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Solving flexible flow-shop problem using hybrid multi criteria Taguchi based computer simulation model and DEA approach

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Abstract

In this paper, an efficient approach for production line policy and planning problem is presented. Here, all of activities are simulated by incorporating learning effects using historical data. After validation process, "what if analysis" is carried out for different scenarios derived from the Taguchi method. Several performance measures estimated for all simulation runs. Then for such homogenized multi-criteria problem, data envelopment analysis (DEA) is used to select the preferred policy. In order to show the applicability of the proposed approach, the data for a series production line is used. Results show that the proposed approach could help managers to identify the preferred strategy considering and investigating various parameters and policies. Finally this study introduces an integrated multi-criteria approach for optimum maintenance policy and planning. In this algorithm, many relevant parameters cover any uncertainty using statistical distribution. We used DEA as a multi-criteria decision making techniques to seek more appropriate assignment. Therefore, using a combination of computer simulation model and an attribute-deductive tool such as DEA, a near optimal solution can be achieved.

Keywords: Flexible flow-shop, computer simulation, Data Envelopment Analysis (DEA), Taguchi method.

1- Introduction

Since economic prosperity of manufacturing factory is related to manufacturer's ability in identification of customers' needs and production of fast and inexpensive products. To achieve prosperous production is the products result that is produced with profitable method and its sales. Beside current competitive market situation is a significant problem for manufacturing factories that increase production variety and flexibility considered in all operations. Flexibility is significant strategic change for manufacturing system in the organizations technology. The past investigations are shown that making correct politics and applying principle technology determine Organization's Competitive ability in future. As a consequent, flexible system is based on technology that organization has been able to achieve best opportunity in competition field of manufacturing. Flow-shop scheduling is one of the major problems in many manufacturing systems(Gheisariha et al, 2020).Flexible manufacturing system (FMS) (under the routing and machine flexibility) is made of a group of processing work stations with highly automated cellular manufacturing. Sophisticated and interconnected factors affect the FMS performance and FMS design and processing includes the above factors.

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On the other hand, the problem of finding the optimal configuration of a Flexible manufacturing system (FMS) is a complex stochastic non-linear problem which includes both physical and operating system characteristics (Tansel et al. 2014). Hybrid flow shops have widespread applications in real-world manufacturing systems. Most of extensions of the flow shop scheduling problems are Np-Hard and they are expensive to achieve the optimal solution in large scale problems (Kong et al, 2019).

In a practical production process, uncertainty commonly arises due to the difficulty of knowing exact information of facilities and jobs beforehand, In order to improve processing quality and customer satisfaction of manufacturing systems in uncertain environments (Fu et al, 2020). Simulation technique is one of the most important and applicable tool for complexity of manufacturing systems. The simulation and optimization integration can maximize the FMS performance. It can be defined as the process of finding the best input variable values from among all possibilities without explicitly evaluating each possibility. The objective of simulation optimization is to minimize the resources spent while maximizing the information obtained in a simulation experiment and optimization strategy to provide feedback simulation Model on progress of the search for the optimal solution that is displayed in figure 1 (Carson et al. 1997).

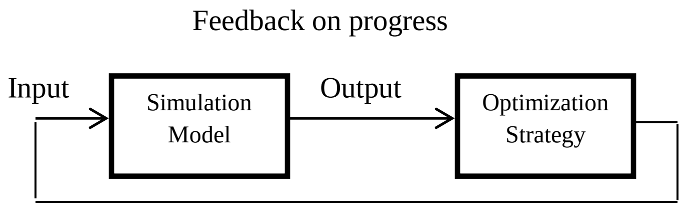

Fig 1. A simulation optimization model

In this research, by using simulation method investigate the optimization of the research production line by using multi criteria Taguchi and DEA approach for flexible flow shop problem to select best scenarios that originated from design of experiments (DOE).

2- Literature review

In a research by Hasani & Hosseini (2020), proposed a flexible flow shop scheduling problem with machine-dependent processing stages. This problem is described with a numeric example, and its parameters and decision variables are defined. Then a linear mathematical model is developed to solve the problem in small-sized scales. The result indicated that the solution approach can provide proper alternatives for managers in different various situations.

