IMPLEMENTATION OF R-TECHNIQUE IN PRODUCTION PLANNING AND CONTROL

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ABSTRACT

The planning engineering is considered a vital part in the industrial operations series that leads to achieve the proposed production plan. Because of scientific advancement and technical development in the industrial field, the managements of the companies and job shops start to automate the engineering and management activities for the aim of quickness and accuracy in making proper decisions for the production process in order to get final product in a better quality and minimum cost. This is achieved by the future estimation of production plan. The research concern with evaluating the size of work arrival to the manufacturing shops and determining the amount of capacity that is required to perform these evaluated job volume in a manner that warrant decreasing the cost of orders and machines waiting. To achieve this aim, a constructation of simulation system by using Visual Basic computer program that helps the user in future estimation of job volume and determination of the best process capacity of the job shop which through it the job can be accomplished. Actual and realistic data that are collected from the documents of Electrical Industrial Company (EICO) factories is in random orders arriving to factories in one man-day and also the actual time to perform number of these orders. Through the designed software which is used as a tool for simulating of the target production system in this research, the best simulation daily process capacity was obtained for the job shop to be 130 hr per day where as, it achieved the minimum value of the total cost. There is a great effect for this increment of job shop daily process capacity in decrement of waiting of orders and this lead to optimal exploitation for these presented capacities. To verify simulation results and obtain the optimum selection for these results, the researcher used a modern technique called R-Technique or Response Surface Methodology (RSM), which the desirability function which is used as a dual-purpose standard to obtain the optimum value of job shop process capacity.

الخلاصة

إن هندسة التخطيط تعتبر الجزء الحيوي في سلسلة العمليات الصناعية, التي تؤدي إلى تحقيق الخطة الإنتاجية المؤملة وبسبب التقدم العلمي والتطور التكنولوجي في المجال الصناعي أخذت إدارات الشركات والمعامل والورش بأتمتة سلسلة الفعاليات الهندسية والاداريه لغرض السرعة والدقة في اتخاذ القرارات الصحيحة للعملية الانتاجيه من اجل الوصول إلى منتج نهائي بأقل كلفه ويأتي هذا من خلال التخمين المستقبلي للخطة الإنتاجية. يهتم البحث بتقدير حجم العمل الواصل إلى ألورشه و تحديد مقدار الطاقة الانتاجيه المطلوبة لإنجاز حجم العمل الواصل إلى الورشة بشكل يضمن تقليل كلف كلا من كلفه انتظار الطلبات و المكائن ولتحقيق هذا الهدف قام الباحث ببناء نظام محاكاة باستخدام الحاسوب(لغة الفيجوال بيسك) يساعد المستخدم في التنبؤ المستقبلي لحجم العمل وتحديد أفضل طاقه إنتاجيه للورشة يمكن من خلالها إنجاز العمل, تم جمع بيانات واقعية و فعلية من سجلات معامل الشركة العامة للصناعات الكهربائية وهذه البيانات تخص عدد الطلبات العشوائية الواصلة لهذه المعامل في اليوم الواحد وكذلك

الزمن الفعلي لإنجاز عدد من هذه الطلبات,. ومن خلال النظام ألحاسوبي المصمم والذي استخدم كوسيلة لمحاكاة النظام الإنتاجي المستهدف بالبحث فقد تم الحصول على أفضل طاقه إنتاجيه يوميه للورشة وهي 130 ساعة في اليوم والتي حققت أقل قيمه للكلفة الكلية. إن لهذه الزيادة في الطاقة الانتاجيه اليومية للورشة الأثر المهم في تقليل وقت الانتظار الطلبات بحيث أدى ذلك إلى الاستغلال الامثل لهذه الطاقات المتزايدة وللتأكد من النتائج أعلاه والحصول على الانتخاب الامثل لهذه النتائج، استخدم الباحث تقنيه حديثه تعرف بمنهجية الاستجابة ألسطحيه والتي استخدمت فيها داله المرغوبية كمعيار ثنائي الهدف للحصول على القيمة المثلي للطاقة الإنتاجية المتاحة للورشة.

KEYWORDS: Production Planning, Scheduling, Simulation, Optimization, Response Surface Methodology (RSM), **R- Technique**

CONTEXT AND MOTIVATIONS

Production planning is fundamental to the operation of a manufacturing enterprise. The basic problem is to determine the type and quantity of the products to produce, to meet uncertain demand in the future time periods (**Venkateswaran et al., 2004**). Operations planning and control systems cover three stages: planning, scheduling and execution (**Volkmann et al., 1997**). The planning stage is concerned with balancing supply with demand. It includes demand management, resource planning and master scheduling. The scheduling stage produces more detailed plans for material and capacity requirements. Finally, in the execution stage orders are dispatched and fulfilled using the materials and resources that were allocated in earlier stages. In the classification of (**Sheer 1994**), scheduling is concerned with sequencing orders that have already been released for production and with deciding exactly when and on which machines jobs should be processed. The primary goals of scheduling are to avoid late job completion, minimize flow times and to maximize resource utilization (**Vollmann et al., 1997**). The job shop scheduling problem is the problem of finding a way to schedule a number of operations, such that the last operation is completed as soon as possible. Here an *operation* is a task that must be executed on a resource, called the machine (Lennartz,1999).In job shop scheduling, any job can be processed on any machine in an order that is predetermined but can be different for each job (**Lehtonen et al., 2003**).

SIMULATION IN PRODUCTION SCHEDULING

Simulation is emerging as a part of decision support systems for production scheduling. It provides an alternative when optimization approaches are too heavy and simple approaches such as priority rules are insufficient. Classical optimization techniques use an appropriate mathematical description of the scheduling problem that is minimized through the application of an algorithm (**Sellers, 1996**). The simulation approach provides a great level of detail without being computationally too heavy. A schedule is created by simply simulating the execution of the factory and taking the recorded execution history as the schedule (**Smith, 1992**). The result will be a feasible schedule if all the relevant constraints are included, which is easy as a simulation model can include a large number of details. However, the simulation model does not necessarily come up with the best schedule, although it will be a feasible one.(**Roy and Meikle 1995**) recommend discrete event simulation for estimating the operative performance of proposed schedules that are generated using other methods. As a part of a decision support system, simulation provides a way to get detailed information about the consequences of scheduling decisions, regardless of whether they are based on manual or optimization-based schedule generation. (**Lehtonen et al., 2003**).

OPTIMIZATION

Optimization means finding the specific certain set of inputs to a function, such that any change to any of the inputs will result in a less desirable function output. Optimization approaches are generally thought of as either analytical/mathematical or direct/empirical. Regardless of the specifics, in an optimization routine in the most general sense is a procedure that, when applied to a model, will result in the determination of the best model as defined by the fitness of an objective function. Most problems are solved by matching a modeling approach with an optimization, or solving approach. Simulation is a specific computer based modeling approach which uses a chain of cause and effect relationships to help the user build complex models from the ground up, one link at a time. On the other hand, optimization often requires a simplistic modeling approach in order to have a model that can be completely optimized (**Hicks, 1999**). In this paper we present an optimization approach to a real-world production planning problem. Response Surfaces Methodology was derived by evaluating the system at several points using computer simulation. The results were then used to depict them graphically.

