine the finished or semi-finished jobs arrive where the decision is taken, that is to weather reallocate the semi-finished task to the next machine or to transport the finished task to the AS/RS based on the task type and purpose. Reactive dispatching decision making is done at the output buffer of the machine. In dynamic programming problem, certain emergency conditions like that of urgent job arrival, tool failure, car breakdown, etc. when happens the reactive decision is implemented to tackle such situations. In such events, alternative machine allocation is performed based on various dispatching rules like MINQ i.e. Minimum queue in the input buffer and MWTQ i.e. minimum waiting time in queue. At long last, the optimized output is set up. This phase can be likewise called as the emergency decision phase.

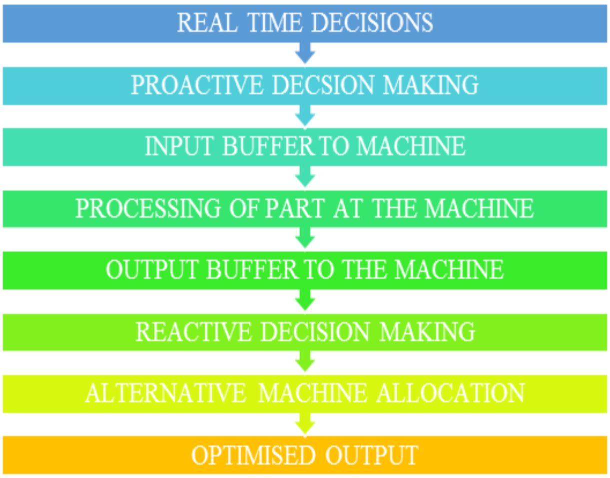

Fig.3 Decision making process flow diagram for FMS

A. Classification of Decision-Making Approaches;

Decision-making consists of various activities like collection of shop floor data, appealing the decision-making activity, evaluation of available alternatives and finally the implementation of the same. The decision-making process can be further subdivided into various approaches. They are: - (a) Real time decision making, (b) proactive decision making, (c) reactive decision making and (d) pre-active decision making. The entire decision-making process is a time dependent process. Time takes on a key role in the decision-making process to hold station. Hence, it can be put forward that the decision-making process is a function of time as it requires a certain measure of reaction time for all of these bodily processes to hold home. Real time decision is depending on the dynamic scheduling problem such as sudden changes in the Master Production Schedule (MPS). These decisions take place quickly without any time delay. In proactive decision making where the decision- making process is appealed or called before the happening of the activity and the execution is executed as shortly as the action takes place. Such type of decision is based on the planning level. The determination regarding the type of sequencing and dispatching rules to be followed are taken in such cases and based on this the allocation of the tasks to the machine is done. Normally such decision is read at the input buffer to the machine. Certain cases where to use such approach are as follows:

- When it is assured that an activity which requires decision making is going to occur.
- The start time of the activity is concisely known to the production managers.

There is another decision- making technique which is referred to as reactive decision-making technique where the decision-making process is appealed at the time or after the happening of the activity just as a reaction to it. The execution of the decisions will take place afterwards. It is also called an emergency decision-making phase. Such cases of decision-making are used in any emergency conditions, i.e. in cases of machine breakdown, urgent job arrivals, tool failure, etc. Some dispatching rules like MINQ and MWTQ are followed and accordingly the relocation of the partially completed jobs to the available alternative machines is done based on it. Normally such decisions are taken at the output buffer of the machine. The conditions where the reactive decision-making approaches are applied are as follows:

- When the production managers are ignorant of the state of affairs of the occurrence of the action which requires decision- making or it can be brought up to as any unexpected activity that is taking place in the shop floor.
- Their occurrence time is unknown to us.
- No probabilistic prediction of the occurrence of activity is there.

Pre-active decisions refer to the prognostication that is depending upon the market survey and that includes customer demands. Essentially, it's the probabilistic demand function. Here in such process the occurrence of the future activities is predicted with certain probabilities and the decision is taken accordingly in advance. This research work does not centre on such type of decision-making techniques and such operations are exempted from work.

B. Decision-Making Analysis;

The decision-making process is a time dependent process. Thus, as a matter of fact various times are linked up with these operations. The times which are associated are:

1. The time at which data regarding decision making is collected which can be stated as data collection time i.e. denoted as T_{dat}.
2. The time at which activity is occurring or stated as the activity happening time, which can be denoted as T_{hap}.
3. The time at which the decision appealing activity takes place which is denoted as T_{appl}.
4. The time at which execution of the decision takes place and can be denoted as T_{exe}.

The entire decision-making process is a function of these four times only. The various combinations of these times result in the propagation of several examples which are shown in this part. Some restraints are required to be taken in this decision-making process such that it can be managed effectively without keeping the system idle. These restraints are considered in each and every case that is generated from studying the process.
Certain constraints to be utilized in the decision-making analysis can be submitted below: -

- The information needed for the decision making can be collected either before the invoking in the decision-making process or at the time of it. It can be stated as: $T_{dat} \leq T_{appl}$.
- The execution of the decisions will be done after or at the time of the decision appealing activity. It is done because the decision cannot be executed before the appealing of the decision which is practically impossible. It can be stated as: - $T_{appl} \leq T_{exc}$.
- The condition where the time required for assembling data for the decision making is greater than the time needed for the decision appealing activity to hold home. It signifies the arrangement causes to wait idle after the invoking of the decision for the data aggregation process to take place which is a great red ink due to increase in the non-productive time. Therefore, the condition: -$T_{dat} > T_{appl}$ is not seen in our subject field as it will be scaling down the efficiency of the system by increasing the non-productive time.

Hence, by combining those three conditions we arrive at an equation that: - $T_{dat} \leq T_{appl} \leq T_{exc}$. The above condition should be followed strictly while analysing the different cases of the decision making. First of all, the data will be collected and then accordingly the decision process is appealed otherwise chances are there for a wrong decision to take place and finally the process is executed afterwards without making the system idle. The time at which the data for the decision-making process was taken is known as a data system, whereas the fourth dimension at which the decision-making process is executed is known as the execution system.

As expressed in previous sections the decision-making process in FMS is really a complicated and a very difficult process. It requires a detailed analysis of the state of affairs and also a huge amount of danger is incurred in this operation. Hence, some response time is needed for the entire operation to go forward.

As referred to as earlier that the decision-making process is a function of time, hence a thorough analysis of the time needs to be made out in analysing the process and its impression on the FMS control. By making out this analysis different cases are generated and examined in detail along with their mathematical aspects. In the Table.2., the different cases of the different decision-making approaches are summarized in detail and accordingly the analysis is portrayed. The analysis is well outlined stating the position of both of the data system as good as the execution system. The mathematical expressions for various approaches are outlined here in this table for the various approaches. The real-time FMS problem is resolved using these various approaches, i.e. by implementing the various instances of the decision-making to the FMS problem at various steps and seeing the answers accordingly.

(A) CASE-I;

$T_{dat} = T_{hap} = T_{appl} = T_{exc}$ (Real time decision-making)

The above is the real-time control decision making arrangements. This one is an ideal case where it expresses that the decision-making process takes place without any time delay. It does not require any response time in decision making as all the results are real time. Such conditions are ideal cases and can be considered as a reference condition to consider the diverse examples of decision making, but in reality, the real-time decision takes some small sum of time. Essentially, the situation as described here in this case is a case when there is any sudden change in MPS that depends upon the customer demand or customer change in society. The decisions are implemented quickly without any time delay because the management cannot afford to spend more time on this instead of spending the time on the shop level.