In a research by yuan et al (2020), investigated a flow shop group scheduling problem where both sequence-dependent setup time between groups and round-trip transportation time between machines are considered. The objective is to minimize make span. They first developed a mixed integer linear programming model and then proposed an efficient co-evolutionary discrete differential evolution algorithm. The results showed that the proposed method based on co-evolutionary discrete differential evolution algorithm is effective in solving the studied problem.

In a research by Zheng et al(2020) investigated A cooperative coevolution algorithm for multi-objective fuzzy distributed hybrid flow shop, in their research addressed a multi-objective fuzzy distributed hybrid flow shop scheduling problem with fuzzy processing times and fuzzy due dates. To optimize the fuzzy total tardiness and robustness simultaneously, a cooperative coevolution algorithm with problem-specific strategies is proposed by reasonably combining the estimation of distribution algorithm and the iterated greedy search. The effect of the key parameters on the performances of the proposed algorithm was investigated by Taguchi design of experiment method. Comparative results and statistical analysis demonstrated the effectiveness of the proposed algorithm in solving the problem.

In a research by Chaouch et al(2019) investigated A novel dynamic assignment rule for the distributed job shop scheduling problem using a hybrid ant-based algorithm, The objective of this research was to minimize the global makes pan over all the factories. Since the problem was NP-hard to solve. A hybrid ant colony algorithm combined with local search to solve the Distributed Job shop Scheduling Problem was proposed. A novel dynamic assignment rule of jobs to factories was also proposed. The Taguchi method for robust design was adopted for finding the optimum combination of parameters of the ant-based algorithm. To validate the performance of the proposed algorithm, intensive experiments were carried out on 480 large instances derived from well-known classical job-shop scheduling benchmarks. The results illustrated the algorithm can process up to 10 factories, also the results proved the efficiency of the proposed algorithm in comparison with others.

In a research by Li et al (2019), investigated about the Energy-efficient hybrid flow shop scheduling problem, the relative importance of objectives is seldom considered in the previous works. In this study, Energy-efficient hybrid flow shop scheduling problem with total tardiness, make span and total energy consumption is addressed, in which the third objective has lower importance than other ones.

In a research by Xu et al (2019), investigated about the Many-objective flow shop scheduling optimization with genetic algorithm based on fuzzy sets, Experimental results showed that genetic algorithm based on the relative entropy of fuzzy sets can solve may-objective benchmark functions and many-objective flow-shop scheduling problems.

In a research by Apornak et al (2018) presented an experimental study of a manufacturing system in order to maximize performance based on response surface modeling and optimization of response variables based on multi objective optimization, In order to response surface modeling mixed level design consider for eight factors in the study, Response surface methodology is applied successfully in analyzing the effect of process parameters on different levels. The first order mathematical models in terms of manufacturing system are developed based on experimental results. The results illustrated that the optimum objective function is obtained when the levels of the factors are in zero code of them.

In a research by Sharma & Jain(2017) presented a simulation-based experimental study on the effect of routing flexibility and sequencing rules on the performance of a stochastic flexible job shop manufacturing system with sequence-dependent setup times while considering dynamic arrival of job types. Six route flexibility levels and six sequencing rules are considered for detailed study. The performance of manufacturing system is evaluated in terms of flow time related and due date–related measures. Results revealed that routing flexibility and sequencing rules have significant impact on system performance, and the performance of a system can be increased by incorporating routing flexibility. The results shows that when flexibility exists, earliest due date rule emerges as a best sequencing rule for maximum flow time, mean tardiness and maximum tardiness performance measures.

