The performance improvement of water pump manufacturing system via multi-criteria decision-making and simulation (a case study: Iran Godakht Company)

Mohammad Ziaei
Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Isfahan, Iran
Email: Mohammad.ziaei@hotmail.com

Seyed Mojtaba Sajadi
Faculty of Entrepreneurship, University of Tehran, 1439813141, Tehran, Iran
Email: Msajadi@ut.ac.ir

Mohammad Mehdi Tavakoli*
Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Isfahan, Iran
Email: mohamadmahdi.tavakoli@gmail.com
*Corresponding author

Abstract: The performance improvement of a manufacturing system is a major component of maintaining the position of a company in the present competitive world. In the present dynamic environments and complex markets and based on the responding time significance, the optimisation of the performances has become a vital factor for the companies and their competitive. In this paper, simulation software is applied to evaluate the process of water pump manufacturing in Iran Godakht Company, in order to determine the barriers present in supplying the final customers with their needed products, and then some suggestions are offered to meet these barriers. To do so, the production process was assessed. Then their time distribution was determined for the simulations. In the next step, the ARENA Software was utilised to perform the modelling of the manufacturing process and based on the results, three new scenarios were introduced, and finally, multi-criteria decision-making approaches were applied to select the optimised scenario.

Keywords: simulation; assembling line; ARENA software; multi-criteria decision-making; MCDM; TOPSIS.

Biographical notes: Mohammad Ziaei graduated in Iran with BS degree in Industrial Engineering in 2011. Currently, he is an MSc student of Industrial Engineering at Najafabad Branch, Islamic Azad University, Isfahan, Iran. He is interested in quality management, data envelopment analysis, multi-criteria decision-making and resource management. Also, he has published several papers at national levels in refereed journals and conferences since 2013.

Seyed Mojtaba Sajjadi is an Assistant Professor of Faculty of Entrepreneurship at University of Tehran, Iran. He received his BA in Industrial Engineering, Industrial Production, from Sharif University of Technology, MS in Industrial Engineering from the University of Tehran and PhD in Industrial Engineering from Amirkabir University of Technology. His research interests include discrete event simulation, meta-heuristic algorithms, production planning, supply chain management, queuing theory and design of experiments. His published research articles appear in *IJAMT, Energy Journal, Operation Production* and others. He has presented several papers at the CIE40, ENBIS9, IJPR21 and several national conferences.

Mohammad Mehdi Tavakoli graduated in Iran 2010 and 2012 with BS and MS degrees in Industrial Engineering. He is a PhD candidate in Industrial Engineering at Research and Science Branch, Islamic Azad University, Tehran, Iran. He is interested in quality management, data envelopment analysis, multi-criteria decision-making and resource management. Also, he has published several papers at national and international levels in refereed journals and conferences since 2011.

1 Introduction

In order to remain in the present competitive world, organisations require a dynamic and optimised system in such a way that they should be ready to meet their clients’ continuous changing needs (Wang et al., 2011). Determining the best planning approach for production is an old challenge in engineering in a way that at first, the specialists were looking for the optimisation of the machineries and equipments and their efficiency to achieve the maximum production. The improvement of any system is performed with some purposes such as the investment reduction on machineries and facilities, reduction of the production time, space optimised utilisation, material transfer cost reduction, and facilitating the production process (Nahmias, 2005).

In order to optimise the manufacturing systems, various heuristic algorithms are proposed and useful software packages are available (Balakrishnan, 2000). As some industries are greatly complicated, such as automobile manufacturing companies and assembly ones, it is not easily and readily possible to quickly modify their manufacturing systems and it is hard, expensive, and time-consuming to determine and measure their compatibility with the customers’ needs. Therefore, it is first needed to determine and evaluate the proposed plans and run after their approval (Carlson and Yao, 1992; Tjahjono and Fernandez, 2008). Nowadays, manufacturing lines undergo the evaluations via computerised simulation tools and analytical models to improve them and increase their efficiency and operational power. These tools simulate the manufacturing systems with their different components and reveal the operational results (Li et al., 2009).
In the process of human development, more complex systems are developed and accordingly, their management, surveillance and control get more complicated. Due to the interactive influences of various parts of system on each other, the simulations help managers and engineers to properly analyse the systems. Simulations are in fact the modelling of a system with the aim of its real behaviours determination (Banks et al., 1996).