(B) CASE-II;

$T_{dat} < T_{appl} < T_{hap} = T_{exc}$ (Proactive decision-making)

This one is a case of proactive decision making. Here both the information and the execution system are not real-time processed; both of them are entailed with certain response time to it. It occurs when certain periodic updating of information system or phased development of the data system are taking home. In such instances, the data aggregation and decision execution should be managed effectively for better decision making. It is enforced in this real-time FMS problem initially when the decision is to be taken whether to swear out the jobs in the machines operation wise or job wise under the conditions of full routing flexibility.

(C) CASE-III;

$T_{dat} = T_{appl} < T_{hap} = T_{exc}$ (Proactive decision-making)

This one is also a case of proactive decision making. In such instances, the decision making is appealed before the happening time of action. The data system occurs in actual time as no time delay is there, only the execution system occurs with certain response time because of the matter of fact that it uses certain optimization techniques in decision making. Usually, it takes place at the machine input buffer where the tasks are allotted to the machines based on priorities assigned to them. Various priority sequencing rules can be employed in such cases for the allotment of jobs to the machines. It takes some time to understand the data and figure out the problem by execution the proactive decisions. Some optimization techniques like AI, expert arrangements, etc. can also be used for reaching at the optimal solution which ensures better decision making.

(D) CASE-IV;

$T_{dat} < T_{hap} = T_{appl} < T_{exc}$ (Reactive decision-making)

This one is a case of reactive decision making. Here it is a limited case in reactive decision-making where one can see that both the data system and the execution system has some response time meant in it. Such type of cases in decision-making finds well its application in the billet of tool failure where the loser of the tool can be forecast by using Taylor tool life equation as per the data that is gathered from the workshop level. As shortly as the failure happens the decision-process is appealed and some response time is implied for the determination to execute, i.e. either to reallocate the job to the alternative machine or in certain cases the job is pulled in to wait in the same machine until a new tool is not installed. The determination is conducted depending upon the shop floor situations like the queue in the alternative machines, number of alternative machines and availability of the material handling equipment. Hence, due to consideration of several ingredients like the investments, best available alternative selection, etc., some response time is counted. The information gathered is also done manually or through programmed functions.

Table II Summarizing Different Cases Of Decision Making Along With Their Analytic Thinking And Mathematical Equations

CASES	DECISION APPROACHES	DECISION MAKING ANALYSIS		MATHEMATICAL REPRESENTATION
		DATA SYSTEM	EXECUTION SYSTEM	
Case-I	Real time	Real time	Real time	$T_{dat} = T_{hap} = T_{appl} = T_{exc}$ Response time (R)= 0
Case-II	Proactive	Response time present	Response time present	$T_{dat} < T_{appl} < T_{hap} = T_{exc}$
Case-III	Proactive	Real time	Response time present	$T_{dat} = T_{appl} < T_{hap} = T_{exc}$
Case-IV	Reactive	Response time present	Response time present	$T_{dat} < T_{hap} = T_{appl} < T_{exc}$ $T_{exc} - T_{dat} = R > 0$
Case-V	Reactive	Response time present	Real time	$T_{dat} = T_{hap} < T_{appl} = T_{exc}$
Case-VI	Reactive	Real time	Response time present	$T_{dat} = T_{hap} = T_{appl} < T_{exc}$ $T_{exc} – (T_{dat} / T_{appl}) = R > 0$

(D) CASE-IV;

$T_{dat} < T_{hap} = T_{appl} < T_{exc}$ (Reactive decision-making)

This one is a case of reactive decision making. Here it is a limited case in reactive decision-making where one can see that both the data system and the execution system has some response time meant in it. Such type of cases in decision-making finds well its application in the billet of tool failure where the loser of the tool can be forecast by using Taylor tool life equation as per the data that is gathered from the workshop level. As shortly as the failure happens the decision-process is appealed and some response time is implied for the determination to execute, i.e. either to reallocate the job to the alternative machine or in certain cases the job is pulled in to wait in the same machine until a new tool is not installed. The determination is conducted depending upon the shop floor situations like the queue in the alternative machines, number of alternative machines and availability of the material handling equipment. Hence, due to consideration of several ingredients like the investments, best available alternative selection, etc., some response time is counted. The information gathered is also done manually or through programmed functions.

(E) CASE-V;

$T_{dat} = T_{hap} < T_{appl} = T_{exc}$ (Reactive decision-making)

This one is a reactive decision-making case. Here in this case the data system occurs by response time, but the execution system occurs in substantial time. The decision appealing process takes place after the happening time of the action. The cause for that is because of certain decisions like that of selection of the machine from the number of available alternatives by applying certain dispatching rule under the event of urgent job arrival that is submitted after the activity happening time itself.

(F) CASE-VI;

$T_{dat} = T_{hap} = T_{appl} < T_{exc}$ (Reactive decision-making)

This is also a case of reactive decision-making process. The implementation of the decision may hold some amount of time, which is shouted as the reaction time in decision making as described in former parts. For this reason, only it is greater than the decision appealing time. The movements of machine breakdown are encountered under such type of events. When sudden cases of the machine breakdown are observed, then the data is at once collected from the shop floor and the decision process is appealed simultaneously without any time delay. Some dispatching rules like MINQ are used for assigning the partially processed job or the job in the queue to the alternative machines. The execution is taking place afterwards.

The grounds for the necessity of response time in execution system can be denoted to as: -
(a) Decision regarding the selection of the best among the availability of various alternatives
(b) Coordination with the management in the decision making
(c) Cost concerns in decision making.
Such elements need to be studied because under certain cases of machine breakdown the capital incurred by the management is very high and some cost cutting needs to be done in decision-making cases.

C. Detailed Solution;

The problem is solved by using ARENA simulation software. ARENA software creates a virtual manufacturing environment for the calculations and simulation of the real-time problems. The ARENA is developed by the Rockwell automation in the year 2000. ARENA the user determines the program by creating a current diagram that goes from left to right of the ARENA screen. The flow diagram consists of modules or boxes of different figures and sizes that are utilized to stand for various processes. Connector lines are used to connect the corners which represent the direction of flow of entities. In that respect is also a provision of animation design tool bar where the user can design the animation depending upon their demands. In one case the model is complete and the animation run is reversed on the flow of entities can be very easily kept throughout the model as in the case of real time industrial problems. At the terminal of the simulation the detailed report is brought forth which can be kept and studied for understanding the decision systems. To solve the problem for this paper work ARENA software of version 14.50.00002 is used. A brief introduction about ARENA needs to be made to clear cut understanding of the process that is occurring in the ARENA working environment. Fig. 4 shows the work screen for ARENA software. The white space on the screen is the place for making ARENA models. The simulation run is also done as shortly as the model is complete and run option is turned on. Towards the left of the screen there is provision of specifying the basic processes like to create, dispose, process, etc. These are the main elements of the model.