In a research by Rane et al, (2015), systematically identifies and unfolds the consequential parameters by systematic review. The aim of this Research is to develop a novel relegation of literature on Assembly Line and to ameliorate the performance of conveyance assembly line utilizing Lean implementation and Simulation approach. Further a mathematical model is developed considering the effect of number of resources, Break time, Downtime of machines and Absenteeism. An authentic world case study is done for a period of one year in a reputed conveyance assembly manufacturing plant. Results: Analysis of research on Assembly Line Balancing and optimization within many different industrial scenarios has been done her. This paper contributes to subsisting domain by relegating and comparing the expedient for input data, constraints and methodology utilized. It has been relegated into five heads. An authentic world case study is done in reputed Company. Cycle time was reduced from 110 seconds to 100 seconds. Conclusion: It is arduous to perform the experiments like Design of Experiments (DOE) in intricate manufacturing systems. Simulation sanctions us to test different concepts, sundry options without having to build prototypes. A case study done in Conveyance assembly shows the consequentiality of simulations to amend its performance measures.

In a study by Sharma & Ajai, (2015) present a simulation experimental study on the effect of routing flexibility and sequencing rules in order to analyze the performance of a stochastic flexible job shop manufacturing system with sequence-dependent setup times, Six route flexibility levels and six sequencing rules are considered in this study, Results demonstrate that routing flexibility and sequencing rules have significant impact on system performance.

In a research by (James & Chen, 2015) demonstrate the value of the simulation optimization approach for practical applications, the approach includes a simulation model for performance evaluation, for optimization each scenarios used a genetic algorithm, and an expedition technique via an optimal computing budget allocation. In this study presents a simulation optimization approach for a hybrid flow shop scheduling quandary in a semiconductor back-end assembly facility. The intricacy of the quandary is predicated on demand and supply characteristics. Demand varies with orders characterized by different quantities that is determined product types, and relinquishes times and Supply varies with the number of flexible manufacturing routes; a simulation optimization approach is adopted due to the intricate and stochastic nature of the quandary.

The aim of paper by Cordero, et.al, (2015) is to vigilant DEA practitioners about the precision of their estimates under the presence of endogeneity. For this, first we illustrate the endogeneity quandary and its causes in engenderment processes and its implicative insinuations for the efficiency quantification from a conceptual perspective. Second, utilizing synthetic data engendered in a Monte Carlo experiment we evaluate how different calibers of positive and negative endogeneity can impair DEA estimators. They concluded that, albeit DEA is robust to negative endogeneity, a high positive endogeneity level, i.e. the existence of a high positive correlation between one input and the true efficiency level, might partialness astringently DEA estimates.

In a research by Rui et.al, (2014), concentrate on the relationship between operations-predicated variables (categorically, engenderment speed, scrap rate and maintenance speed) and the manufacturing cost. These variables conventionally engender antithesis influences on the variable cost and the fine-tuned cost. An optimization approach is compulsory to determine the optimal values of the operational variables for minimizing the average cost. First, a discrete-event simulation procedure is designed for describing the stochastic engenderment environment and for evaluating the settings. Then, an optimization approach predicated on the ordinal optimization philosophy and particle swarm optimization is utilized to probe in the perpetual space of the operational variables. In this process, the optimal computing budget allocation technique is applied so as to planarity utilize the computational resource and potentially preserve the computational time. Determinately, numeric computations are conducted for verifying the efficacy of the proposed algorithm. Sensitivity analysis and discussions are withal presented.

In the process of production planning, it is important to define the quantity of production that to be loaded to the production line, the decision is mainly based on avoiding late completion of contracts and minimizing costs. In the research by Long Che, et.al, (2014) investigate to explore the impact of lot size and its interaction with operator competence on manufacturing system performance utilizing simulation technique. A simulation-predicated factorial design is conducted for study, during the simulation process, two inadequacies regarding simulation of operator learning curves and simulation experimental analyses are identified in the subsisting literature which obstructs precise analysis. The application of a three-parameter hyperbolic function is suggested in this study to simulate the practical trend of operator learning curves which is often overlooked in the subsisting literature. In addition, the inopportuneness of the subsisting approach for simulation experimental analysis is identified; hence an incipient approach is applied to give a more comprehensive analysis in this study.

AL-Refaie,et al,(2014) implemented simulation and truculent formulation technique using DEA method to amend the performance of the emergency department in a Jordanian hospital. Four replications of main interest, including number of nurses, average waiting time in system, nurses' utilization, and number of accommodated patients and ten scenarios for nurse assignment configurations are proposed utilizing the concept of nurses' flexibility in cellular accommodation system. Simulation is run for one month period (672 h) each with 10 replicates for each of the ten scenarios then by using DEA formulation best scenarios determined in the research.

