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# A Simulation Model of Production Scheduling

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**Abstract:** Today's industrial world is the arena of competition between managers, industry owners and optimum methods for efficient utilization of resources in order to decrease the costs and increase productivity in production systems. Since the use of computer simulation as an efficient tool for analyzing the systems is not common in Iran, so this research try to provide a suitable context for using this tool widely in industries of Iran through a simulation experiment in Mahak Motlagh industrial manufacturing company. Collecting production rate data took 6 months demand then different methods of production were investigated. The result was extracting 8 methods for this purpose. Available information implied that production circulations are close together in each of those methods confirming production distribution function as normal. In order to confirm this fact, we used MINITAB, STATISTICAL software and distribution function of each production method were extracted. Then production simulation model was developed and real data were written using ENTERPRISE DYNAMICS and was run for 6 months. Through investigating the costs of each method and simulation model output, optimum synthesised model was selected. Finally the processes of validity confirmation of optimum simulation model were conducted using variances hypothesis test with 99.5% accuracy.

**Key words:** Optimum production model · Computer simulation · Productivity · Production simulation model

## INTRODUCTION

Today, high complexity of systems organized by humans for society makes management highly difficult. That complexity is the result of interactions, mutual relationship among different elements of organizations and physical systems related to them [1]. Therefore Implementing change can be a difficult task for any organization, big or small. For this purpose modeling of complex systems such as manufacturing systems is an arduous task. Simulation has gained importance in the past few years and allows designers imagine new systems and enabling them to both quantify and observe behavior. Whether the system is a production line, an operating room or an emergency-response system, simulation can be used to study and compare alternative designs or to troubleshoot existing systems [2]. In this regard Simulation technology holds tremendous promise for reducing costs, improving quality and shortening the time-to-market for manufactured goods. Unfortunately, this technology still remains largely underutilized by industry today [3].

Now, we have found that making part of a system changed can lead to wide changes in other parts of the system or causes the need to change in them. Therefore, engineering science and system analysis are developed for helping the managers to study and understand the results occurred through those changes. Simulation helps the user to test real or offered systems without which, testing would be impossible or impractical [4]. from the viewpoint of Banks Simulation involves the generation of an artificial history of the system and the observation of that artificial history to draw inferences concerning the operational characteristics of the real system that is represented. Simulation is an indispensable problem-solving methodology for the solution of many real-world problems. Simulation is used to describe and analyze the behavior of a system, ask what-if questions about the real

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Table 1: Application of simulation in different systems.

| Type of system | Simulation application | Type of system | Simulation application |
|---|---|---|---|
| Production systems | Design of factory and constant optimization location<br>Capacities and resources management<br>Evaluation of production capabilities | Financial systems | Decision making in applying the capital<br>Analysing financial flows Risk analysis |
| Transportation systems | Material transportation<br>Evaluation of rail road systems<br>Planning, sending and exchanging the goods | Environment studies | Food control<br>Pollution control<br>Energy usage<br>Agricultural management Pests control |
| Communication and computer systems | Air traffic control<br>Evaluation of terminals and goods warehouses operations<br>Performance assessment<br>Information flow evaluation<br>Evaluating reliability | Ergonomics | Instruments management<br>Designing working room<br>Planning human forces<br>Evaluation of organizations interrelationships |
| Production control and management | Production planning Marketing analysis<br>Scheduling and controlling the production | | |

system and aid in the design of real systems [5]. One approach that companies have taken in this regard is to increase the level of automation and computerization of their production system [6,7].

Studies conducted during $70^{th}$, $80^{th}$ and $90^{th}$ decades in U.S.A. revealed that simulation and statistics were found to be the most important and common tools for guiding the managers in service based organizations and industrial units [8,9]. some of those applications are summarized in Table 1.

As you can see in Table 1, simulation models have wide range applications in most of industries and sciences such as social and economic, commercial, production, environmental, transportation, engineering and medical systems. With simulation models, how an existing system might perform if altered could explored,or how a new system might behave before the prototype is even completed, thus saving on costs and lead times. In conclusion Modeling and simulation are emerging as key technologies to support manufacturing in the 21st century. However, there are differing views on how best to develop, validate and use simulation models in practice [10,11]. On the other hand production scheduling problem is one of the main areas of research. In general terms, the problem can be described as follows: given a set of required tasks, what is the best way to assign the available resources to the tasks, within the existing constraints that would maximize the desired performance of the system[12].