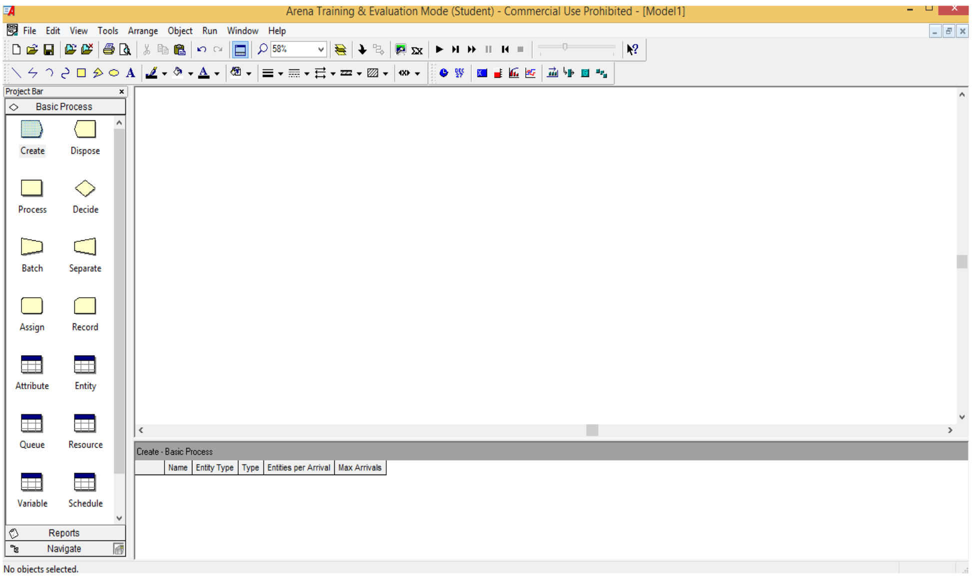

Fig.4 Screen showing arena work environment

The detailed solution to the problem can be evidenced as by the implementation of the various decision-making cases that are mentioned previously in this chapter. Out of the cases as given above, the problem is solved using Case-II, Case-III and Cases- V. It is because as referred to the problem statement there are no such cases of tool failure and machine breakdowns. The real-time decision is also not considered as because such decisions are happening while designing the process plans of the system and that completely depends upon the changes made by the customer after placing the order. Such type of decisions is not shop floor decisions and with this problem only shop floor decisions are encountered.
Directly utilizing the diverse instances of decision making to the problem;
CASE II; $T_{dat} < T_{appl} < T_{hap} = T_{exc}$ and CASE-V; $T_{dat} = T_{hap} < T_{appl} = T_{exc}$
Case-II is a case of proactive decision-making which is executed before the entry of job to the machine input buffer. As all the machines are equally flexible it is decided whether to assign the jobs to different machine operation wise or considering all operations as a whole for a single job. Hence, the problem is solved by studying the job operation wise and implementing decision making to the system by using the ARENA software. The proactive decision is taken in such scenario that is the jobs are assigned to the machines using the sequencing rule SPT i.e. Shortest processing time. Agreeing to this rule the task with the minimum processing time for a special mental process is assigned to the pool of machines first and then the subsequent assignment takes place.

On that point are certain instances of emergency job arrivals i.e. J12, which is tackled by using the reactive decision-making rule as described in case V. The task is delegated to the machine operation wise based on the rule MINQ i.e. Minimum queue in the input buffer. A simulation model for taking the job operation wise and engaging all the operations as a whole is shown in the Fig.5.

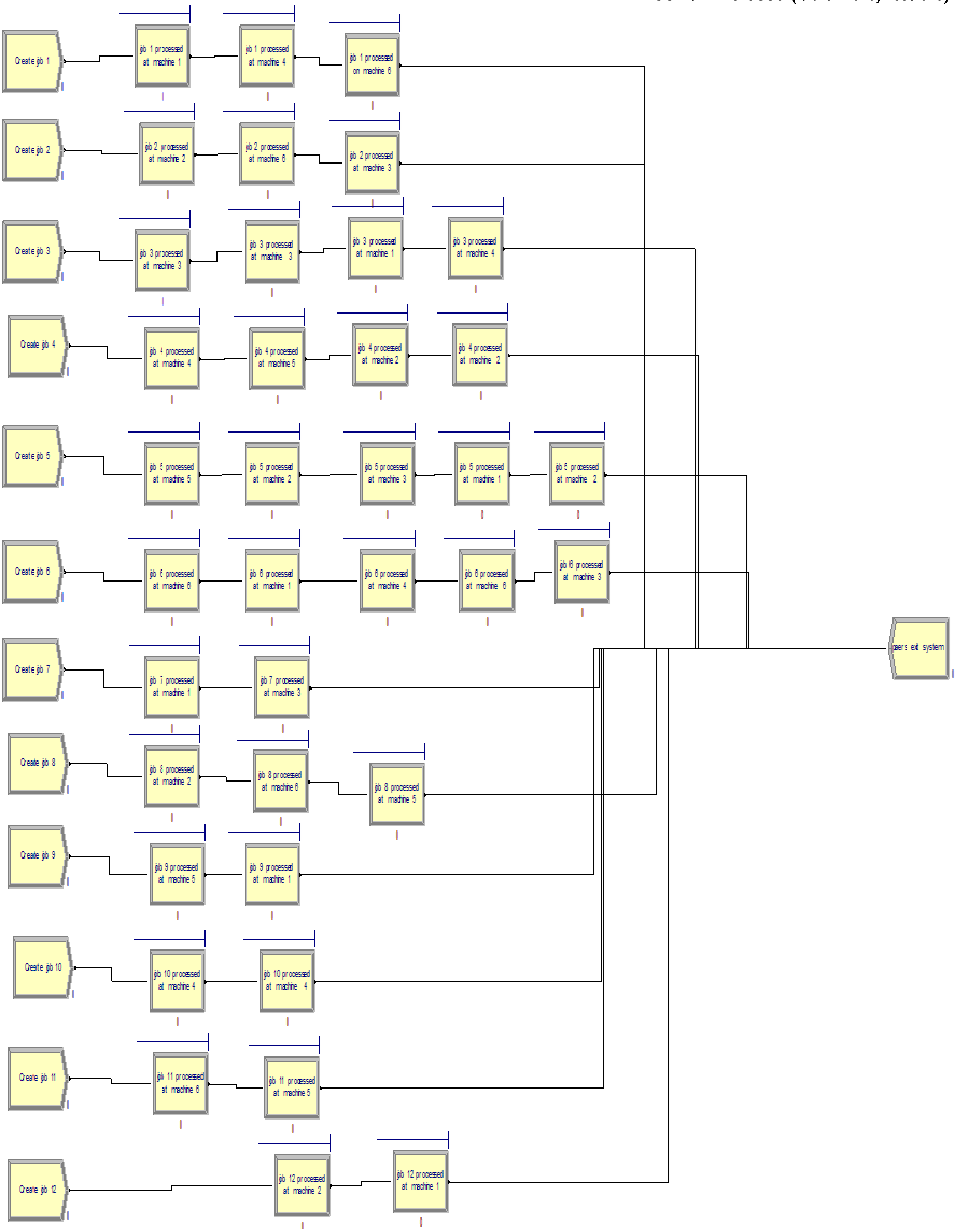

Fig.5 ARENA model for considering the job operation wise

CASE III; $T_{dat} = T_{appl} < T_{hap} = T_{exc}$ and CASE V; $T_{dat} = T_{hap} < T_{appl} = T_{exc}$

This problem is solved by considering all the operations for the job as a whole. Proactive sequencing decision making process is taken at the input buffer to the machine, i.e. how to allocate the jobs to the pool of machines. Sequencing rule SPT is used. In case -v it is a case of reactive decision-making. Thither is a example of urgent job arrival J12 after the completion of 100 minutes and dispatching rule MWTQ i.e. minimum waiting time in queue is used to allocate the respective job to machine 6. The model is shown in Fig.6.