In a research by Azadeh, A., et al, (2013), an incipient approach for maintenance policy and orchestrating quandary is developed. First, maintenance activities are simulated by incorporating learning effects. Engenderment and maintenance functions are estimated utilizing historical data. Then, simulation is carried out for different scenarios which are amalgamations of periodic maintenance and different policies. Several outputs including machines and operators' availability, reliability, efficiency and queue length are computed. The proposed methodology can avail decision-makers to determine the optimal scenario for orchestrating maintenance activities. Three different policies were considered for determining the most efficacious one to optimize the orchestrating. Optimal maintenance policies aim to provide optimum system reliability and safety performance at the lowest possible maintenance costs. An operational unit which has six machines was investigated as an authentic case. Due to the Taguchi OA, 81 scenarios were yare and simulation was performed in AweSim. Determinately, these scenarios were ranked by the DEA and the best scenario was culled.

The purport of the paper by Yildiz, (2013) is to develop a hybrid optimization algorithm by integrating positive properties of the Taguchi's method as a design of experiment method to the differential evolution algorithm for minimizing the engenderment cost associated with multi-pass turning quandaries. The proposed approach is applied to optimize two case studies for multi-pass turning operations to illustrate the efficacy of the proposed algorithm in machining operations. The results illustrated that the proposed hybrid algorithm is more efficacious than pervious algorithm that proposed like particle swarm optimization algorithm, hybrid harmony search algorithm, hybrid genetic algorithm and etc.

Azadeh et al. (2010) used integrated fuzzy data envelopment and computer simulations to presents optimize operator location in cellular manufacturing systems. A computer simulation model, which considers sundry operators layout, is developed. The output data is fuzzified for considering more information from computer simulation report, FDEA is utilized to assess simulation alternatives in sundry levels of skeptically. In integration, in their study, an integrated FDEA simulation approach was purposed for the optimization of operator allocation in their case. The inputs of their study were determined: Average lead time of injunctive authorizations, average waiting times of authoritative ordinances, and number of operators, and average of operator/machine utilization and annual numbers of consummated components were defined as outputs. Both inputs and outputs were derived from the simulation of CMS by considering sundry layout systems and the data was fuzzified, for ranking and analysis of scenarios fuzzy data envelopment analysis model was utilized. Because of the fact that a DMU with a simple radial efficiency score of one is not always ideal; FDEA ranking of DMUs are clustered by fuzzy C-denotes method. Each of the clusters denotes a degree of desirability for operator allocation (Azadeh, et al, 2010).

In many cases the results of the simulation can be facilely analyzed, but in some cases it is compulsory to consider measures liable to conflict with each other, to interpret the results of the research by Rashed & Dehghan, (2010) seeks to solve a quandary FSMP In such a condition. The quandary is such that the desideratum to find the best solution to a discrete space is a good solution. To find the best solution among the available alternatives (the justification for the answer) and the positive and negative criteria (which are in conflict with each other), this study has utilized data envelopment analysis. Unlike typical cases that only one of the models DEA utilized for ranking, we utilized in this paper coalesced the results of two models is congruous.

In a research by Azadeh, A., et al, (2008) presents an integrated model with computer simulation by using data envelopment analysis and analytical hierarchy process (AHP).The integrated model can be used for determining best scenarios by considering multiple quantitative and qualitative inputs and outputs. Their research based on 3 phases, first, computer simulation in order to verify and validate the model. Second, AHP method for determining the weight of criteria and at the end DEA model is utilized to solve the multi objective model to identify the best scenarios.

In research by Azadeh et al, (2005) an integrated framework for development of the practical optimum JIT design for dynamic engenderment systems. Several factors must be noted to accomplish a practical optimum JIT design through simulation. First, all detailed operations, processes and activities of the system being studied including interacting systems, repairs, maintenance and inspections must be considered and modeled. Second, inhibition, constraints, and dynamic deportment of the system being studied must be considered when designing a practical optimum JIT design. Third, an integrated simulation approach to quandaries of dynamic engenderment systems must be incorporated. The distinct feature of the prescribed approach is accomplished by integration of computer simulation, ANOVA, and dynamic deportment modeling of the authentic system. Consequently, the practical optimum JIT design is practical rather than theoretical because it considers dynamic comportment and circumscriptions of the system being studied.