CHARACTERISTICS OF PRODUCTION SYSTEM

One of the Electrical Industrial Company (EICO) factories, is the Tools and Molds Factory. It is one of the major factories in the company. This factory produces several kinds of dies, tools, and fixtures which are used by the company; also making the required maintenance for these dies and tools, which may be damaged during the production operations. This factory contains the machines, as stated in **Table (1).**

Table (1): Machines of tools and molds factory.

No.	Type of machine	Quantity	Serial number
1	Milling	8	M (I – 8)
2	Turning	8	T (9 –16)
3	Grinding	8	G (17-24)
4	Drilling	4	D (25-28)
5	Shapers	2	S(29-30)
6	Cutting	3	C (31-33)
7	Furnaces	4	F(34-37)
8	pressing	2	P(38-39)
9	Assembly bench	3	A(40-42)

Assessment of Factory Capacity

The capacity of work for factory is represent by the number of machine in the tools & molds factory and the Spare parts factory. They are (57) machines, but they do not works completely daily, because of failures that occurs from the work and maintenance, and also because of broken machines which can not be repaired. Therefore the about number of working machines are (40) with (5) hours running per day are calculated using:

$$C_a = M \times h_r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{hr/day} \quad (1)$$

Where:

C_a : Process Capacity, M : Number of machine, h_r : Number of activity hours.

Type of Order Arrivals

Orders arrive to the shop randomly between increasing or decreasing in the number and type and depend on customer needs and as shown in the **Fig. (1).**

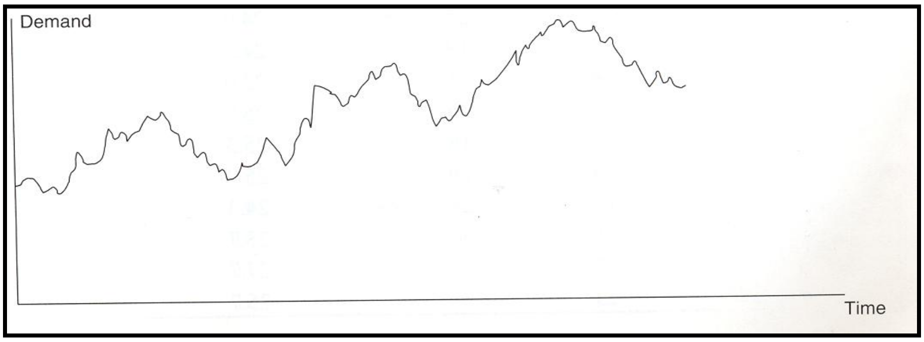

Fig. (1): A random Order Pattern.

EXPERIMENTAL STUDY

Refereeing to the production planning in EICO, the establishment depends in programming of there random requirements and forecasting upon the experience of the technicians without making use of computers and updated software, a computer program is designed to be used in future calculation of the orders which arrive to the factories and at any period. In this section a description for the procedure for random orders arrivals approach is developed depending on a data base system, absolute records and other simulations method technique. Each order entails a certain number of machine hours, analysis of past records which are summarized in **Table (2).**

Table (2): Orders Data.

Number of order	Days frequency	Sum. of orders
1	9	9
2	14	28
3	18	54
4	25	100
5	20	100
6	13	78
7	8	56
8	2	16
Total	109	441

Collection of Data

The collected data shown in **Table (2)** from past records of the plant are random orders arrived to the job shop and were performed to determine the kind of the distribution which presents the shown in the above table. The histogram must be drown as shown in the following steps:

$$R = x_l - x_S \tag{2}$$

Where:

R: The range of orders
x_l: Upper of limit
x_S : Lower of limit

In our case study $x_S = 0$, $x_1 = 8$.

$$H = R / K \tag{3}$$

Where: H: Ranking of period , K: Number of ranking , in the case study K=7.
For calculation the relative frequency use the equation below:

$$F_R = (F_A / N_{O.}) \times 100 \tag{4}$$

Where:

F_R = Relative Frequency.
F_A = Absolute Frequency.
$N_{O.}$ = Number of Data.

Data Analysis

From the continuation of the method for random orders arrival and the nature of the work in the associated factories, it was established that the arrival of random orders follows normal distribution as shown in the steps of the sketch of the histogram , that is the facts of manufacturing world show that a lot of changes take the curve trend of normal distribution. Therefore the normal distribution curve describes the changes of manufacturing which can be calculated from the following relation:

$$\mathbf{f}(z) = [(1 / (2\pi)^{½}] \times e^{-0.5z^2} \tag{5}$$

Where:

f (*z*): Function of normal distribution curve where:
e: 2.7182 , π : 3.1415
z:: random variable.

The form of normal distribution curve is depending upon the values of the arithmetic mean (μ) and standard deviation (σ).

$$\mu = \frac{\sum x}{N} \tag{6}$$

where

x= Orders number
N = Number of data points

$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{N-1}} \tag{7}$$

The value of μ & σ in this research are 4&2 from **Table (2)** respectively. To calculate (the arithmetic mean) μ and (standard deviation) σ, it must draw a normal distribution curve taking into consideration the limit of x, i.e. $-\infty < x < +\infty$. The assumption of normality is standard in the assumption of a shifted distribution does to some extent mitigate the effects of that assumption. **Fig. (2)** shows geometrically the relationship of the shifts to the long term fraction of conforming units

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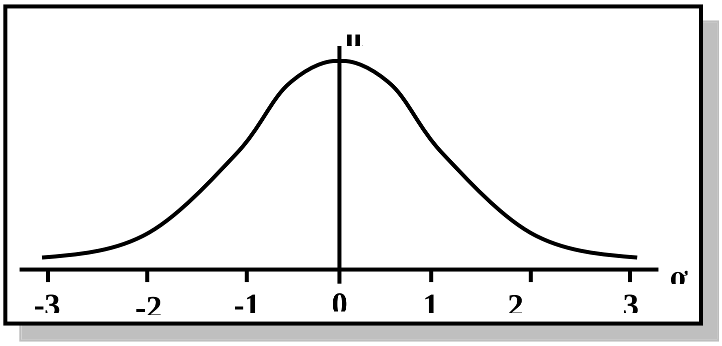

Fig. (2): Quantities Used to Calculate the Proposed Distribution Function.