For system analysis, various tools are available, such as linear and nonlinear programming, dynamic programming, integer programming, queue theory and GERT mathematical models, but in all these tools, some features of the real system are dealt with and they try to simplify the real system. These approaches cannot reveal the complex relations and random factors of a real system which it decreases the accuracy level of the system analysis. Therefore, simulations are regarded as one of the most efficient and advanced tools for system analysis (Banks et al., 1996). Generally, simulation are those techniques that help the organisations predict, compare, and optimise their operational results and their decision-making processes without having more expenditures and current flow changes risk and running new processes. The main purpose of the simulation models is providing some bases for system behaviour predictions. Generally, simulations are used when the analytical approaches are not applicable due to the complexities of the system of interest (Banks et al., 1996; Shannon, 1975).

Several efforts have been done to improve the manufacturing systems via computerised simulation tools. For example, in a research, the simulation tools were utilised to evaluate the results of applying flexible manufacturing systems (Smith, 2003). Suresh (1992) has evaluated different establishment plans by considering several concurrent factors such as the inventory level, the size of the manufacturing cells and the amount of the inter-cellular movements. In another research, the role of computers in fostering the production process was dealt with through applying simulation tools (Iassinovski et al., 2008). Baykoc and Erol (1998) have evaluated the performance of the just in time (JIT) production system under various conditions. They benefited from computerised simulations to evaluate the influence of various factors on the system performance such as the goods, production lines and different stages of the production and determining the most influential factors on the system inefficiency (Baykoc and Erol, 1998). In another research by Merkuryev et al. (2002), the combinatory effect of the two strategies of divergent and convergent information distribution with the inventory control systems of MINMAX and STOCK TO DEMAND were concerned in predicting the demands. To do so, they utilised computerised simulations and ARENA Software (Merkuryev et al., 2002). Other research applied kanban tools to simulate the production. Kanban is a data card which is utilised in manufacturing controls, especially in micro ones. They simulated the application of this tool for scheduling, process leadership and operation timing (Iassinovski et al., 2008). Ekren and Ornek (2008) concurrently applied simulation tools and design of experiment (DOE) planning in their study to evaluate the results of selecting two cellular layouts (CL) or functional layouts (FL) on the performances of the manufacturing system (Ekren and Ornek, 2008). Cha et al. (2012) evaluated those factors affecting on ship manufacturing to prevent probable dangers by developing simulation tools. Not only they simulated some manufacturing equipments like cranes and electricity wires, but also the external factors like water pressure and wind flow that all affect the improvement of the manufacturing systems were concerned (Cha et al., 2012).
Here, in this study, in order to optimise the production line of water pumps in Iran Godakht Company, computerised simulation tools are utilised. To do so, at first, the production process and working stations were evaluated and by time-measuring tools, the time or duration of the processes are obtained. In the next step, the probable distribution of each process is determined and then, the ARENA software is utilised to perform the simulations of the production process. In the following parts of this study, the software results are used to define some scenarios and at last, the best one is selected according to the results of each scenario via applying multi-criteria decision-making (MCDM) approaches. Section 2 provides the Shannon’s entropy weighting approach. Section 3 explains TOPSIS techniques for prioritising or ranking of the scenarios. The description of the problem and manufacturing process are dealt with in Section 4. Section 5 includes the modelling and simulations of the manufacturing process and the results are given in Section 6. Then the proposed scenarios are expressed to improve the manufacturing line of water pumps, and in Section 7, the best scenario is selected and the conclusion is provided in Section 8.

2 Entropy Shannon weighting approach

Shannon (1948) defined the concept of entropy as measuring the uncertainties of the data present in a problem. Entropy is a simple and important approach for weight evaluation in which, the value dispersion of an index is utilised to determine the index weight and it reveals the contradiction intensity of each index to show the data (Zeleny, 1996; Wang and Lee, 2009).