With reviews in previous literature reviews, it can be concluded that so far no research has been done at the level of flexible systems to select the best conditions. This research has concluded that based on previous studies, using simultaneous simulation methods and envelopment analysis process. By designing different scenarios we can select the best layout In order to achieve the optimal design.

3- The proposed methodology

Modeling the activities of a flow shop problem could be a crucial Np-Hard task. Here due to complexity in analysis and expensive process time for bargaining optimum solution, we offered a simulation based optimization approach. The proposed method presented schematically in Fig. 2.

This figure shows a three phase hierarchical structure for flow shop problem which started by designing an appropriate valid computer simulation model in phase I and followed by design of experiment (DOE) methods for different scenario design in phase II. Here in after scenario analysis is carried out based on different input sets and the derived system performance measures as flow-shop outputs. At phase III one could consider each scenario as a typical decision making unit (DMU) in DEA. Solving such standard DEA model could guide planners to seek the more efficient scenario in job shop scheduling, where there is strict order of all operations to be performed on all jobs.

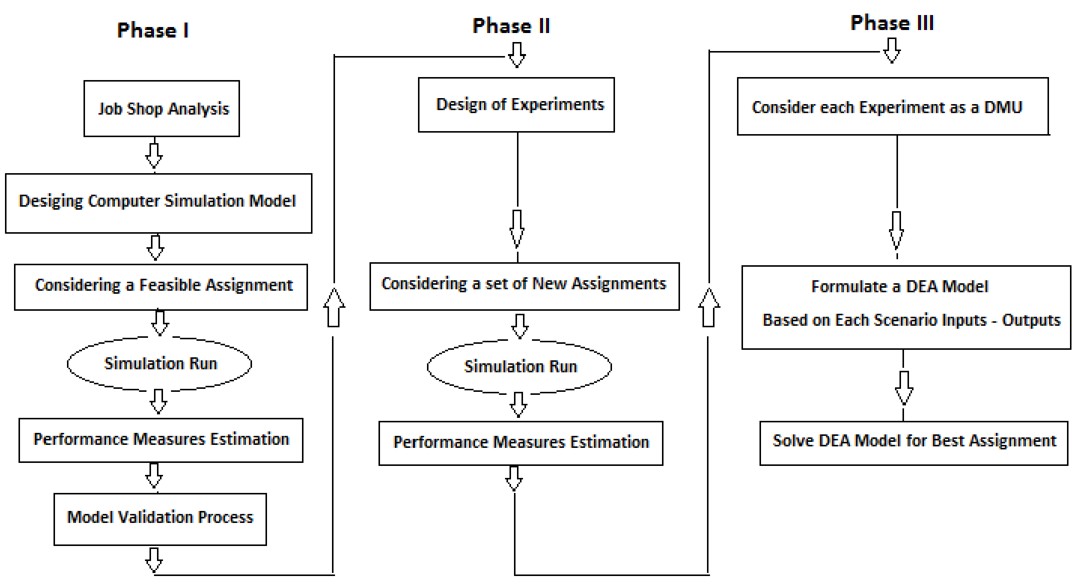

Fig. 2. A schematic view of the proposed method

The distribution functions are fitted to the data and the best one is selected for each data-set. Considering production line and machine and input data, the simulation network is designed using Enterprise Dynamic(ED) simulation. Decision variables are chosen in different policies the combination of these parameters consists several scenarios.

The production line of this research is consist of one source, one Queue that is before two servers, Servers do defined activity on the materials that enter to them, then the material go to the conveyors that is provided after servers and transmit from them to the assembler and by lift truck, the final product go to the sink that is provided in the model. Thus, a multi-criteria method must be applied for handling this problem. In this paper, DEA is used for solving the proposed problem. In the following sections ED simulation, DEA and Taguchi method are described.