From the **Table (2)** the maximum number of orders is (8) and the minimum number of orders is (1) / day. To represent the limits of order on the normal distribution curve, the ranges (-2σ, 2σ) is selected as shown in the following equation:

$$n = (x - \mu) / \sigma \qquad (8)$$

Where:

n =Limit of Range

1= At ***x***=0, ***n*** = $\frac{0-4}{2}$ ➡ ***n*** =-2

2- At ***x***=8, ***n*** = $\frac{8-4}{2}$ ➡ ***n*** =2

The Simulation Model

After collecting the required data which are concerned with flows, processes and the times of each single operation, the mathematical models are constructed so as to achieve results by using simulation technique as follow:

1- A mathematical model is used to the estimate the number of daily random orders arriving to the job shop as follow:

$$z = (x - \mu) / \sigma \qquad (9)$$

Substituting the value of ***z*** with limits (-2σ, 2σ) using the represented mathematical model equation:

$$x = \mu + \text{random number } (\sigma) \qquad (10)$$

Then the value of (***x***) is calculated by using one digit from a generated random numbers from the designed system. Where:

x: number of estimated daily random orders arrivals.

2- Other mathematical model is used to estimate lead time to finish the orders which arrived to the job shop in the previous mathematical model. This model depends upon on available data recorded in the establishment for the same job shop. For that task a number of orders is tabulated and using the data of this table(table 2) in (***x***- ***y***) chart. A curve which represents the 2nd mathematical model was established. By using two digits from a generated random numbers from the designed system which represent percentage accumulative frequency and by intersection of these numbers on the curve. The estimated time for each estimated random order arrived to the job shop can be calculated. All these data is arranged and interred to the computer system Automated Scheduling System (ASS) in order to get accurate results.

The Industrial Case Study

The proposed case study was elaborated at the workshop of the tools and molds factory and spare parts factory that produces mechanical products by using machining and welding resources, assembly and inspection stations and some highly specialized machines. The goals of the implemented simulation model are: maxim utilization of one type of available recourses (Available Daily Machine Capacity) and minimizing the inherent cost matched within the context. Execution within the discrete, event-driven simulation module beside the component that allows an interactive simulation, the simulator provides another interface to the optimization module. The second part of the research is the functional relationship between various factors which have been investigated in order to improve production capacity as well as to investigate a better planning process. Such part was implemented via Response Surface Methodology (R- Technique) by using a quadratic model for a Central Composite Design (CCD).

Experimental Assumptions

The following assumptions are depended in order to facilitate the calculation of the actual time of work requirements in the job shop as mentioned below:

1- The daily actual time work for the job shop is (5) hours.
2- Processing times are modeled by independent random variables.
3-Setup times and removal times are included in processing times.
3- Transportation times are negligible.
4- Worker rest time not consider.
5- Machines break down un suppose.
6- Availability of skilled employee.
7- Availability of tools and production requirements operations.
8- A suitable workshop environments.
9- Friday is considered as a working day.

Independent Variables

The main effective factors of the production operation are the availability of production capacity (C_a) which depend upon the number of working machines. Shop capacity can be calculated as follow:

$$C_a = M \times hr \qquad (11)$$

Where: : C_a Daily capacity, M: Number of machine, hr: Number of activity hours

Dependent Variable

There are some dependent variables that appear when the system is working such as:

1- Average daily machine running time:

$$R_a = \frac{\sum_{i=1}^{n} Mh}{W_d} \qquad (12)$$

Where: R_a : Average daily machine running time, Mh: machine hours, W_d : Working days.

2- Idle time: or machine waiting time, it appears in the production operation and is affected on the production capacity and can be calculated:

$$I_d = C_a - R_a \qquad (13)$$

Where I_d : Idle time

3- Average daily order waiting time:

$$O_{dw} = \frac{\sum_{i=1}^{n}\left(Mh - C_a\right)}{w_d} \tag{14}$$

4-Cost of idle time:

$$C_{it} = I_d \times C_{hi} \tag{15}$$

Where C_{hi} : cost per hour of idle time.

5- Cost of waiting orders:

$$C_{ow} = O_{dw} \times C_{hw} \tag{16}$$

C_{hw} : cost per hour for order waiting.

6-Total cost:

$$C_t = C_{ow} + C_{it} \tag{17}$$

C_t , the total cost represented as a sum of C_{ow} and C_{it} must be small value and it's useful to identify the best capacity C_a .

ARCHITECTURE OF THE SHOP-LEVEL PRODUCTION SCHEDULER

The deterministic job shop scheduling problem consists in finding a production capacity which minimizes a criterion. In order to solve this performance evaluation problem, two techniques are proposed: discrete event simulation and optimization technique based on Response Surface Methodology (R-Technique). While discrete event simulation is an extremely accurate modeling approach, capable of predicting system performance, model optimization improved output analysis of the simulation technique. Due to the complex requirements of the production simulation, in-house software in Visual Basic with a Microsoft Excel front-end is developed. The simulation model of the case-study implements dual frame architecture (Simulation & Optimization frames). Simulation is responsible for the data preparation, model creation, initialization and evaluation. The components of the system are created into the model frame in **Fig. (3).** The object-oriented hierarchical simulation module of the proposed planning system is based on the functional decomposition approach. The simulation includes the modeled elements of the case study and is created following the simulation modeling process as described in book record data for the workshop. Automated Scheduling System (ASS) using visual basic 6 in designing the system main windows in addition to computation of arithmetic operations. The system ability to define the best process capacity for the workshop via determining the lowest cost through a real and continuo interactions between system components which are mainly constructed from the following:

A- User interface.
B- Data base.
C- Estimation number of orders arrival model.
D- Estimation machine hour's model.
E- Scheduling evaluation.
F- Capacity simulation.
G- Applying R-Technique (Response Surface Methodology) (RSM).

Simplified details for the main system components can be shown in Fig. (3).