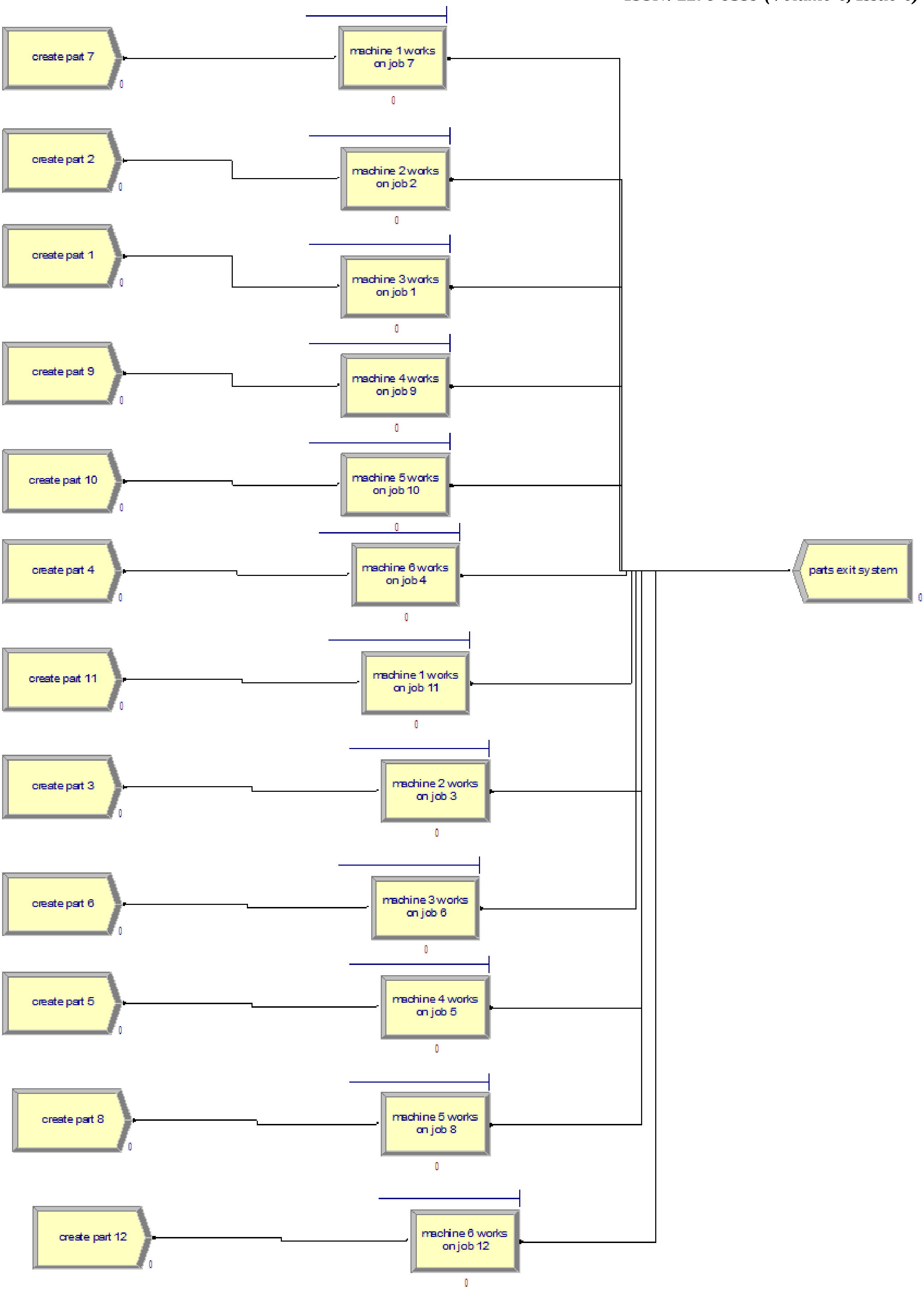

Fig.6 ARENA model for considering the job as a whole instead of considering them operation wise.

The problem is solved without any such decision-making approaches. Here in such problem the jobs are allotted to the pool of automobiles in a random succession. The model is shown in Fig.7.

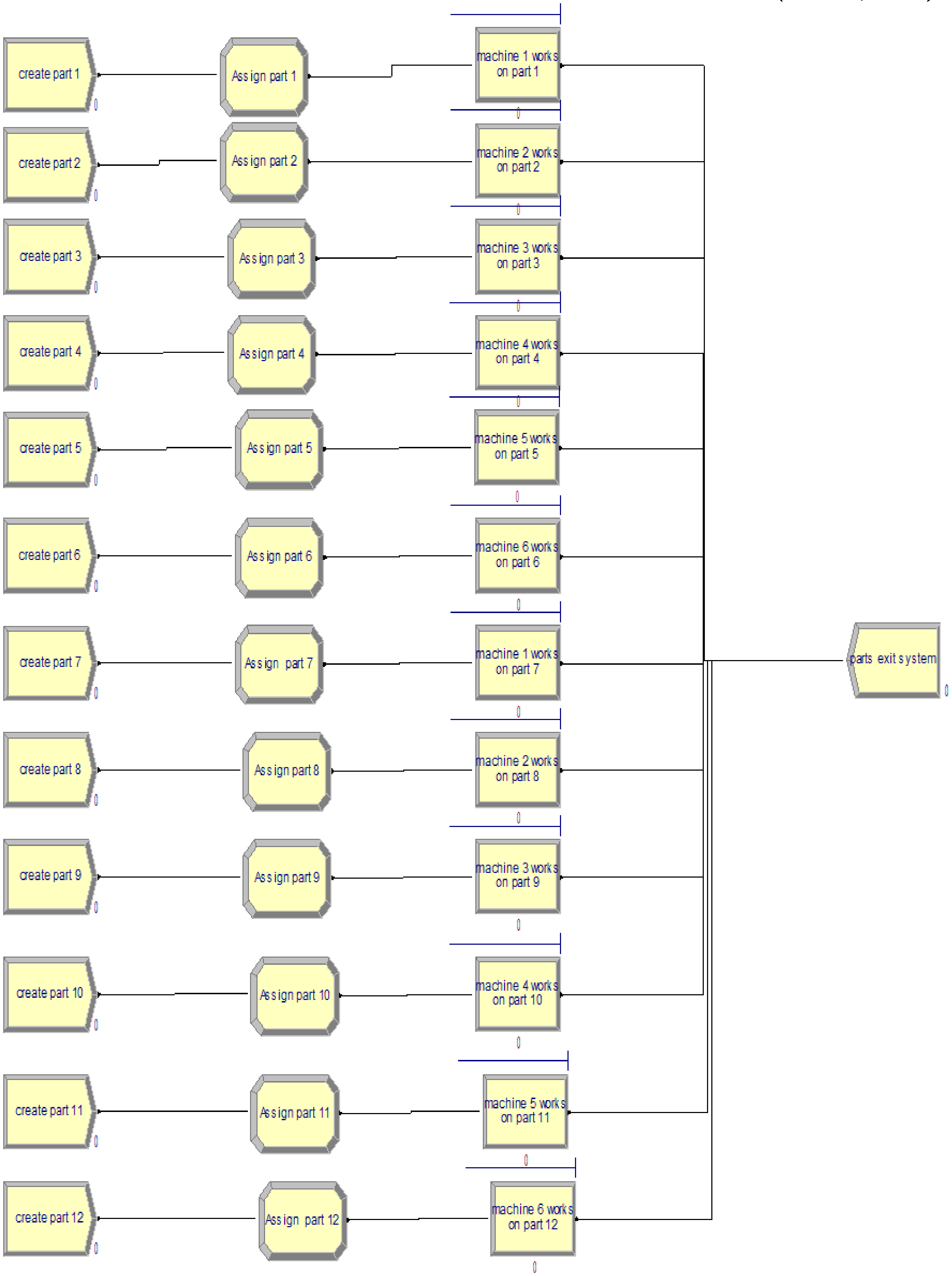

Fig. 7 ARENA model for the problem without considering any decision-making approaches.