3-1- Simulation

Computer simulation has excellent capabilities such as proper description of the system behavior, scenario analysis and forecasting capabilities. Simulation is an attractive tool because it allows generating random variables, which could define the complex behavior of input data for forecasting problems. One of the unique features of this study is development of simulation network for modeling maintenance activities which allow decision-maker to adjust and change the problem parameters easily. By finding the distribution from a set of realistic data, then by using Enterprise dynamic simulate the problems that are originated from the scenario that is created from Taguchi designs. Observation periods in simulation in this study were 100 hours and numbers of observations were 25 times in a separate run simulation method.

According to performance measures estimation in phase I for model validation process the results from calculation illustrated that the validation of model.

3-2- Taguchi design

To critically examine the effects of the factors on the chosen objectives, we used mixed level design for each factor, which are given in Table 1. Each column indicates the different factors and each row indicate the levels of them in table 1. Taguchi design considers the scenarios and analyzes them to find the preferred policy.

3-3- Data envelopment analysis

Data Envelopment Analysis (DEA) is a linear programming based model which evaluates the efficiency of decision making units (DMUs), with multiple inputs and outputs. DEA generates a surface called the frontier that follows the peak performers and envelops the remainder (Charnes, et al, 1978).

In this research it has been created the scenarios in Taguchi design and for identifying the performance of this scenario that the results of them obtained from simulation evaluate by data envelopment analysis, As a matter of fact by using data envelopment analysis it can be find the best scenarios.

4- Results

A case study has been carried out in a medium size industry which is producing various kinds of seats for the freight cars. The company certified by ISO-9000 quality management standard and well equipped with foam injection molding machine. Figure 3 presents a schematic flow of entities through a part of the system. Here final displacement carried by a forklift toward product storage.

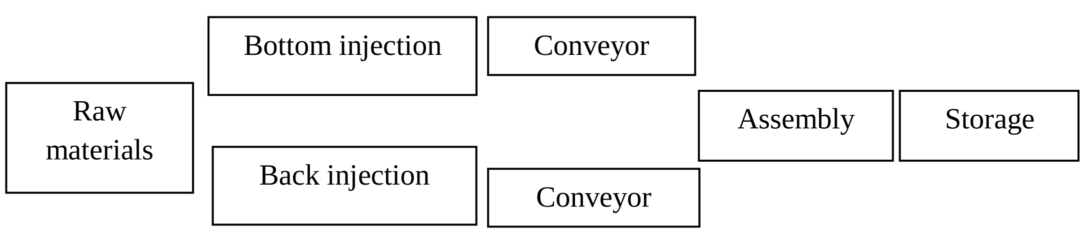

Fig 3. General overview of car seats manufacturing

The main objectives of this study are to find the proper process adjustment to follow the system more efficiently. Here we considered five performance measurements (PFM) as $Y_1, Y_2, ..., Y_5$. One of them for average waiting time of raw materials, two for average injection times, and two for transporter and assembler product outputs. Casual investigation reveals that eight affecting factors or $x_1, x_2, ..., x_8$ can be set at different levels by engineers. They are raw material queue capacity, queue discipline, seat bottom injection setup time, seat back foam injection setup time, two conveyors speed,one assembler cycle time and forklift speed.

In this study Enterprise Dynamics^{TM} (ED)" is applied for object oriented computer simulation modeling. For setting up the simulation model we used observation gathered for a period of four months ended to January 2019. Here system translated using ED atoms and entity flow verified severally to ensure that the simulation model deploys similar behavior as the real world case study.

In order to run the simulation model, different scenarios generated by applying design of experiments. Here, each atom's configuration set based on data gathered from a period of three-month long. In order to generate scenarios, we applied codified value in [-1, 1] interval. Here -1 depicts equivalent code for the lower level and +1 for the higher level. Table 1 presents affecting factors and their relevant levels.