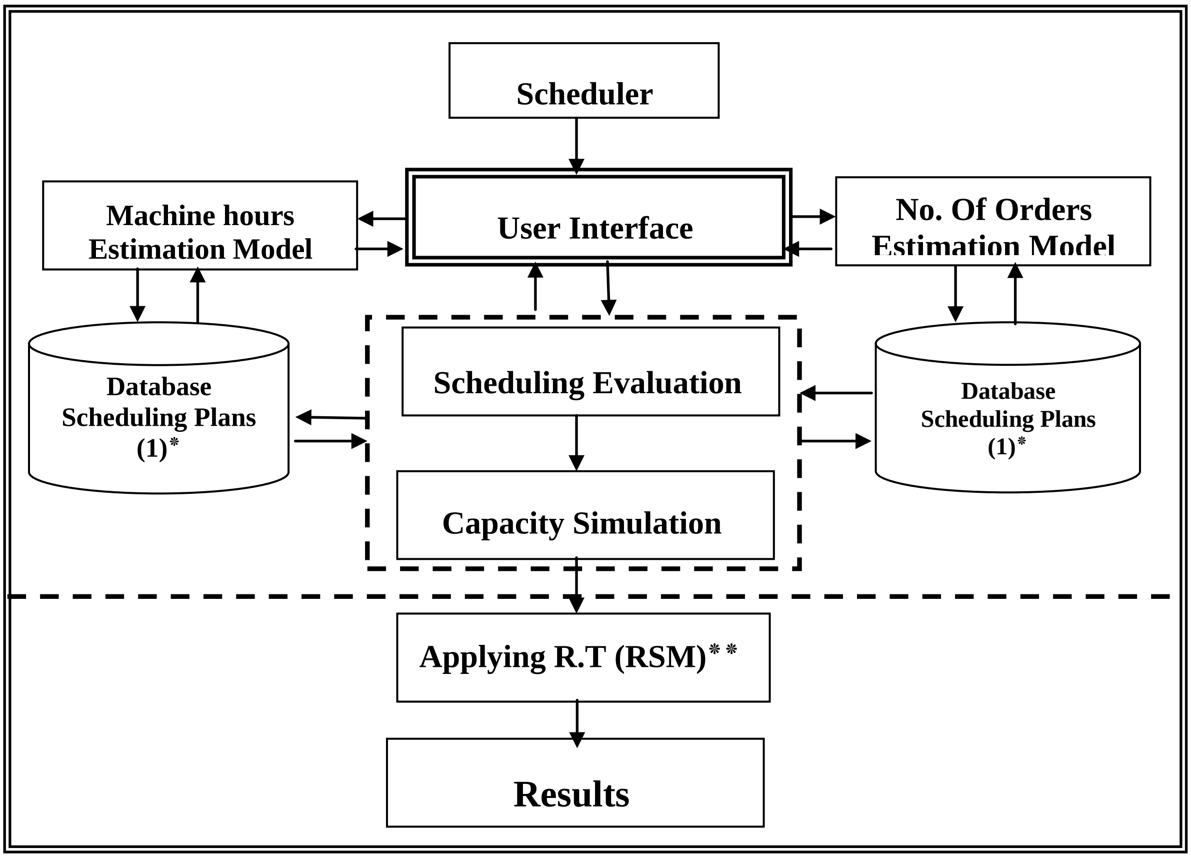

Fig. (3): Architecture and the main process flow in the Shop-level Production Scheduler.*: the same data, **: software package.

Automated Scheduling System

At the program start to apply the designed system a preliminary window will appear to illustrate the system name Automated Scheduling System(ASS). ASS is an organized system to estimate the number of orders, machine hours, and selection of optimal capacity to assist decision makers at workshop level. it consist of:

- Number of orders estimating module.
- Machine hour's estimation module.
- Scheduling evaluation module.
- Capacity simulation module.

ASS Context

The main characteristics of ASS approach, with respect to the other software, are respectively:

- Accurate and rapid computation of the arithmetic operations.
- The ability of the system to estimate any time period that is defined by the planner to the production operations
- The capability of the system estimate the data distribution types.
- The main logical steps that are performed is illustrated in figure (3).

SOLUTION REPRESENTATION

Preliminary Industrial Application

Using the result simulation system (ASS) for the current production capacity in the workshop, indicate that trade-offs between expected production cost and maximize available resource utilization under demand uncertainty is un justice. A review for current state of the daily capacity process in workshop through investigation by (ASS) system forecast the results shown in **Table (3).**

According to that data, distinction needs to be made between the available daily capacity process and total cost associated with maximum utilization for that resource. The fitness is generated by increasing the level which allows to confirm to the objective.

Table(3): Simulation results for current daily process level in workshop.

Daily Capacity (M/c.hr)	Average Daily Machine Running (M/c.hr)	Average Daily Idle Machine Time (M/c.hr)	Average Daily Waiting Orders Time (M/c.hr)	Cost Idle Time (ID)	Waiting Orders Cost (ID)	Total Cost (ID)
100	91.53	8.47	141.79	42.35	283.58	325.43

Improvement by Job Shop Production Scheduler (ASS)

For 75 work days in workshop, the proposed system evaluated that the optimum capacity lies at 130 machine hours. This value of daily process capacity ensure the performance criteria , maximize utilizing accomplished with minimum cost. The **Table (4)** and **Fig. (5)** and (**6**) indicated that result. This level of process capacity considered as aggregate solution and will be refining in next step by the technique optimization Response Surface Methodology (R-technique).

Table (4): The Results (based on a period of 75 days).

No.	Capacity(hr.)	Running(hr.)	IdealTime(hr.)	WaitingTime(hr.)	IdealTime	OrdersWaiting	Total
74	123	110.82	12.18	161.10	60.90	322.20	383.10
75	124	111.58	12.42	160.10	62.10	320.20	382.30
76	125	112.35	12.65	159.10	63.25	318.20	381.45
77	126	113.12	12.88	158.10	64.40	316.20	380.60
78	127	113.88	13.12	157.10	65.60	314.20	379.80
79	128	114.65	13.35	156.10	66.75	312.20	378.95
80	129	115.42	13.58	155.10	67.90	310.20	378.10
81	130	116.18	13.82	154.10	69.10	308.20	377.30
82	131	116.95	14.05	157.68	70.25	315.36	385.61
83	132	117.68	14.32	161.51	71.60	323.02	394.62
84	133	118.40	14.60	160.51	73.00	321.02	394.02
85	134	119.13	14.87	159.51	74.35	319.02	393.37
86	135	119.85	15.15	158.51	75.75	317.02	392.77

It can be noted from these results that when as assumption of values of daily process capacity, values of average daily machine running appear to be in continuous increment with every increment of the assumption of daily process capacity; i.e. the relation between them is proportional. After that the system calculate the values of machine waiting time (Idle time) which also appear to be in continuous increment with any increment of the daily process capacity. Then the values of average daily order waiting time appears in **Table (4)** and it is in continuous decrement with every increment in the assumption of the values of daily process capacity, then the columns of the cost as shown in the same table. These columns illustrate the cost of idle time which appears to be in continuous increment because the idle time is already in continuous increment. The cost of order waiting time is always in decrement situation according to the decrement of the values of average daily order waiting time. After that the system sketches these results as a curves as shown in **Fig.(4).** The same figures and tables show that the optimum capacity lies at 130 machine hours. This level of process capacity is considered as aggregate solution and will be refining in next step by technique optimization Response Surface Methodology (R-technique).