The index weights are provided by applying Shannon’s entropy. To do so, the following steps should be followed (Wang and Lee, 2009):

1 Index normalisation in direct style:

\[ P_j = \frac{X_{ij}}{\sum_j X_{ij}} \]

2 Obtaining the index of \( E_j \) for each of the criteria by the following relation:

\[ E_j = -k \sum P_j \ln(P_j) \quad K = \frac{1}{\ln m} \quad m = \text{number of alternatives} \]

3 Obtaining the index of \( D_j \):

\[ D_j = 1 - E_j \]

4 Getting the final weight of each index:

\[ W_j = \frac{D_j}{\sum D_j} \]
3 TOPSIS

In MCDM approaches, several criteria are applied to evaluate some alternatives. The purpose of these approaches is supporting the decision-maker in the selection process among some items. In these approaches, the final answer may contradict with each of the criteria and no items may satisfy all the others (García-Cascales and Lamata, 2012).

TOPSIS is one of the best and most popular multi-index decision-making approaches which based on easy and simple logic, was first introduced by Hwang and Yoon in 1981. The logic of this approach is in this way that it generates a positive and a negative ideal item and then it evaluates and ranks the selection item based on the least and most distances from the positive and negative ideal items, respectively (Yoon and Hwang, 1995). The ideal item is the one with the maximum benefits and the anti-ideal one is the opposite (Langkumaran and Kumanan, 2009). In other words, the positive ideal item maximises the profitability items and minimises the expenditure ones while the negative ideal solution does the opposite (Behzadian et al., 2012).

Due to the item comparisons with the best and worst items, TOPSIS is regarded as one of the most suitable approaches for service plans. That means, it enables us to determine those problem generated in long term for the customers due to the lack of service-providing. This is also performed through determining low performances (Nejati et al., 2009).

The following steps are required to solve TOPSIS problems (Jamali and Sayyadi, 2009):

Step 1 Weightless decision-making matrix determination

At first, the decision-making matrix \((N)\) is generated and as the indices have different scales the following formula is utilised to make the decision-making scale-less matrix.

\[
n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}
\]

Step 2 Weighted/harmonic scale-less decision-making matrix determination

At this stage at first the weight of each index is determined and by multiplying the weight matrix into the scale-less decision-making matrix, the weighted/harmonic scale-less decision-making matrix is given.

\[
N D \times W_{w_h} = V
\]

Step 3 Ideal and anti-ideal item determination

(The vector of the best value for each matrix index \(V\)) = ideal item \((V_j^{+})\)

(The vector of the worst value for each matrix index \(J\)) = anti-ideal item \((V_j^{-})\)

For the positive indices, the best value is always the highest one and the worst value is always the lowest one.

For the negative indices, the best value is always the lowest one and the worst value is always the highest one.
Step 4 Determining the distance of each item from the ideal and anti-ideal items

In order to find the distance of each item from the ideal and anti-ideal ones, the following relations are utilised:

\[
S_i^+ = \sqrt{\sum_{j=1}^{n} (V_y - V_j^+)^2} \quad i = 1, 2, \ldots, m
\]

\[
S_i^- = \sqrt{\sum_{j=1}^{n} (V_y - V_j^-)^2} \quad i = 1, 2, \ldots, m
\]

Step 5 Similarity index measurement of each item with the ideal item and final ranking

For this step, the similarity index (CL) is found by the following relation and the item with the higher CL is the better one.

\[
cl_i = \frac{S_i^-}{S_i^- + S_i^+}
\]

4 Methodology

The present study tries to determine the available deficiencies in the process of water pump manufacturing and then, providing some suggestions in order to remove these deficiencies. Through detailed analysis on the production line of this company and performing work and time measurements, the data regarding each work station are collected and then ARENA Software is utilised to simulate the manufacturing line of this company for evaluations and optimisations.

In order to perform the modelling of the manufacturing process with computerised simulations, required resources and time are needed for each manufacturing operation. Therefore, work and time measurements are done to determine the time-data of each activity. Then based on the provided time-data of each activity with time measuring and by applying MINITAB Software, the probability distribution of each work station is obtained for the simulation model.