The FMS problem is immediately solved by considering certain response time that is entailed in decision making. It is done to see the effect on the results. The response time that is usually taken is around 1 to 2 units of time for the problem. The ARENA model is presented in the Fig.8.

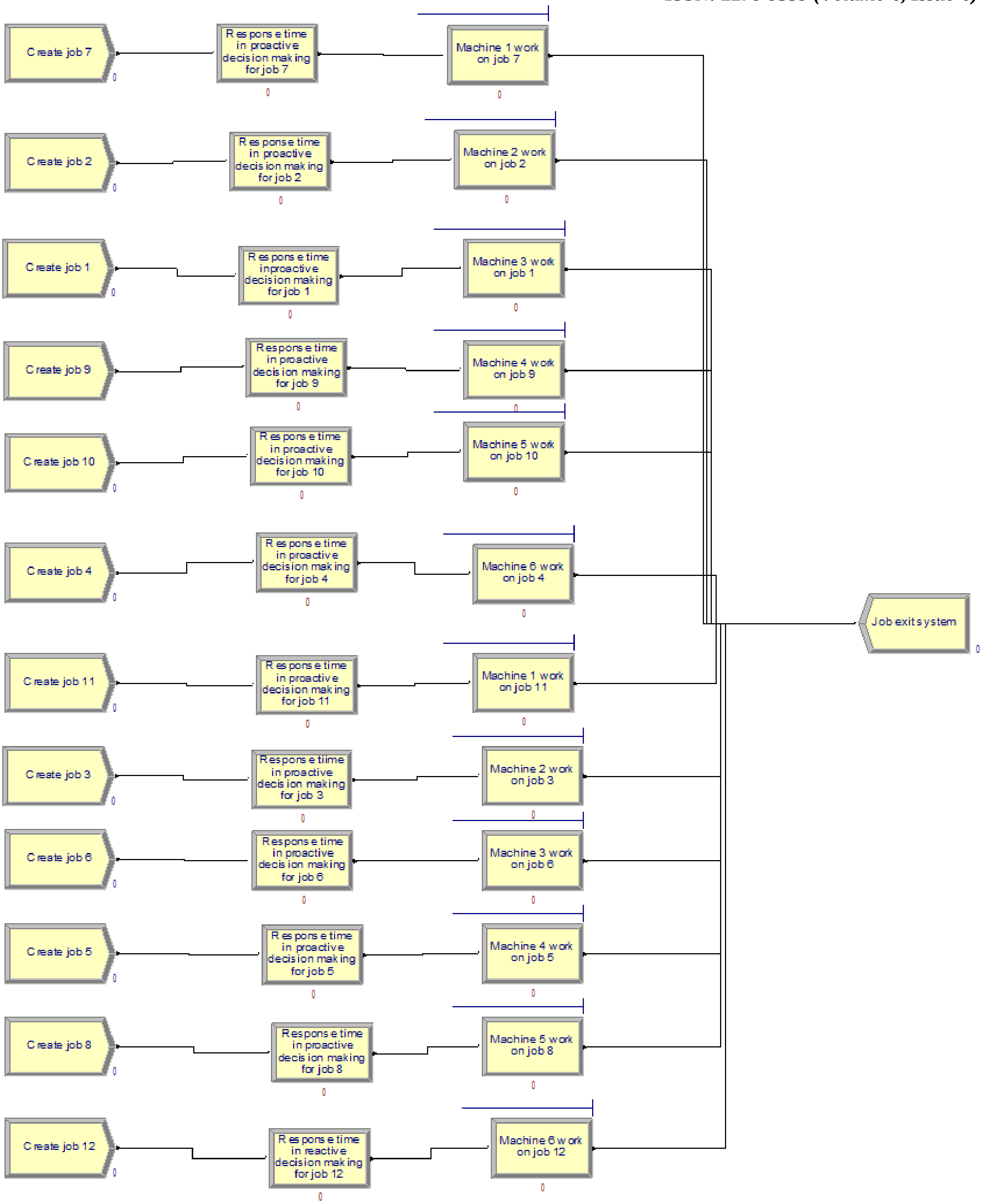

Fig.8 ARENA model for the problem by considering response time in decision-making approaches

Working out by considering the job operation wise using ARENA simulation model the following solutions are ground with reference to ARENA model in Fig.5. The shift duration is selected to be 8 hours, i.e. 480 minutes. The results are: - (using CASE II and CASE V of the decision-making approaches) MFT= 327.75 minutes, MJWT= 139.33 minutes and AU= 78.16 %

Hence the values that are found from this approach shows that about 140 minutes of time are spent in job waiting, i.e. it will be more than 2 hours in an 8-hour shift. The upshot of this is instantly found in MFT where the value is found to be really high. Hence the decision is read not to use such type of attack on the shop-floor as it will increase the MFT and MJWT resulting in very low FMS performance. Such type of conclusions is a proactive decision-making approach.

Computing the overall values of the objective functions by studying the decision-making approaches and solving the problem by viewing all the operations as a whole for a job the following answers are found using decision making patterns with reference to ARENA model in the Fig. 6.; - (using CASE III and CASE V of the decision-making approaches)

MFT= 267.25 minutes, MJWT= 79.5 minutes, AU= 77.6%

Solving the same problem without using any such decision-making techniques with reference to ARENA model in Fig.7.:-

MFT= 284.83 minutes; MJWT= 97.08 minutes; Avg. utilization of machines= 77.6 %

Puzzling out the same problem by seeing just about response time entailed with decision-making, we got the following answers with reference to ARENA model in Fig. 8.: -MFT= 271.58 minutes, MJWT= 83.83, AU= 77.6%

The detailed analysis of the results is done in the next section, i.e. the results and discussion. The graphical representation and the comparison between the terminations are shown and at the conclusion the conclusion is made accordingly.

V. RESULTS AND DISCUSSION

This section deals with the detailed analysis of the results. The observation made from the results is represented on a graph and the findings are highlighted. The core findings of this paperwork are mentioned and discussed in this chapter. The purpose of the various decision-making approaches to the FMS and its consequence on the real-time problem is considered and broken down. The result of the advances on the objective function, i.e. the operation parameters of FMS are focused on the detail. First of all, the results that is found by using ARENA is focused in detail.