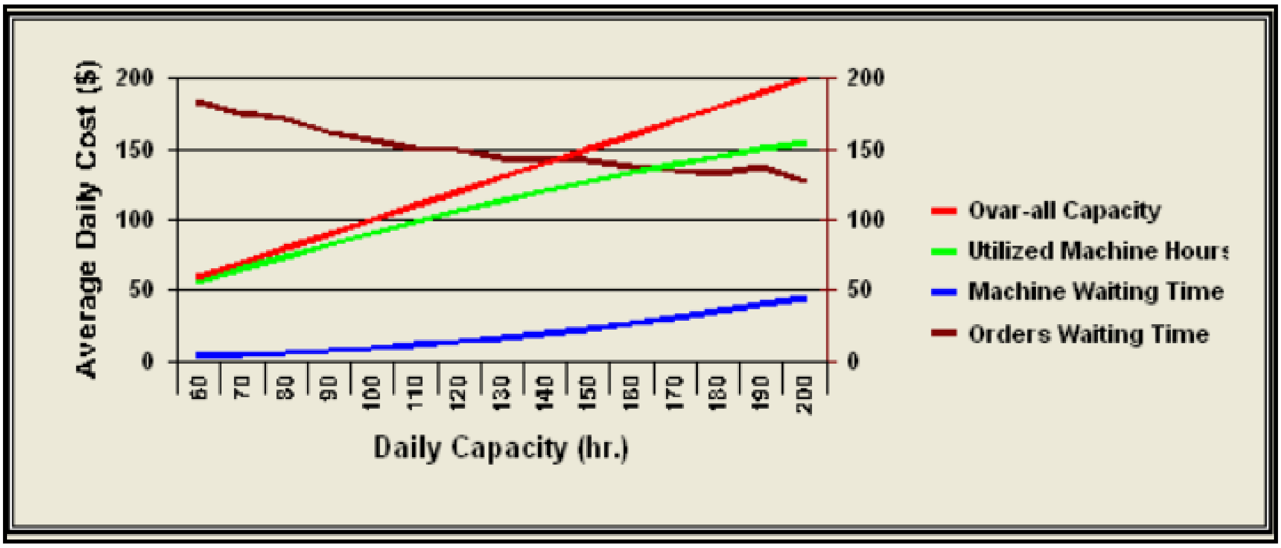

Fig. (4): Effect OF Altering the Plant Capacity.

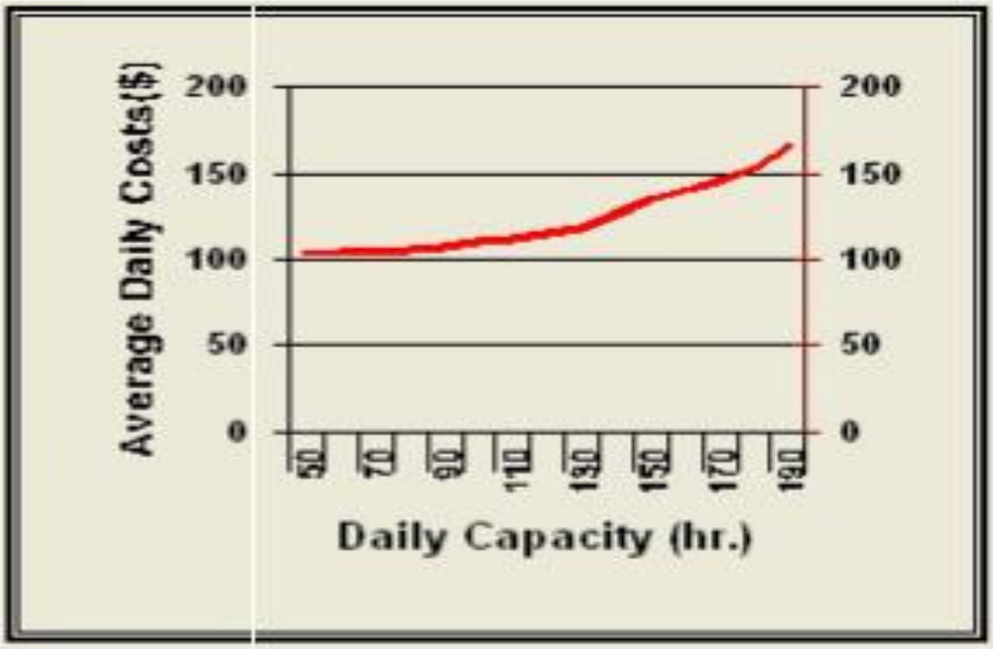

Fig. (5): Effect of Plant Capacity on Average Penalty Costs per Day.

After applying the daily process capacity which determined by ASS system in workshop, the queue of waiting order decreases as shown **Fig. (6).**

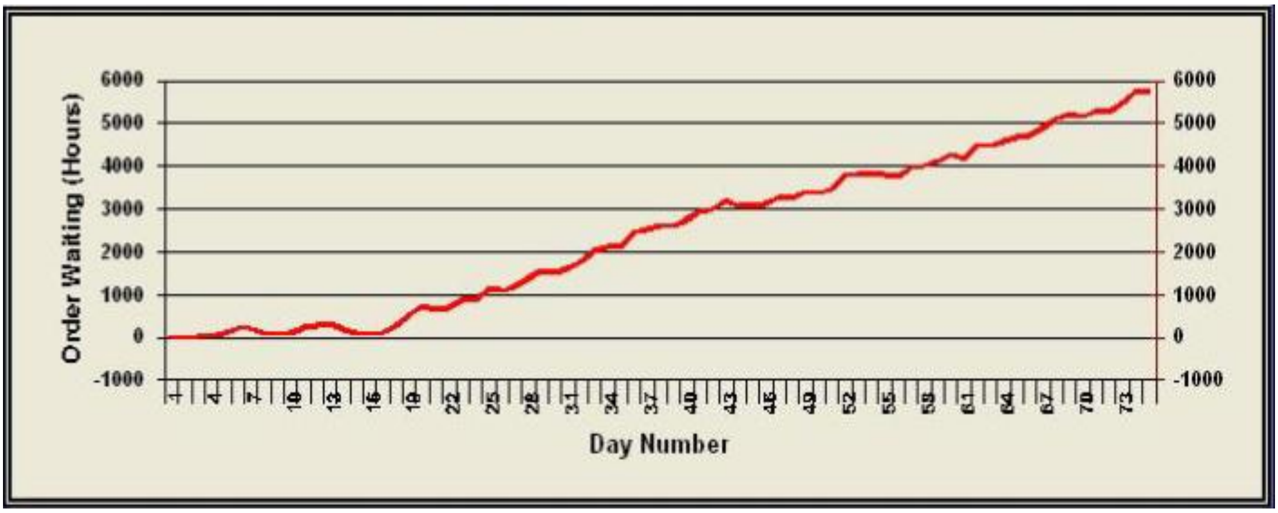

Fig. (6): Queue of Waiting Orders (measured in Machine Hours) when Capacity is 130hours).

Applying Optimization RSM Techniques to Refine the Design Solution

The objective of the proposed simulation-based optimization is to arrive at the closest to optimal solution alternative (in terms of a set of Daily Capacity value as a design parameters and a set of Total cost as a system performance metrics) at which the overall machine capacity utility score is maximized with minimum cost.