In continues, ARENA Software is applied for simulating the manufacturing process of the company. This software allows the users to generate objects called modules which are the base of the model generation. All the components of a process like the data, logic, animation, and statistics collection could be modules for the determination of a process from which the entities pass. The entity is everything flowing through the model which here they mean the raw materials and semi-manufactured products which pass the work stations and lead to the final products.

At last, based on the simulations out comes, some scenarios are offered to improve the system performance, and by considering TOPSIS method, they are evaluated in order to recognise the most efficient one.

5 Case study

The problem of interest concerns with optimising the water pump manufacturing line in Iran Godakht Company. The company has been working in the field of manufacturing
different aluminium parts for cars and trucks since 1984, and at the moment, different water pumps produced by this company are used in Saipa and Iran Khodro Car Manufacturing Factories. As the automobile factories require their contractors to have quality license, all the products of Iran Godakht Company meet the global standards, and they have guarantees. As the investment of this company is provided by the private sector, profitability is the major concern of this company. In order to achieve that profit of interest for the shareholders, the company should have an optimised production line.

As stated earlier, Iran Godakht Company manufactures Peugeot 405 water pumps. To do so, the process of water pump manufacturing is done in three manufacturing workshops. Here at first, the materials are carried to the casting workshop and after passing thorough six working stations, they are transferred to the machining workshop to complete the process. In this workshop, five major operations are done on the body of the water pumps, and it finally enters the assembly workshop and it is by three working operations that the final products are manufactured. It is worth mentioning that the raw material for manufacturing the water pumps is the aluminium ingots.

**Figure 1** Manufacturing water pumps process

5.1 The description of the processes in casting workshop

As stated above, in the first step of manufacturing water pumps, the primary materials enter the casting workshop. At first, aluminium ingots are heated in special furnaces to the melting temperature. Then the additives are added. After the preparation of the melting materials, the next step includes the water pump body casting. Following the initial finishing, the parts are transferred to the grinding and countersinking stations. The final stage is the shot blast operation and the parts are carried to the machining workshop.

**Figure 2** Manufacturing process in casting shop
5.2 The description of the processes in machining workshop

At first, the parts are located in fixtures to label tracing numbers on them. Then based on the samples and operational instructions, the five-hole drilling is performed on the body. Washer housing drilling is performed by the supervision of the production managers and after the machining, the bodies undergo the leakage tests.

**Figure 3** Manufacturing process in machining workshop

5.3 The description of the processes in assembly workshop

In this stage, the final operations for water pump production are done and the products are transferred to the customers. In this workshop, following the arrival of the bodies, they enter the ball bearing assembly department. Finally, the water pump leakage tests are performed and the products leave the process.

**Figure 4** Manufacturing process in assembly shop

Regarding to the aforementioned, performing the modelling of the above mentioned manufacturing process with computerised simulations, needs proper resources and time for each manufacturing operation. Therefore, based on the time measuring of each activity and by applying MINITAB Software, the probability distribution of each of the working stations are obtained for the simulation model. The provided durations and the probability distribution for each of the working stations are shown in Table 1. All the times are in minutes (s).

Now, ARENA Software is applied to simulate the manufacturing process of the company. By choosing proper modules, the related simulation model is completed. The raw input ingots are arrived with exponential distribution with the average time of 1 minute, and after passing through 14 working stations with independent resources and the capacity of 1 unit, they are transferred to the customers. It is worth mentioning that the transfer time between two stations follows a triangular distribution with (1.5, 1.7, 2) minutes. The model is run for 12 hours (equal to a working day with two shifts) and the results were evaluated to determine the probable problems in the production line of Iran Godakht Company.
Table 1  Provided durations and the probability distribution for each of the working stations