Table1. Factors & levels of the research

Levels	Queue Capacity	Queue discipline	Setup Time SERVER 1	Setup Time SERVER 2	1st Conveyor speed	2nd Conveyor speed	Assembler cycle time	Transporter speed
+1	20	FIFO	Without set up time	Without set up time	1000mm	1000mm	γ(1.86, 149.88)	5m/s
0	25	LIFO	Fixed Setup Time	Fixed Setup Time	1100mm	1100mm	γ(0.93, 149.88)	10m/s
-1	-	-	-	-	900mm	900mm	γ(3.72,149.88)	2.5m/s

Table 2 presents 36 scenarios generated randomly using mixed level design of experiments as well as the mean of simulation results for PFMs. Each simulation run embeds more than 2500 hours long and the first 10% of time cleared to avoid bias on estimation. Each scenario replicated 25 times and simulation output calculated based on arithmetic average.

Table2. Simulation results according to codified scenario setting

Coded Variables								PFMs				
								Queue	**Server1**	**Server2**	**Transporter**	**Assembler**
-1	-1	-1	-1	-1	-1	-1	-1	721.91	93.12	59.23	1986.12	9932.60
-1	-1	-1	-1	0	0	0	0	723.25	93.29	59.34	1982.40	9914.08
-1	-1	-1	-1	1	1	1	1	724.57	93.46	59.45	1978.68	9895.60
-1	-1	-1	-1	-1	-1	-1	0	723.50	93.53	59.27	1981.76	9911.08
-1	-1	-1	-1	1	0	0	0	724.08	93.37	59.42	1980.08	9902.48
-1	-1	-1	-1	1	0	1	1	723.85	93.55	59.30	1980.84	9906.36
-1	-1	0	0	-1	-1	0	1	827.15	103.31	69.25	1733.76	8671.68
-1	-1	0	0	0	0	1	-1	826.98	103.21	69.26	1734.40	8673.96
-1	-1	0	0	1	1	-1	0	826.48	103.03	69.28	1735.28	8678.72
-1	0	-1	0	-1	-1	1	0	86.99	93.63	69.50	1802.00	9012.20
-1	0	-1	0	0	0	-1	1	88.00	93.42	69.13	1809.36	9049.12
-1	0	-1	0	1	1	0	0	92.30	93.76	69.49	1801.24	9008.56
-1	0	0	-1	-1	0	1	-1	80.44	103.12	59.37	1908.12	9542.80
-1	0	0	-1	0	1	-1	0	83.53	103.57	59.47	1903.20	9517.60
-1	0	0	-1	1	-1	0	1	80.08	103.26	59.15	1911.76	9560.64
-1	0	0	0	-1	0	1	0	61.01	103.82	69.40	1728.20	8643.08
-1	0	0	0	0	1	-1	-1	62.67	103.36	69.37	1731.64	8660.80
-1	0	0	0	1	-1	0	-1	61.46	103.49	69.38	1730.60	8655.48
0	-1	0	0	-1	0	-1	1	1032.50	102.93	69.28	1736.00	8682.20
0	-1	0	0	0	1	0	-1	1035.22	103.65	69.26	1731.40	8659.48
0	-1	0	0	1	-1	1	0	1034.60	103.47	69.27	1732.32	8663.64
0	-1	0	-1	-1	0	0	1	940.06	103.39	59.36	1906.56	9535.00
0	-1	0	-1	0	1	1	-1	938.94	103.33	59.27	1908.68	9545.88
0	-1	0	-1	1	-1	-1	0	941.83	103.87	59.38	1903.00	9516.76
0	-1	-1	0	-1	1	0	-1	990.81	93.38	69.19	1808.88	9046.56
0	-1	-1	0	-1	-1	1	0	990.06	93.12	69.23	1810.24	9053.56
0	-1	-1	0	1	0	-1	1	993.30	93.49	69.43	1804.36	9024.16
0	0	0	-1	-1	1	0	0	89.83	103.53	59.32	1906.40	9533.96
0	0	0	-1	0	-1	1	1	81.95	103.91	59.44	1901.40	9509.16
0	0	0	-1	1	0	-1	-1	83.83	103.07	59.24	1911.24	9557.92
0	0	-1	0	-1	1	1	1	62.21	103.10	69.35	1733.60	8670.00
0	0	-1	0	0	-1	-1	-1	65.54	103.56	69.31	1731.32	8658.20
0	0	-1	0	1	0	0	0	57.56	103.26	69.32	1733.24	8668.08
0	0	-1	-1	-1	1	-1	0	82.48	103.32	59.28	1908.72	9545.32
0	0	-1	-1	0	-1	0	1	81.13	103.08	59.43	1907.16	9538.16
0	0	-1	-1	1	0	1	-1	81.61	102.97	59.25	1911.36	9559.04