Model Fitting

Once the simulation results are acquitted, model fitting technique can be implemented to portray analytically the relations between input factor (Daily Capacity) and the output measures (Average Daily Machine Running, Average Daily Machine idle time, Average Daily Order Waiting time, Idle Time Cost, Order Waiting Cost, Total Cost). Due to the effect of one factor, Linear Fitting is performed with respect to all performance measures. **Table (5)** is obtained from the Statistical Discovery Software™ (JMP) version 5.0 which was used in this research for regression and graphical analyses of the data obtained for the Idle Time Cost model. This table contain model-fitting measures, including coefficients of determination and the contribution of term to the model sum-of squares and the linear equations fitted by the method of least-squares for all output measures. This linear regression equation is obtained through the analysis of variance for the simulation results. Fitted values are as close as possible to observed values, namely, minimization of residuals or error of prediction. The required assumptions of uncorrelated error with mean zero and constant variance has to be carefully verified through residual analysis. Linear fit plot for the Idle Time Cost model presented in **Fig (7).**

Table (5): Summary of linear fit analysis with respect to the Idle Time Cost.

Analyses of Variance (ANOVA)

Source	***Sum-of-squares***	***DF***	***Mean square***	***R^2***	***F** Ratio*	***p-value Prob > F***
Model	2253.6562	2	448.461	0.99995	125.7436	< 0.0001
Residual	0.1131	38	3.566	0.054561	-	-

Cor Total	2253.7693	40	-	-	-	-

Parameter Estimates

Term	***Estimate***	*Std Error*	***t Ratio***	***Prob >*** **|*t*|**
Intercept	-46.65721	3.216401	65.05	<.0001
Daily Capacity	0.6254077	0.02464	-16.04	<.0001

Expected Idle Time Cost = **-46.65721 + 0.6254077 Daily Capacity**

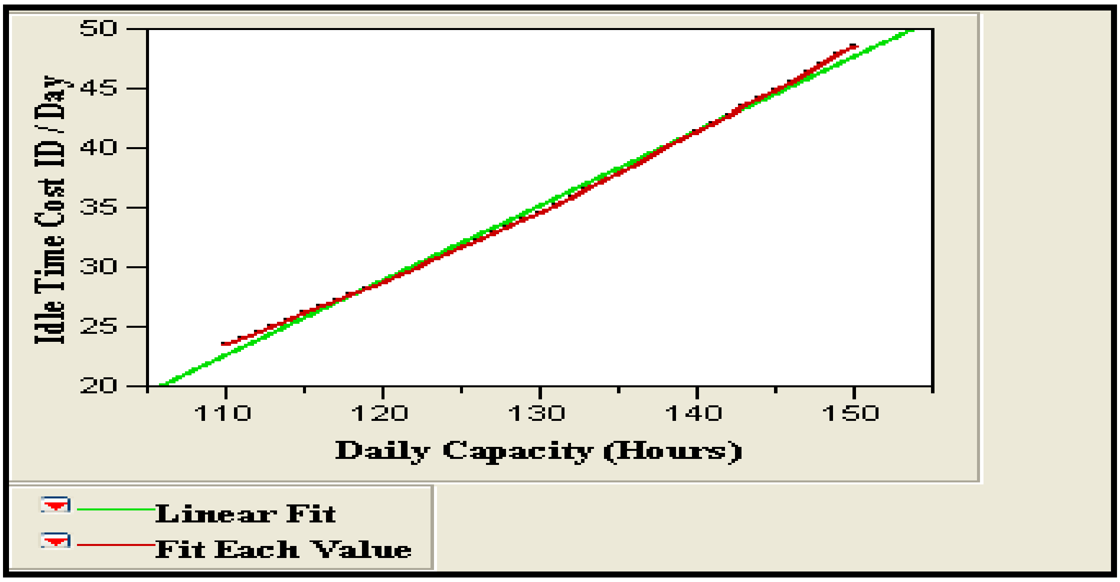

Fig. (7): A Model Fitting plot for the Idle Time Cost.

The statistical significance of the regression equations was checked by an F-test (ANOVA). The ANOVA results showed that the model of performance measures is appropriate. The models was lowly significant ($p < .0001$) with a satisfactory value of determination coefficient $R^2=0.999$ for idle time cost, $R^2= 0.868$ for Order waiting cost, $R^2= 0.969$ for total cost, indicating that 99 %, 86 %, and 96 % of the variability in the response could be explained by the expected model equations given above in **Table (6).** This indicated a good agreement between the experimental and predicted values for out put measures**.**

Table (6): Regression equations for all performance measures.

Performance Measure	***Expected Model Equation***
Idle Time Cost	**-46.65721 + 0.6254077 Daily Capacity**
Order Waiting Cost	**104.59392 - 0.1973885 Daily Capacity**
Total Cost	**58.289843 + 0.4293258 Daily Capacity**

Optimizing By RSM

The factor in the design was studied at 41 values starting by 110 hours and the increment by one hour for each run end at 150 hours. The minimum and maximum conditions for the performance measures is set with respect to their requirements centrifuged at the best resources utility, and low cost.

Numerical Optimizing

A- Performance Mesures Settings

Table (7): Input settings of both the Input Factor (Daily Capacity) and Performance Mesures

Name	*Goal*	*Lower Limit*	*Upper Limit*	*Lower Weight*	*Upper Weight*	*Importance*
Daily Capacity	**Is in Range**	110	150	1	1	3
Idle Time Cost	**Is in Range**	23.58	48.58	1	1	3
Orders Waiting Cost	**Is target ≤ 74.76**	74.76	83.6	1	1	3
Total Cost	**Minimize**	107.18	125.13	1	3	3

B- Solutions for 41 Combinations of Categoric Factor Levels

Table (8): 30 Solutions found for 41 Combinations of Categoric Factor Levels.

Number	*Daily Capacity*	*Idle Time Cost*	*Orders Waiting Cost*	*Total Cost*	*Desirability*	
1	130	34.55	77.05	111.6	0.563	**Selected**
2	129	33.95	77.55	111.5	0.547	
3	128	33.38	78.05	111.43	0.528	
4	118	27.68	80.75	108.43	0.510	
5	127	32.8	78.55	111.35	0.508	
6	126	32.2	79.05	111.25	0.488	
7	121	29.33	80.4	109.73	0.478	
8	114	25.58	81.6	107.18	0.476	
9	117	27.15	81.25	108.4	0.464	
10	125	31.63	79.55	111.18	0.464	
11	120	28.75	80.9	109.65	0.443	
12	124	31.05	80.05	111.1	0.438	
13	116	26.63	81.75	108.38	0.412	
14	123	30.45	80.55	111	0.410	
15	119	28.2	81.4	109.6	0.401	
16	122	29.88	81.05	110.93	0.378	
17	131	35.13	78.84	113.97	0.360	
18	115	26.1	82.25	108.35	0.353	
19	111	24.58	82.6	107.18	0.336	
20	112	24.58	82.6	107.18	0.336	
21	139	40.65	77.26	117.91	0.216	
22	140	41.35	76.76	118.11	0.215	
23	138	39.98	77.76	117.74	0.215	
24	137	39.28	78.26	117.54	0.214	
25	141	42.05	76.26	118.31	0.213	
26	136	38.58	78.76	117.34	0.212	
27	142	42.75	75.76	118.51	0.211	
28	143	43.43	75.26	118.69	0.209	
29	135	37.88	79.26	117.14	0.208	
30	144	44.13	74.76	118.89	0.205	

Because the most important objective in the case study - workshop daily capacity machine level setting –closely related with total cost (Idle Time Cost & Orders Waiting Cost) , this fact take into consideration, the trade-offs between expected production cost and robust capacity planning.