The conduction processes used in this research is primarily based on reviewing the literature performed in this field and conducting case studies in one production system applying simulation techniques, i.e. at first, current production models identified and simulated trough identification of current systems then, through different performances and developing different combinations of production simulation models, the best scenario is chosen and finally it is validated.

In 1998, Law and Mccomas presented an article concerning application of simulation in production systems and described the quality of using simulation models in designing production systems and explained the ways those simulation methods are applied in designing new production systems and optimization of current production systems performance [13]. Regarding artificial intelligence and simulation in optimization of production systems, numerous studies have been conducted including Viharous and Monostory [14]. Baseler *et al*. investigated the application of simulation and artificial intelligence in optimization of productivity of wood factory. The results of this research indicated that applying optimized and suitable combination of resources and facilities of organization can lead to 18% decrease in average total waiting time and through investigating just 1.6% of total possible combinations and applying genetic algorithm, optimized combination of resources and facilities were obtained [15]. Todi *et al*. performed an extensive study relating to the use of simulation methods in optimization of operations of a wire and cable manufacturing company. In this research, simulation was studied for the purpose of increasing production rate, smoothing production flow by determining the optimum amount of input batches of raw materials [16]. In another study Etrak *et al*. investigated the application of simulation in estimation and optimization of quality and productivity of wire and cable manufacturing factory [17]. Williams identified the reasons and causes of adopting simulation systems as the means of increasing usage rate of simulation in normal situations of organization[18]. Miller and Pegden investigated different aspects of production simulation and explained the application of simulation in designing production systems and scheduling the operations [19]. Some researchers examined the application of simulation in reengineering organization's processes [20,21]. In many researches, simulation has been used for analyzing so complicated operational operations as scheduling, sequencing, material handling and layout of machines and equipments. In some researches, simulation has been used as the toll for daily scheduling and sequencing of production process [22]. Wang and Halpen developed an analytical method composed of simulation, tests designing, regression analysis and mathematical planning for determining optimum plan of concrete production and transportation [23].

Mahak Motlagh industrial manufacturing company was established by Mr. Ali Keshavarz holder of PhD in polymer in 1991. This company has two extended pneumatic production line with more than 200 personnel. It is the sole producer of industrial and domestic gas meter diaphragm in Iran. Foreign competitors of this company are located in China and several European countries such as England and France. This company has been successful in competing against the prices offered by China and quality of its European competitors, but has not been successful in achieving its goals regarding on time delivery strategy. This is due to highly variable and diverse demands of main customers. The current production sequencing of this company is as follows: 5 days before the end of month, the request of future month is announced by commercial unit to planning unit. Based on received demand and request, planning unit schedules production line of raw materials (material making unit) and product manufacturing line (pneumatic line) while considering the limitations of materials life span and durability (10 days maximum), time of materials preparation (one week), time of mould loading (1 day), number of available moulds for each product, inventory level and shortage rate of each product at the end of 6 month periods and number of individuals. But during the month, the requests for products vary frequently and planning unit must change remained days plan until the end of month for supplying required demands of end of the month that requires changing production schedule of other products, human force arrangement, changing material making program, changing the mould, etc. Besides human forces related problems such as difficulty of scheduling, high volume of changes for planning unit, dissatisfaction of production line workers of those frequent changes that causes unregulated shift changes will lead to production related problems such as preparation time for performing new program, high possibility of insufficient supply for announced demand egarding time and resources limitation, possibility of error in planning regarding the volume of changes, all of which will make the company facing to serious problems in achieving delivery time strategy. Regarding successful conducted projects of performance and timing measurements, the time and method of production is in its best situation and condition. In order to optimize delivery time, we cannot manoeuvre on production time and method optimization and we should look for other optimization solutions in the level of production scheduling. For that purpose, we chose Prima diaphragm production line regarding the priority determined by factory's production manager because of high volume of demand changes and its strategic conditions as pilot.

By analysing demands for this product and investigating production models, we developed production simulation model, then suggested sequencing systems were run in simulated model and finally, by analyzing the costs, surplus and shortage amount of each model with production sequencing method, optimum production model was selected that besides possessing minimum variability, is capable to respond the trend of demands. Now we are faced with this question that Can we regulate and adjust sequencing plan for Prima diaphragm production line such that does not influenced by frequent changes in demands and can respond to the needs of customers, its maximum variability at the end of each month not to be more than one box with the least cost, while considering limitations of production?