Initially the results that are found out by the using decision-making approaches to the real-time FMS problem by processing the job operation wise are mentioned. Therefore, using CASE II (Proactive decision-making); $T_{dat} < T_{appl} < T_{hap} = T_{exc}$ and CASE-V (Reactive decision-making); $T_{dat} = T_{hap} < T_{appl} = T_{exc}$ of the decision approaches to the problem the results that is found with reference to ARENA model in Fig.5.: -

Mean Flow Time (MFT) = 327.75 minutes, Mean Job Waiting Time (MJWT) = 139.33 minutes and Average Machine Utilization (U) = 78.16 %

Total Time	Average	Half Width	Minimum Value	Maximum Value
part 1	340.00	(Insufficient)	340.00	340.00
part 10	265.00	(Insufficient)	265.00	265.00
part 11	250.00	(Insufficient)	250.00	250.00
part 12	363.00	(Insufficient)	363.00	363.00
part 2	244.00	(Insufficient)	244.00	244.00
part 3	365.00	(Insufficient)	365.00	365.00
part 4	358.00	(Insufficient)	358.00	358.00
part 5	478.00	(Insufficient)	478.00	478.00
part 6	447.00	(Insufficient)	447.00	447.00
part 7	185.00	(Insufficient)	185.00	185.00
part 8	355.00	(Insufficient)	355.00	355.00
part 9	283.00	(Insufficient)	283.00	283.00

Fig.9 The details about the flow time of various parts considering the problem operation wise

Scheduled Utilization	Value
machine 1	0.8917
machine 2	0.8500
machine 3	0.7083
machine 4	0.7604
machine 5	0.6771
machine 6	0.8229

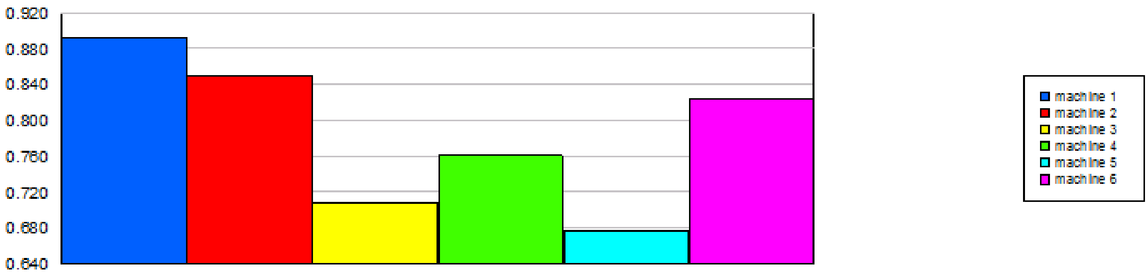

Fig.10 The details about the utilization of all 6 machines considering the problem operation wise for a job

Total Time	Average	Half Width	Minimum Value	Maximum Value
part 1	150.00	(Insufficient)	150.00	150.00
part 10	175.00	(Insufficient)	175.00	175.00
part 11	330.00	(Insufficient)	330.00	330.00
part 12	348.00	(Insufficient)	348.00	348.00
part 2	149.00	(Insufficient)	149.00	149.00
part 3	347.00	(Insufficient)	347.00	347.00
part 4	180.00	(Insufficient)	180.00	180.00
part 5	400.00	(Insufficient)	400.00	400.00
part 6	393.00	(Insufficient)	393.00	393.00
part 7	145.00	(Insufficient)	145.00	145.00
part 8	435.00	(Insufficient)	435.00	435.00
part 9	155.00	(Insufficient)	155.00	155.00

Figure.11 The details about the flow time of various parts using decision making and considering the job as a whole.

Scheduled Utilization	Value
machine 1	0.6875
machine 2	0.7229
machine 3	0.8188
machine 4	0.8333
machine 5	0.9063
machine 6	0.7250

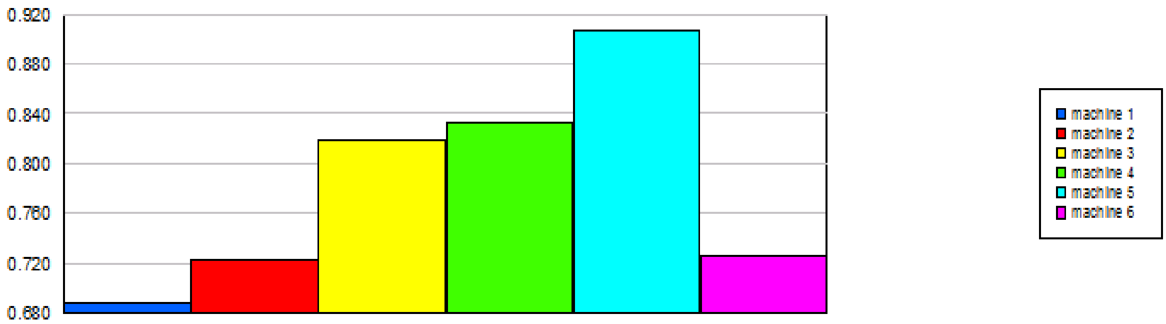

Figure.12 The details about the utilization of all 6 machines by considering decision making and a job as a whole.

The Fig. 9 and 10 shows the detailed report of all the flow time of parts and the scheduled utilization of the machines as obtained from ARENA.

Computing the overall values of the objective functions by taking the determination- making approaches and solving the problem by viewing all the operations as a whole for a job the following answers are found using CASE III (Proactive decision-making); $T_{dat} = T_{appl} < T_{hap} = T_{exc}$ and CASE V (Reactive decision-making); $T_{dat} = T_{hap} < T_{appl} = T_{exc}$ decision making patterns with reference to ARENA model in the Fig..6.: -

MFT= 267.25 minutes, MJWT= 79.5 minutes, U= 77.6%

The Fig. 11 and 12 shows the detailed report of all the flow time of parts and the scheduled utilization of the machines as obtained from ARENA by using decision approach and considering job as a whole.

The order of sequence for this result after using the decision-making tools, i.e. proactive sequencing decisions SPT rule and reactive dispatching decisions MWTQ rule the sequence that is finally generated is as follows: - J7-J2-J1-J9-J10-J4-J11-J3-J6-J5-J8-J12

The real-time FMS problem is resolved without any such decision-making approaches. Here in such problem the jobs are allotted to the pool of automobiles in a random succession. The results of the performance parameters shown with reference to ARENA model in the Fig.7 are as follows: -

MFT= 284.83 minutes, MJWT= 97.08 minutes, U = 77.6 %

The Fig.13 and 14 shows the detailed report of all the flow time of parts and the scheduled utilization of the machines as obtained from ARENA without considering decision approaches. The order of sequence for this effect that is found without using any such decision-making tools can be stated as: - J1-J2-J3-J4-J5-J6-J7-J8-J9-J10-J11-J12

Total Time	Average	Half Width	Minimum Value	Maximum Value
part 1	150.00	(Insufficient)	150.00	150.00
part 10	355.00	(Insufficient)	355.00	355.00
part 11	430.00	(Insufficient)	430.00	430.00
part 12	411.00	(Insufficient)	411.00	411.00
part 2	149.00	(Insufficient)	149.00	149.00
part 3	198.00	(Insufficient)	198.00	198.00
part 4	180.00	(Insufficient)	180.00	180.00
part 5	245.00	(Insufficient)	245.00	245.00
part 6	243.00	(Insufficient)	243.00	243.00
part 7	295.00	(Insufficient)	295.00	295.00
part 8	409.00	(Insufficient)	409.00	409.00
part 9	353.00	(Insufficient)	353.00	353.00

Fig.13 The details about the flow time of various parts without using decision making.

Scheduled Utilization	Value
machine 1	0.6146
machine 2	0.8521
machine 3	0.7354
machine 4	0.7396
machine 5	0.8958
machine 6	0.8563

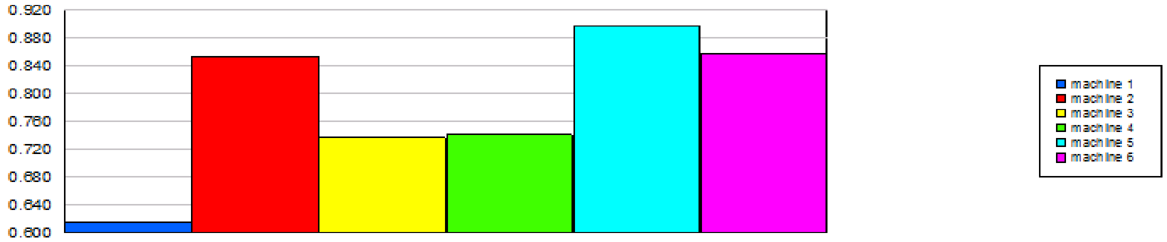

Fig.14 The details about the utilization of all 6 machines without using decision making approaches.