<table>
<thead>
<tr>
<th>Process number</th>
<th>Working stations</th>
<th>Durations</th>
<th>Probability distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Melting</td>
<td>1</td>
<td>Constant (1)</td>
</tr>
<tr>
<td>2</td>
<td>Casting</td>
<td>1.6, 1.7, 1.4, 1.5, ...</td>
<td>Uniform (1.4, 1.8)</td>
</tr>
<tr>
<td>3</td>
<td>Finishing</td>
<td>1.9</td>
<td>Constant (1.9)</td>
</tr>
<tr>
<td>4</td>
<td>Grinding</td>
<td>2.7, 2.6, 2.8, 2.6, ...</td>
<td>Uniform (2.6, 2.8)</td>
</tr>
<tr>
<td>5</td>
<td>Countersinking</td>
<td>3</td>
<td>Constant (3)</td>
</tr>
<tr>
<td>6</td>
<td>Shot blast</td>
<td>2</td>
<td>Constant (2)</td>
</tr>
<tr>
<td>7</td>
<td>Engraving</td>
<td>1.9, 1.9, 1.9, 1.8, ...</td>
<td>Triangular (1.6, 1.9, 2)</td>
</tr>
<tr>
<td>8</td>
<td>Body drilling</td>
<td>1.15, 1.12, 1.11, ...</td>
<td>Uniform (1.11, 1.15)</td>
</tr>
<tr>
<td>9</td>
<td>Washer housing drilling</td>
<td>1.26, 1.25, 1.27, ...</td>
<td>Uniform (1.25, 1.30)</td>
</tr>
<tr>
<td>10</td>
<td>Machining</td>
<td>1.29, 1.28, 1.30, ...</td>
<td>Triangular (1.27, 1.29, 1.32)</td>
</tr>
<tr>
<td>11</td>
<td>Leakage test</td>
<td>1.9, 2, 2.3, ...</td>
<td>Uniform (1.9, 2.4)</td>
</tr>
<tr>
<td>12</td>
<td>Ball bearing assemblage</td>
<td>1.9, 1.8, 2.1, ...</td>
<td>Triangular (1.7, 1.9, 2.2)</td>
</tr>
<tr>
<td>13</td>
<td>Pully assemblage</td>
<td>1.8, 1.9, 1.7, ...</td>
<td>Uniform (1.6, 1.9)</td>
</tr>
<tr>
<td>14</td>
<td>Water pump leakage tests</td>
<td>1.13, 1.14, 1.12, ...</td>
<td>Uniform (1.11, 1.15)</td>
</tr>
</tbody>
</table>

Figure 5  Process simulation in arena software (see online version for colours)

6  Simulation result analysis

In this level, the results and findings of the simulated model of the previous stage are evaluated.

a  The entities in the simulation duration waited about 6,063 seconds in queues and lines to have services from the resources and transporters. Just about 1,482 seconds of the total time for the primary raw materials generated value-added and about 207 seconds were spent for the material transfer between two stations. This is depicted in Figure 6.

b  The value-added time (VA time) of each working station is shown in Table 2. As we can see the working station of body drilling spends the lowest time and the working stations of grinding and countersinking spend the highest time for adding the values to the products.
The working efficiency and productivity of each station for the needed operation on the primary input materials are shown in Table 3. As we can see, the present resources of working stations number 4 and 5 have efficiency close to 100%.

The average number of the entities waiting in line and queues in the grinding working stations is about 36.58 units and its mean value is 4,269.45 seconds, which has the highest value among all the 14 stations.

The number of the output completed products in a working day (equal to 720 minutes) is 231 units. The average number of the work-in-process (WIP) products is 64.56 units.

Figure 6 Different type of elapsed time in the system

![Figure 6](image)