Table (7) shows the input settings of both the input factor (daily process capacity) and performance mesures that are used by optimization procedure.

C- Optimum Solution

The results of performance measures for 41 combinations of categoric factor levels to yield a desirable answer of input factor as shown in **Table (8)** which indicated that similar results were obtained for the optimum value founded in search region for performance mesures satisfied. The value found to be 130 hours with a predicted a desirability grade of 0. 563. However, these are based on restrictive assumptions about the Input settings of both the Input Factor (Daily process Capacity) and Performance mesures. **Table (9)** summarizes the values of performance mesures associated with prediction optimum value of input factor listed in table. Therefore, it can be concluded that optimum daily process capacity level 130 hours as presented in **Fig. (8) &Fig. (9).**

Table (9): The values of Output Measures with respect to prediction optimum value of Input Factor.

Input Factor			
Name	***Low Level***	***High Level***	***Predicted Value***
Daily Capacity	110 Hours	150 Hours	130 Hours
Out Put Measures			
Name		***Predicted Value***	
Idle Time Cost		34.55 ID / Day	
Orders Waiting Cost		77.05 ID / Day	
Total Cost		111.6 ID / Day	

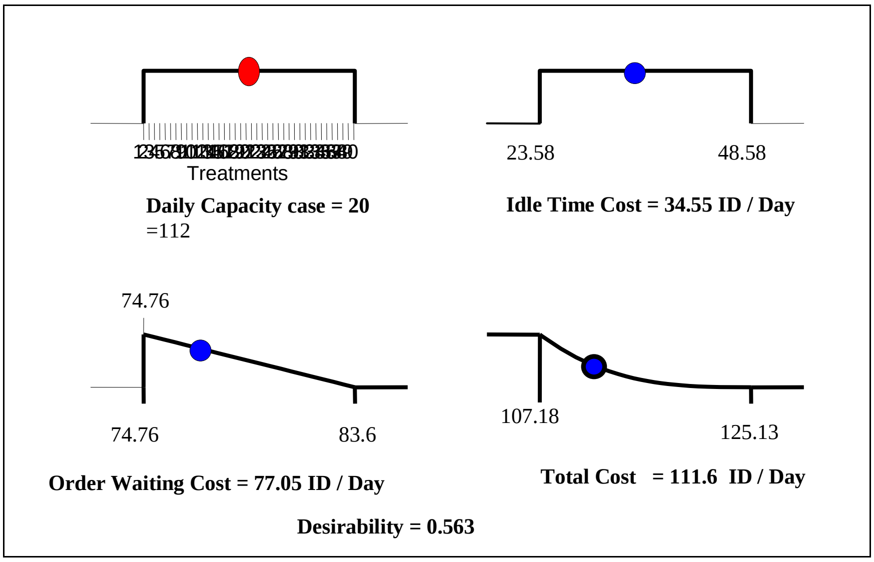

Fig. (8): Input Factor and Output Measures Values of the Best Solution calculated by RSM technique.

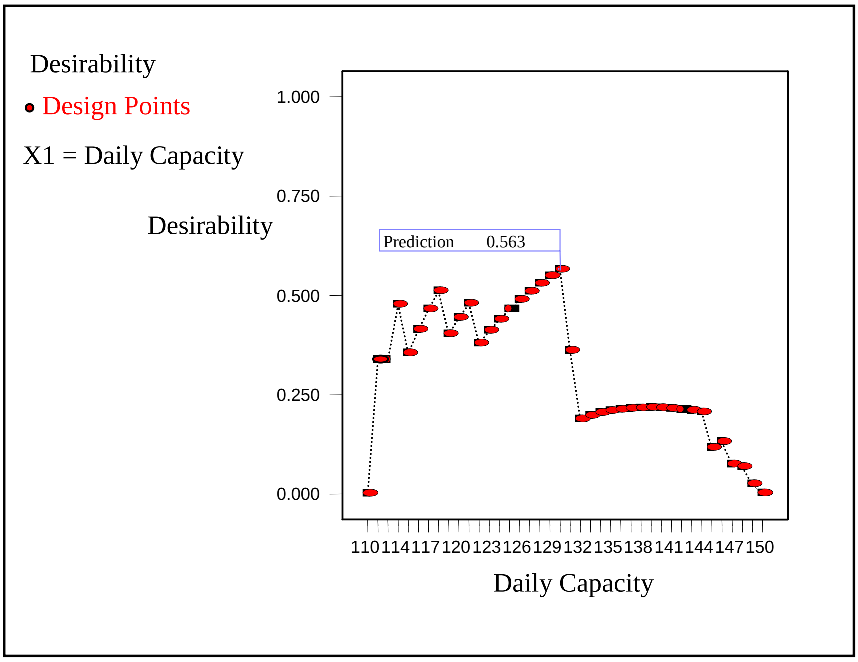

Fig. (9): Desirability grade for prediction point of optimum daily capacity.

These **Fig. (8) &Fig. (9)** reflects the role of input factor (Daily Process Capacity) on the controlled responses and then the out put measures (the costs) and this defined medium optimizing by one variable for determine the performance criteria , maximize utilizing accomplished with minimum cost. Further optimization for that variable to drawn at the desired value. Design Expert (Ver.7.0) was used in this investigation**.**

Graphical Optimizing

As mentioned, desirable feature for response surface design of input factor (daily process capacity) demonstrated at center point (130 hours), this factor was selected as key parameter to maximize the utility resources. **Fig. (10) and Fig (11**) present two-dimensional contour plots for the daily process capacity with respect to responses and output measures. The shapes of the contour plots, indicate that the interactions between the corresponding responses are significant and also indicates that the effects of input factor on responses & output measures on are significant. The optimum conditions inside the design boundary for daily process capacity were 130 hours.