The real-time FMS problem is immediately solved by considering certain response time that is entailed in decision making. It is executed to determine the upshot on the terminations. The response time that is usually taken is around 1 to 2 units of time for the problem. The outcomes of the performance parameters established with reference to ARENA model the figure. 8. are shown as follows: -

MFT= 271.58 minutes, MJWT= 83.83, U= 77.6%

The consequences for the MFT and U is shown the Fig.15 and 16.

A. Graphical Representation;

The graphical assessment of the results is shown in this division. The graph is plotted based on the results that is found by applying diverse approaches and comparisons of the outcomes is done last.

The Fig.17 shows the effect of using the various approaches on the Mean Flow time (MFT). It is distinctly noted that solving the problem using the decision-making approach provides most optimized results than by solving the problem without applying any such attack. When, certain response time is considered in decision-making, then there is no such remarkable change in the outcomes.

Total Time	Average	Half Width	Minimum Value	Maximum Value
part 1	151.00	(Insufficient)	151.00	151.00
part 10	176.00	(Insufficient)	176.00	176.00
part 11	186.00	(Insufficient)	186.00	186.00
part 12	349.00	(Insufficient)	349.00	349.00
part 2	150.00	(Insufficient)	150.00	150.00
part 3	348.00	(Insufficient)	348.00	348.00
part 4	181.00	(Insufficient)	181.00	181.00
part 5	401.00	(Insufficient)	401.00	401.00
part 6	394.00	(Insufficient)	394.00	394.00
part 7	331.00	(Insufficient)	331.00	331.00
part 8	436.00	(Insufficient)	436.00	436.00
part 9	156.00	(Insufficient)	156.00	156.00

Fig.15 The details about the flow time of various parts by considering response time in decision-making.

Scheduled Utilization

	Value
machine 1	0.6875
machine 2	0.7229
machine 3	0.8188
machine 4	0.8333
machine 5	0.9063
machine 6	0.7250

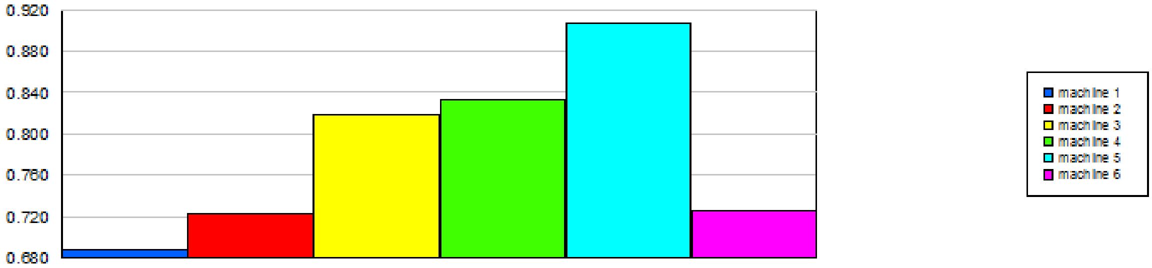

Fig.16. The details about the utilization of all 6 machines by considering response time in decision-making.

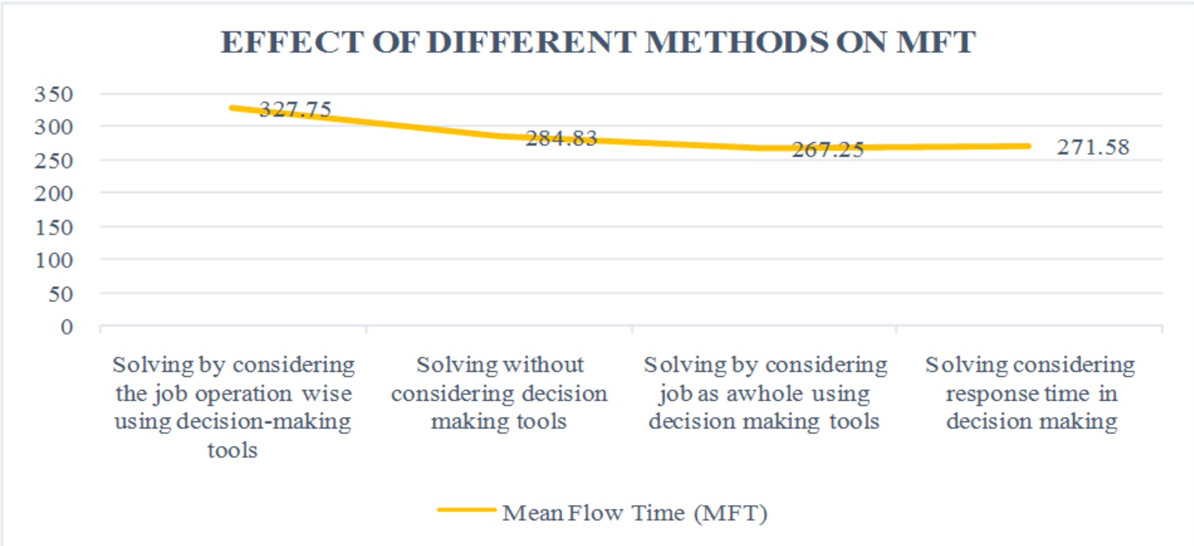

Fig.17 The Graphical representation of the MFT that is obtained by various methods.

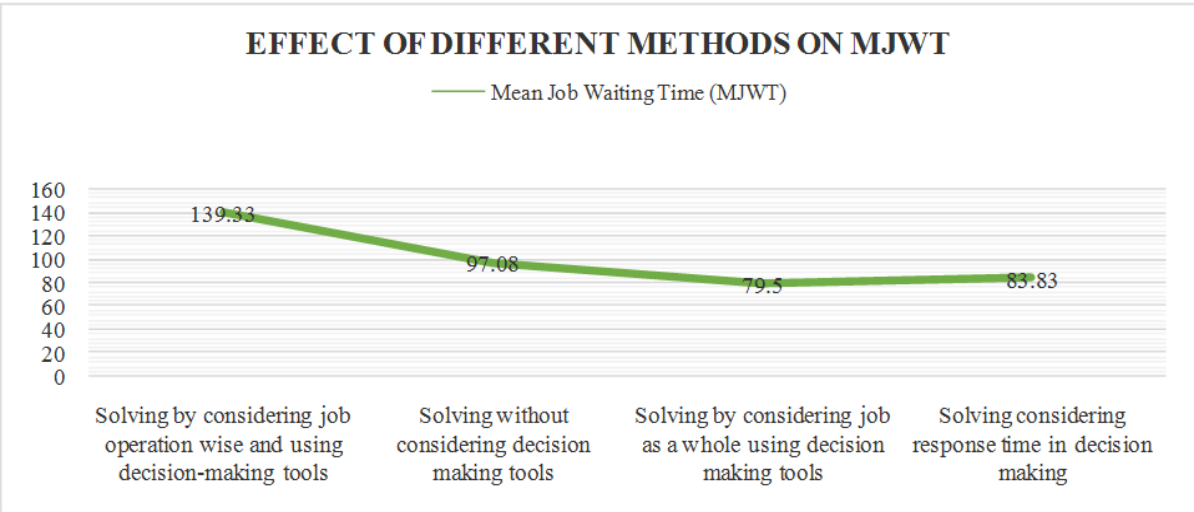

Fig.18 The Graphical representation of the MJWT that is obtained by various methods

The Fig.17 shows the effect of using the various approaches on the Mean Flow time (MFT). It is distinctly noted that solving the problem using the decision-making approach provides most optimized results than by solving the problem without applying any such attack. When, certain response time is considered in decision-making, then there is no such remarkable change in the outcomes. Fig.18 imprints the effect of the different methods on the MJWT of FMS. The utilization of methods like decision-making tools to the FMS problem gives more optimized results as compared to the solving the problem without utilizing any such instruments. The response time entailed to decision-making when considered does not experience any remarkable impact on the outcomes. Fig.19 shows the effect of the various methods on the mean machine utilization (U) when the shift hours are taken as 8 hours. The value of U is expressed in percent.