The purpose of this research is based on solving the problem of production scheduling with variable demands of Mahak Motlagh industrial manufacturing company in order to minimize production time as well as decreasing frequent changes in scheduling. In other words, the main goal of applying simulation method is solving the problem of scheduling the production or variable demands in order to find a solution for the problem of production scheduling in manufacturing companies. Consequently by solving this problem, a solution similar to Mahak Motlagh's industrial production Company becomes available for managers to plan production units, so with any change no variation is caused in the arrangement of production scheduling plan and arrangement of their equipments, so considering all variable conditions and investigating the behaviours of customers and benefiting from simulation method, the most optimum scheduling plan can be selected and the line would not be confronted with problems such as employments working shift, different arrangements, delay in performing new program due to the time of raw materials preparation, etc.

## MATERIALS AND METHODS

By investigating 6 months statistical data of Prima diaphragm production line, 8 different modes of production were extracted from among mentioned data. Since these different modes are repeated during several years and learning has been created by them as well as performing timing and performance measurement on these lines has caused each of those production modes to be in their best arrangement condition regarding the line, time and methods of production. Since the problem of production scheduling are not in the levels of micro-arrangement of line, etc, we have tried to use simulation in macro scales for this project and through performing the process of constant optimization in simulation while considering system limitations, the best mode for production scheduling to be achieved. Probability distribution functions of 8 different production modes together with the number of required human forces and costs of human forces per each unit extracted using 6 months data of production line are presented in Table 2.

In order to prepare and run simulation model, we use Enterprise Dynamics Studio. The reasons for choosing above mentioned software are described below.

If model maker uses one of public and customary languages, he/she would be free to make use of mentioned methods. If model maker wants to special simulation languages, then she/ he has to follow the approach dominating that special language. In Table 3, a general comparison is made between some available software for simulation.

- Understanding block (mesh) diaphragm in excellent order models
- General languages have no major in simulation. The programmer creates required major and selects modelling approach.
- There are various library scientific sub programs for producing random quantities of general programs.
- GPSS/11 is optimized compared to GPSS/V
- Supposing that the model is programmed as sufficient as possible, general programs would be quick.
- There is in many computations.

Visual Slam has provided a flexible modelling framework in all aspects. In this language, simulation of a discrete variable can be modelled with the approach of events or processes' interaction approach or a combination of both approached while considering some facilities to be used based on activities search approach. Modelling approach with activities interaction approach provides a networked modelling framework consisting of elements called node and branch. This software provides the capability of programming in C, visual basic environments, making possible to use events approach in system modelling and in both approaches, presents special and certain functions such as STOPA, so using activities search approach would be possible. The approach of Visual Slam in modelling discrete processes networks is based on two principles that are as follows:

- Existences in model of network cause the events to occur.
- The events can change the flow direction of existences in network.

According to above statements, Enterprise Dynamics Studio software whose base is Visual slam software was selected. It must be stated that other software such as Arena that is based on Visual Slam, has the capabilities of Enterprise Dynamics Studio software, but accessing to original versions requires high costs and its lock broken version is not usable, so finally, two factors of access to original version and capabilities of Enterprise Dynamics Studio software resulted in using that software.

In next stage, software model for simulating 8 production model identified in part 5(trough data collecting) was developed using information related to 6 months demand of Prima diaphragm and distribution function of production of each of mentioned modes and finally after running each model for 6 months, the performance and behaviour of model is indicated compared t o demand in the form of positive (surplus) or

Table 2: Probability distribution functions of 8 different modes of production together with the number of required human forces and the costs of human forces per unit.