DEA has been widely adopted in recent years to assess the performance of a group of units. These quantified units are called decision making units (DMUs). Predicated on the concept of an efficiency frontier, Charnes et al. first modeled DEA through mathematical programming. Thus, DEA can measure the relative efficiency of DMUs with multiple inputs and outputs.

The DEA model introduced by Charnes et al. is called the CCR model. The CCR model utilizes a virtual multiplier to integrate multiple inputs and outputs into a single index. The virtual multiplier generated as the sum of weighted outputs divided by the sum of weighted inputs is utilized to represent the efficiency of each DMU. The CCR model selects the input and output weights that maximize relative efficiency of each measured DMU. The relative efficiency of the tth DMU analyzed by the CCR model is obtained by equation (1).

Max $$Dmu = \frac{\sum_y u_y O_{ty}}{\sum_x v_x l_{tx}}$$

s.t:

$$\frac{\sum_y u_y O_{ty}}{\sum_x v_x l_{tx}} \leq 1, \; w=1, 2 \ldots L \qquad (1)$$

$$u_y \geq 0, v_x \geq 0$$

Cross-evaluation is applied to rank the best performers of simulation results in this research. Cross-evaluation was first proposed by Sexton et al. (1986) & Doyle and Green (1994) extended cross-evaluation and further developed a cross-efficiency method to distinguish efficient DMUs. They regarded the relative efficiency in the CCR model as a self-appraisal measure.

Actually By using DEA method the best levels of the factors recognized, the results has been shown in table 3.

Table 3. DEA Ranking

DMU	RANK	DMU	RANK	DMU	RANK	DMU	RANK
1	10	10	31	19	23	28	1
2	11	11	29	20	27	29	6
3	7	12	34	21	21	30	9
4	6	13	4	22	8	31	35
5	12	14	2	23	7	32	32
6	16	15	3	24	5	33	26
7	20	16	24	25	33	34	15
8	17	17	25	26	30	35	14
9	18	18	22	27	28	36	13

5- Conclusion

Flexible Flow-Shop Problem optimization forms a stochastic nonlinear problem which consists of many considerable factors such as system utilization, work-in-process, setup time, tool changes, production rate, due dates, job tardiness and etc. The goal of the optimization process is to select the optimal parameters related to these factors which optimize the performance of Flexible Flow-Shop Problem. In spite of its vast advantages, including the ability to adopt rapidly to produce new products or using multiple machines to perform the same operation on parts, Flexible Flow-Shop Problem which benefits from the integration of computer system to simultaneously monitor information and material flows online, is subjected to complex and sophisticated factors both in design and operation conditions which are resulted from the combination of physical and environmental factors. Thus, this expensive manufacturing system should be designed and optimized carefully and dynamic behavior of each Flexible Flow-Shop Problem components should be closely studied to obtain a precise prediction of system performance this paper proposed an approach based on simulation to solve a particular case of flexible flow shop planning problem. To attain a core competency in the competitive market, the company's approach is to improve performance of each part in the process of production. The proposed methodology can help decision-makers to determine the optimal scenarios for planning the activities. Eight different factors with different levels were considered for determining the most effective one to optimize the planning. Optimal policies aim to provide optimum system performance. Due to the Taguchi, 36 scenarios were prepared and simulation was performed in Enterprise Dynamic(ED). Finally, these scenarios were ranked by the DEA and the best scenarios were selected. According to the results the performance of scenarios 28, 14 and 15 were the best scenarios, respectively. According to DEA result.in this research considered different levels for each factors such as FIFO & LIFO in discipline of the queues in this research, the proposed algorithm includes some shortcomings that can be improved in the future researches. For instance, MTTF for each server can be considered or sensitivity analysis for each parameter can be considered as determine the bound of the answer.

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