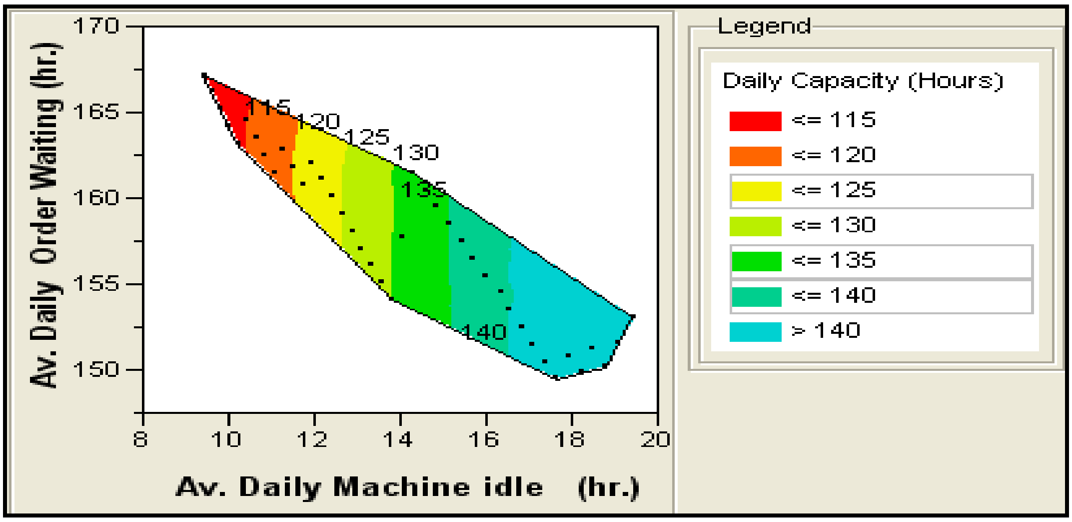

Fig. (10): A counter plot of the daily process capacity with responces average daily orders waiting time & average daily machine idle time in figure.

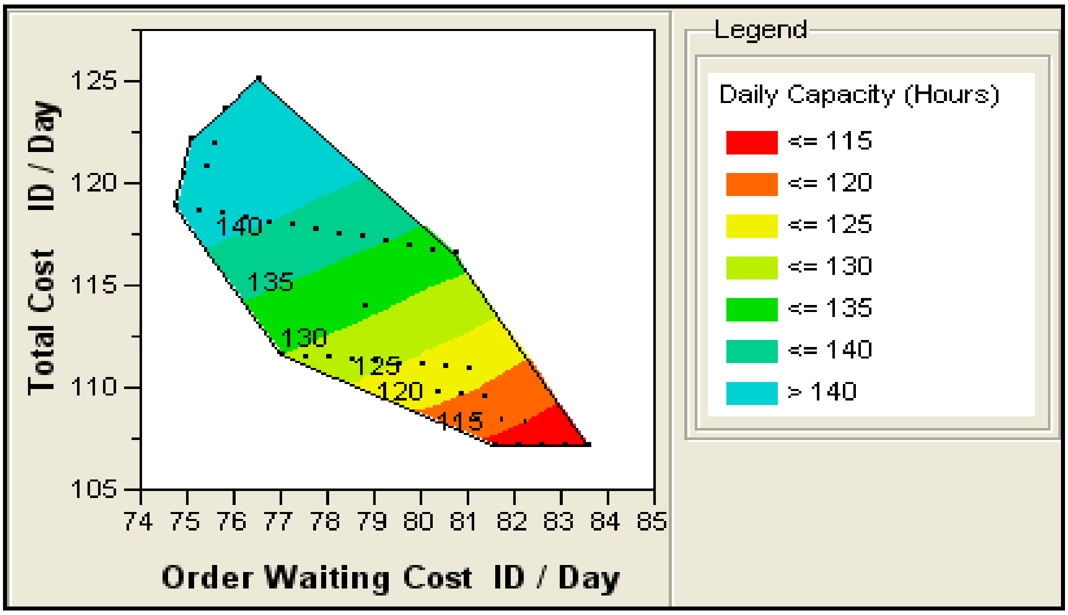

Fig. (11): A counter plot of the daily process capacity with output measures Orders Waiting Cost, and Total Cost .

In an optimization routine in the most general sense is a procedure that, when applied to a model, will result in the determination of the best model as defined by the fitness of an objective function. The optimization objectives can be formulated as follows: (a) maxim utilization of one type of available recourses (Available Daily Machine Capacity) (b) Minimizing the inherent cost matched within the context. From **Tables (8),** and **(9), Fig. (8),Fig. (9),Fig (10)** and **Fig. (11**), it is evident that the input data for available daily machine capacity satisfies the optimization objectives in the case study is 130 hours**.**

CONCLUSIONS

The practical investigation indicates that performance of a scheduling system is not evaluated to satisfy a single objective but to obtain a trade-off schedule regarding multiple objectives, this study provide a quick and favorable schedule for the addressed scheduling problem with minimization of one performance measure an economic criterion, namely minimum total cost and maximization of technological criterion utilization of overall capacity processes. Important entity is modeled using state variable that change only is available daily capacity. The simulation model advances by executing specific procedures at these values of variable and terminates when all values have passed**.** It can be concluded that:

1-In most cases, computerized tools enable an individual to simulate and evaluate a large number of design solutions with respect to multiple performance measures they overlook the effect of interactions among design factors that play significant role in the creating of best solution. RSM bridge these gaps by generating a set of alternative design solutions in systematic manner, and apply educated changes to configuration parameters. Such an approach enables to reach a satisfactory solution, with respect to both economical and technological measures, within limited number of examined solutions.

2- The proposed methodology emphasized the advantages of combining computerized tools such as simulation model system, and statistical design approaches such as RSM. Capacity planning is often characterized by continuous metric factors, such as daily capacity available, labor number, workdays,…., and cost that are well suited to be input factors to RSM.

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LIST OF ABBREVIATIONS

ASS	Automated Scheduling System
CR	Critical ratio
EICO	Electrical industrial company
ANOVA	Analysis of variance
ITC	Idle time cost
RSM	Response surface methodology

LIST OF SYMBOLS

DF	Degrees of Freedom
d_i	Individual Desirability Function
D_k	Multiple Objective Function
F Value	The Mean Square for the term divided by the Mean Square for the Residual
PRESS	The Predicted Residual Sum of Squares for the model
P-value	The Probability value that is associated with the F Value for the model
SD	Standard Error
λ	Mean arrival time (number of arrivals per unit of time)
μ	Mean service rate per busy server (number of customers served per unit of time)
Lq	Average (expected) number of customers in the queue
Ln	Expected number of customers waiting in line excluding the time when the line is empty.
ρ	Utility factor
C_a	Process Capacity……………………………………… hr/day
M	Number of machine
h_r	Number of activity hours.
R	The range of orders

xl	Upper of limit
x_S	Lower of limit
H	Ranking of period
F_R	Relative frequency
K	Number of ranking
F_A	Absolute frequency
$N_O.$	Number of data
x	Orders number
μ	Arithmetic mean
σ	Standard deviation
$f(z)$	Function of normal distribution curve
z	Random variable
n	Limit of range
I_d	Idle time ………………………………………………..hr.
R_a	Average daily machine running time ……………………..hr.
W_d	Working days
Mh	Machine hours……………………………………………..hr.
O_{dw}	Average daily order waiting time………………………… hr.
C_{it}	Cost of idle time……………………………………ID/day
C_{hi}	Cost per hour of idle time ………………………………ID
C_{ow}	Cost of orders waiting ………………………………..ID/day
C_{hw}	Cost per hour for orders waiting…………………………..ID
C_t	Total cost ……………………………………………ID/day
M/C.H.	Machine hours……………………………………………..hr.
C.F	Cumulative frequency