| Model of production | System of production | Probability distribution function | Number of human forces | Cost of each human force individual /second (Tooman) | Cost of human force per each unit (Tooman) |
|---|---|---|---|---|---|
| 1 | Two 10 hours production shifts per day with 4 active moulds in each shift | Normal with 39.1389 mean | 5 | 0.580832 | 113.666 |
| 2 | One 10 hours production shift per day with 4 active moulds in the shift | 811.39 | 5 | 0.580833 | 115.6178 |
| 3 | Two 10 hours production shifts per day with 3 active moulds in each shift | Normal with 46.7735 mean | 3 | 0.580833 | 81.50382 |
| 4 | Two 10 hours production shifts per day with 2 active moulds in each shift | Normal with 107.7844 mean | 1 | 0.580833 | 62.60479 |
| 5 | Two 10 hours production shifts per day with 3 active moulds in second shift | Normal with 66.66667 mean | 2 | 0.580833 | 77.44444 |
| 6 | Two 7 hours production shifts per day with 4 active moulds in each shift | Normal with 38.19789 mean | 5 | 0.488095 | 93.22105 |
| 7 | three 7 hours production shifts per day with 4 active moulds in each shift | Normal with 35.0747 mean | 5 | 0.448095 | 85.59896 |
| 8 | Two 10 hours production shifts per day with 2 active moulds in each shift | Normal with 67.79661 mean | 1 | 0.580833 | 39.37853 |

Table 3: A general comparison of some available simulation software.

| | Language | | | | |
|---|---|---|---|---|---|
| Criterion | General | GASP | SIMSCRIPT II | GPSS V | SLAM |
| Learning feasibility | Good | Good | Good | Excellent | Excellent |
| Problem comprehension feasibility | Weak | Moderate | Good | Excellent (A) | Excellent (A) |
| Tended system | Null (T) | All | All | Line | Line |
| Approach, modelling and timing the event | No (B) | Yes | Yes | No | Yes |
| Contrast processing | No (B) | No | No | Yes | Yes |
| Continual | No (B) | Yes | Yes | No | No |
| Possibilities of internal random sampling | No (J) | Yes | Yes | No (D) | Yes |
| Statistics collection capacity | Weak | Excellent | Excellent | Good (D) | Excellent |
| | Weak | Good | Excellent | Moderate | Good |
| Feasibility of receiving standard report | Weak | Excellent | Moderate | Excellent | Excellent |
| Feasibility of designing special report | Moderate | Good | Excellent | Weak (D) | Good |
| | moderate | Good | Excellent | Moderate (D) | Good |
| Duration of running on computer | excellent | Good | Good | Weak (D) | Good |
| Documentation in terms of learning | Very good | Very good | Moderate | Very good | Very good |
| Language and self documentation of code | weak | good | good | excellent | good |
| costs | low (V) | Low (V) | high | Low (D) | moderate |

Table 4: Analysis of costs and behaviour of system.

| Model | Cost of each unit | Shortage rate at the end of each month | Surplus rate at the end of each month | Lost profit in exchange for shortage |
|---|---|---|---|---|
| 1 | 113.666 | | 68835 | |
| 2 | 115.6178 | -73678 | | 623812500 |
| 3 | 81.50283 | | 33966 | |
| 4 | 62.60479 | 160837 | | 2010462500 |
| 5 | 77.44444 | 470169 | | 589612500 |
| 6 | 93.23105 | -10248 | | 128100000 |
| 7 | 85.59896 | | 133232 | |
| 8 | 39.37853 | -49905 | | 930350000 |

negative (shortage) warehouse inventory. Analysing the costs and behaviour of system in each model of production is described regarding following remarks in Table 4.

- Remark 1: due to low volume of product and no limitation in arrangement height, warehousing cost is venial.
- Remark 2: lost profit in exchange for shortage or profit estimation of each diaphragm is 12500 Tooman and at the end of 6 months periods, if they are not compensated, competitors'' goods and products are replaced.
- Remark 3: according to negotiations conducted with factory manager and his statements implying the variability of type and number of demands of customers, the maximum accepted surplus at the end of 6 months period is three boxes equal to 1260 units.

As you can see, in Table 4 production cost of each unit, surplus or shortage rates at the end of 6 months period and lost profit in exchange for shortage for each model is described.

Optimum solution that makes shortage zero and possesses minimum cost is resulted from combining method and 8, such that in two months of 6 months periods, the methods of 3 are used for production for 23 days, 8 days production is performed by method 8, in remained three months: production is done with method 3 for 20 days and method 8 is used for 10 days and for one month, method 3 is used for 21 days and method 8 is used for 10 days and in order to prevent frequent repetition, production with similar combinations of days in each month are constantly considered.