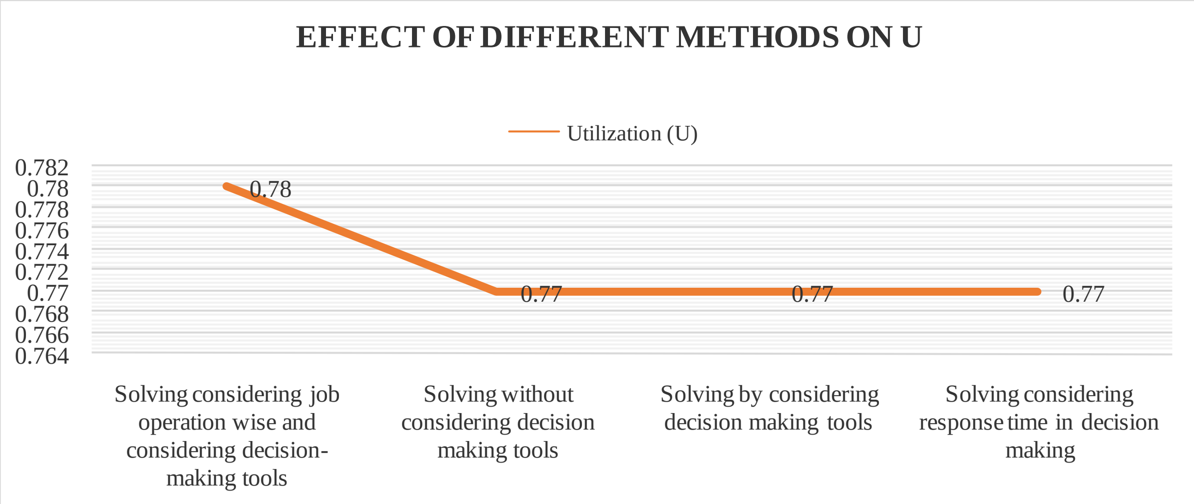

Fig.19 The Graphical representation of the U that is obtained by various methods.

VI. CONCLUSION

This paper gives a detailed analysis about various decision-making approaches that can be used for the shop floor control of the FMS. The stairs of the decision-making process which consists of actions like the data collection, appealing of the conclusion, evaluation of various alternatives and then finally execution of the decision is analyzed in particular. The diverse approaches of decision making are classified as per their operation and accordingly the detailed analysis is practiced. From the analysis six different instances are generated by exchanging the different values of the times entailed with the decision process. The reaction time associated with these activities is explained and a mathematical expression is also formulated for that. The various cases of the decision-making are implemented in the real-time FMS problem and the effect of it on the performance parameters are studied using ARENA simulation software. It was noted from the results that solving the problem using the various decision-making tools gives most optimized results than solving it without using any decision tools. The future scope of this might include the usage of different hybrid AI to the decision-making problem for a real time FMS application to get at more optimal solutions. Certain other performance parameters like production rate, makespan, etc. can also be analyzed by using these optimization tools. Some other cases of shop floor disturbances like machine failure, tool failure can also be considered to see the effect of decision-making techniques on them.

REFERENCES

[1] A. A. M Emin Erdin, “Implementation of an overall design of an FMS,” 8th International Conference Interdisciplinary in engineering, pp. 185-192, 2015.
[2] K. Stecke, “Design, planning, scheduling and control problems,” Annals of Operations Research, pp. 3-12, 1984.
[3] X. L. C. Y. Z. Binghai, “A heuristic algorithm to batching and loading problems in a flexible manufacturing system,” Int J Adv Manuf Technology, p. 903–908, 2004.
[4] G. J. G. a. J. Slomp, “Towards an Integration of Process Planning and production planning and control for FMS,” The International Journal of Flexible Manufacturing Systems, pp. 5-17, 1999.
[5] A. J. .. P. K. J. .. I. P. Singh, “An integrated scheme for process planning and scheduling in FMS,” Int J Adv Manuf Technology, p. 1111–1118, 2005.
[6] S. P. Djamila Ouelhadj, “A survey of dynamic scheduling in manufacturing systems,” J Sched, p. 417–431, 2009.
[7] S. R.A.Dudek, “The lessons of flow shop scheduling research,” Operations research society of America, 2016.
[8] A. S. R. a. V. Subramaniam, “Reactive Recovery of Job Shop Schedules – A Review,” Int J Adv Manuf Technol, pp. 756-763, 2002.
[9] D. M. L. B. G. Frizelle, “Disturbance Measurement in Manufacturing Production Systems,” In Proceedings of ASI, 1998.
[10] Y.-C. C. a. S. C. H.-Y. Huang, “A dynamic system model for proactive control of dynamic contol of full load manufacturing chains,” International Journal of Production Research, p. 2485–2506, 2009.
[11] A. Zaied, “Quantitative models for planning and scheduling of FMS,” Emirates Journal for Engineering Research, pp. 11-19, 2008.
[12] J. R. a. D. S. B. Shints, “Multicriteria dynamic scheduling methodology for controlling a flexible manufacturing system,” International Journal of Production Research, p. 3457–3472, 2004.

[13] J. A.V.Savkin, "Optimal distributed real time scheduling of flexible manufacturing networks modelled as hybrid dynamical systems," Robotics and Computer Integrated Manufacturing, p. 597–609, 2008.

[14] M. A. J. a. S. S. M. Houshang Darabi, "Finite Automata Decomposition for FMS control and scheduling," IEEE transactions on systems, man and cybernics, 2003.

[15] P. U. a. S. Srivastava, "Improving a Flexible Manufacturing Scheduling using Genetic Algorithm," Journal of Academia and Industrial Research (JAIR), pp. 146-150, 2013.

[16] F. T. S. C. a. H. K. Chan, "Dynamic Scheduling for a Flexible Manufacturing System – The Preemptive Approach," Int J Adv Manuf Technol, pp. 760-768, 2001.

[17] R. B. H. K. C. Felix T.S. Chan, "The effect of responsiveness of the control-decision system to the performance of FMS," Computers & Industrial Engineering, pp. 32-42, 2014.

[18] F. T. S. Chan, "The effects of routing flexibility on a flexible manufacturing system," International Journal of Computer Integrated manufacturing, p. 431–445, 2010.

[19] P. C. M.D. Byrne, "Real-time operational control of an FMS with full routing flexibility," International Journal of Production Economics, pp. 109-113, 1997.

[20] N. S. a. P. Amrik Singh, "A Real-time Methodology for Minimizing Flow Time in FMS with full routing flexibility," International Journal of Advanced Mechanical Engineering, pp. 185-192, 2014.