Table 2 Value-added time (VA time) of each working station

<table>
<thead>
<tr>
<th>Process number</th>
<th>Working stations</th>
<th>VA time per entity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MELTING</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>CASTING</td>
<td>96.81</td>
</tr>
<tr>
<td>3</td>
<td>FINISHING</td>
<td>114</td>
</tr>
<tr>
<td>4</td>
<td>GRINDING</td>
<td>161.56</td>
</tr>
<tr>
<td>5</td>
<td>COUNTERSINKING</td>
<td>180</td>
</tr>
<tr>
<td>6</td>
<td>Shot blast</td>
<td>120</td>
</tr>
<tr>
<td>7</td>
<td>Engraving</td>
<td>110.05</td>
</tr>
<tr>
<td>8</td>
<td>Body drilling</td>
<td>67.7978</td>
</tr>
<tr>
<td>9</td>
<td>Washer housing drilling</td>
<td>76.4686</td>
</tr>
<tr>
<td>10</td>
<td>Machining</td>
<td>77.66</td>
</tr>
<tr>
<td>11</td>
<td>Leakage test</td>
<td>129.53</td>
</tr>
<tr>
<td>12</td>
<td>Ball bearing assemblage</td>
<td>115.93</td>
</tr>
<tr>
<td>13</td>
<td>Pully assemblage</td>
<td>104.41</td>
</tr>
<tr>
<td>14</td>
<td>Water pump leakage tests</td>
<td>67.7657</td>
</tr>
</tbody>
</table>
Figure 7  Value-added time (VA time) of each working station

Table 3  Productivity of each resource

<table>
<thead>
<tr>
<th>Number of resources</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5042</td>
</tr>
<tr>
<td>2</td>
<td>0.8129</td>
</tr>
<tr>
<td>3</td>
<td>0.9363</td>
</tr>
<tr>
<td>4</td>
<td>0.9999</td>
</tr>
<tr>
<td>5</td>
<td>0.9901</td>
</tr>
<tr>
<td>6</td>
<td>0.6581</td>
</tr>
<tr>
<td>7</td>
<td>0.5999</td>
</tr>
<tr>
<td>8</td>
<td>0.3688</td>
</tr>
<tr>
<td>9</td>
<td>0.416</td>
</tr>
<tr>
<td>10</td>
<td>0.4207</td>
</tr>
<tr>
<td>11</td>
<td>0.701</td>
</tr>
<tr>
<td>12</td>
<td>0.6233</td>
</tr>
<tr>
<td>13</td>
<td>0.5607</td>
</tr>
<tr>
<td>14</td>
<td>0.3632</td>
</tr>
</tbody>
</table>

Figure 8  Productivity of each resource
Providing the proposed scenarios and selecting the proper scenario with TOPSIS

The first point provided by close evaluation of the results is the fact that the working station of grinding, countersinking, and finishing have the highest efficiency. Not only they increase the wait time of the semi-manufactured products wait time, but also generate some bottlenecks in the trend of manufacturing the needed items. Based on the contracts of this company with Iran Khodro Company to supply 250 units of items per day, the production of 231 parts a day is never enough that leads to the customers’ dissatisfaction and finally, lose the market share. Then it seems that the transfer time between the workshops is a logical one, and it is not needed to increase the number of the transporters. The stations of body drilling, washer housing drilling and machining spend fewer time and duration for adding economic values to the items. Therefore, in order to improve the competitive position of the organisation, some proposed scenarios could be outlined in the headlines of the organisational top management.

1 As the highest efficiency among the 14 working stations belongs to the grinding one, adding any other resources to this station increases its efficiency to 66.42% and in fact, it removes any bottlenecks generated in this working station. But as the bottlenecks from the finishing and countersinking stations are potentially present, the wait time of the parts increases to 7,009.61 seconds and no improvements are seen in the manufactured products of the organisations.

2 If any other resources are added to the working stations of grinding and countersinking, the bottlenecks of these two ones are removed and the wait time is declined to 4,360.73 seconds, which is 1,703 seconds less than before, and then the total number of the manufactured products increases with 92 units. With the production of 323 parts a day, not only this company is able to do its commitments to Iran Khodro Company, but also it can find a greater share in the market.

3 If any other resources are added to the working stations of grinding, finishing and countersinking, which have the greatest efficiency among the other 14 working stations, it can modify or balance their bottlenecks and with a 2,967.62 second decline, which reduces the wait time of the semi-manufactured products to 3,095.38 seconds.

In this stage, the ranking of the proposed scenarios are performed which it is done based on the three indices of the total wait time of the semi-manufactured products, the number of the manufactured products in a week and the production line total efficiency. To do so, TOPSIS approach is utilised and the ranking of the scenarios are as the followings:

Step 1 In the first step, the decision-making matrix is generated which is depicted in Table 4.

Step 2 In this step, weighted/harmonic scale-less decision-making matrix is generated and accordingly, the ideal and anti-ideal items are determined. The results are depicted in Table 5.