In order to validate simulation model, we used variances assumption test. Since optimized simulation model is a combination of models 3 and 8 and following conducted negotiations with production manager of

Mahak Motlagh company concerning that up to 420 units variability at the end of month is admitted, so for validating the correctness of simulation model, the model was run for model number 3 and 8 for 10 times and statistical assumption test was performed for community variance in error level amounting 0.005.

## RESULT AND DISCUSSION

The data relating to end of period inventory in exchange for 10 repetitions and estimation of mean and sample variance suing mentioned information is presented in Table 5.

Now, by using the results of table 5, we can perform statistical assumption test for variance that is as follows:

Assumptions:

$H_0 \leq 176400$

$H_1 > 176400$

$$\text{Test statistic: } \chi^2(x) = \frac{(n-1)S^2x}{\sigma_0^2} = \frac{(10-1)*306.94444}{176400} = 0.015655$$

$$\text{Critical quantity: } \chi^2_{0.005,9} = 23.5893$$

**Decision Making:** Test statistic ($\chi^2 = 0.015655$) compared to critical quantity ($\chi^2 = 23.5893$) is placed in the region of $H_0$, therefore we can say with 99.5% certainty that zero assumption is accepted and validity of model for having the variance lower than or equal to 420 is confirmed.

Information related to inventory at the end of period in exchange for 10 repetitions and estimation of mean and variance of sample using mentioned information is presented in Table 6:

Now, using the results of Table 6, we can perform statistical assumption test for variance that is as follows:

Assumptions:

$H_0 \leq 176400$

$H_1 > 176400$

$$\text{Test statistic: } \chi^2(x) = \frac{(n-1)S^2x}{\sigma_0^2} = \frac{(10-1)*106.27}{176400} = 0.008534$$

$$\text{Critical quantity: } \chi^2_{0.005,9} = 23.5893$$

**Decision Making:** Test statistic ($\chi^2 = 0.008534$) is placed in region $H_0$ compared to critical quantity ($\chi^2 = 23.8593$), so we can say with 99.5% that zero assumption is accepted and validity of model for having standard deviation lower than or equal to 420 units is confirmed.

The results of running optimization model are indicated in Figure 1. As you can see, production trend in optimized model is highly ordered and the combination of two models of 3 and 8 are applied, while in initial scheduling, we had used 9 production models (8 models plus zero production).

Table 5: Summary of information relating to 10 repetitions of model 8.

| Repetition number | Inventory at the end of 6 months period | Number of repetition | Inventory at the end of 6 months period |
|---|---|---|---|
| 1 | -49683 | 6 | -49871 |
| 2 | -49875 | 7 | -49886 |
| 3 | -49876 | 8 | -49904 |
| 4 | -49883 | 9 | -49914 |
| 5 | -49889 | 10 | -49906 |
| Mean | -498855.8 | Variance | 306.844444 |

Table 6: Summary of information relating to 10 repetitions of model 3.

| Repetition number | Inventory at the end of 6 months period | Number of repetition | Inventory at the end of 6 months period |
|---|---|---|---|
| 1 | 22977 | 6 | 22941 |
| 2 | 23037 | 7 | 23952 |
| 3 | 22999 | 8 | 22978 |
| 4 | 23000 | 9 | 22977 |
| 5 | 21696 | 10 | 23008 |
| Mean | 85622.5 | Variance | 167028 |

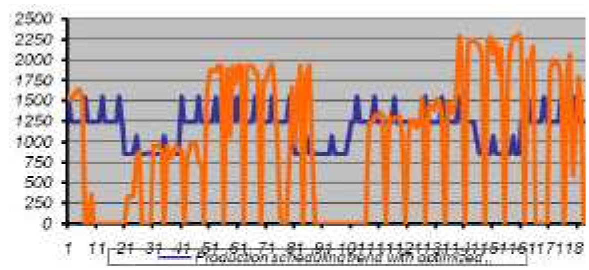


Fig. 1: Comparing Production Scheduling, Before Executing Optimized Scheduling Model And After Executing

As you can see in Figure 1, scheduling trend of production in optimized mode is highly stable and has no changes with high distances and it is only in two levels. This is due to suing two models of 3 and 8, but production scheduling trend in the mode before applying optimized model is highly variable, the changes have high distances and it has 9 levels. This is due to using 9 production models. 8 described model in part 5 and one model with daily production number is zero.

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