Step 3 In this step, the distances of each scenario to ideal and anti-ideal items are determined and accordingly, the similarity index (CI) is obtained and the rank of each scenario is determined. The results of ranking the proposed scenarios are shown in Table 6.
The performance improvement of water pump manufacturing system

Table 4  Decision-making matrix

<table>
<thead>
<tr>
<th>Indexes scenarios</th>
<th>Waiting time (parts waiting times in queue)</th>
<th>Num out (number of produces in each week)</th>
<th>Productivity of production line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario number 1</td>
<td>7009.67</td>
<td>231</td>
<td>0.65</td>
</tr>
<tr>
<td>Scenario number 2</td>
<td>4360.73</td>
<td>323</td>
<td>0.81</td>
</tr>
<tr>
<td>Scenario number 3</td>
<td>3095.38</td>
<td>320</td>
<td>0.84</td>
</tr>
<tr>
<td>Entropy-Shannon weight</td>
<td>0.736</td>
<td>0.167</td>
<td>0.097</td>
</tr>
</tbody>
</table>

Table 5  Ideal and anti-ideal items

<table>
<thead>
<tr>
<th>Parts waiting times in queue</th>
<th>Number of produces in each week</th>
<th>Productivity of production line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal item</td>
<td>0.258</td>
<td>0.105</td>
</tr>
<tr>
<td>Anti-ideal item</td>
<td>0.58</td>
<td>0.075</td>
</tr>
</tbody>
</table>

Table 6  Ranking scenarios on the base of similarity index

<table>
<thead>
<tr>
<th>Number of scenario</th>
<th>Similarity index</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>0.68</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

8  Conclusions

In the recent competitive world, the on-time and quick supply of the products to satisfy the customers is a big necessity to maintain the organisational competitive position. Therefore, it is needed to determine the problems and deficiencies involved in the production, and then planning and involvements are required to meet them. To do so, in the present paper, the deficiencies in the production process of water pumps are determined which it is done by applying ARENA Software and evaluating the processes of Iran Godakht Company. The production line of this company is in the workshop or job shop style; that is, the primary materials pass through the three workshops of casting, machining and assembly and after passing through various manufacturing processes, they are turned into the final products.

The bottlenecks generated in the manufacturing process of the final product which is due to high efficiency of the working station of grinding, finishing and countersinking, makes the company unable to do its commitment for producing at least 250 items a day. Therefore, increasing the number of the manufactured products via the optimisation of the production line is of a great significance. Evaluations performed on the proposed scenarios reveal that the third proposed scenario can improve the performance indices of the organisation in the best way. That means, increasing the resources of each working station of finishing, grinding and countersinking not only removes the bottlenecks and declines the wait time of the parts, but also it increases the daily total number of the products to 320 items.
Generally, it could be stated that the troubleshooting performed here and consequently, the suggestion to meet them can help the organisational managers to increase the efficiency of the organisations of their own and improve their market share and in this way, improve and increase the profitability of the organisations. It is obvious that this profitability can compensate these expenditures spent by the organisational managers to meet these problems in a short time.

Beyond the above mentioned benefits, this article is faced with some limitations. For example, the transfer conditions of the final product from the manufacturing locations to the market place are not considered that deliberation on the time and needed transporters for optimisations can be done. The supply of the primary materials from the supplying centres are not considered either. Moreover, as the needed time for the transferring between the working stations of a workshop is negligible compared to the required time to perform the processes, its value is not considered in the model either. Finally, considering the daily production and the probable malfunctions of the machineries and equipments causes the determination of the deficiencies in the manufacturing process of the final products which the customers require, and the needed solutions to meet these problems are provided. Therefore, the researchers can evaluate the style and conditions of the product transfer to the final market in their future studies. Selecting the suppliers of among the optimised suppliers is another field of study for the researchers. Considering the duration and time of inter-process transfer and the probable damages of the machineries can make the model more efficient, as well.

Acknowledgements

The authors would like to acknowledge the editor and reviewers of *IJPQM* for their valuable comments and suggestions.

References


