

# Application of Taguchi Approach to Forecast the Wages of Persian Silk Carpet Weavers

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## ABSTRACT

One of the remarkable phenomena in recent years is the growing trend of globalization. Iran is also seeking to join the World Trade Organization (WTO) to expand non-oil exports and presence in global markets, and is currently a member of the organization's oversight body. Handmade industries such as hand woven carpet are one of the important trades that can be studied for this purpose. Exports of handmade carpets have fluctuated over different time periods. Despite maintaining its international position as the rank of the largest exporter of handmade carpets, the export position of handmade carpets is decreasing as compared to other Iranian exports. Handmade carpet craftsmanship is a complementary activity of agricultural and rural businesses, but due to the considerable number of workers and the small share of carpet value added in the national economy, it does not have a suitable condition. Other influential parameters such as rivals (e.g., China, India, Pakistan, and Turkey), etc. have caused the economic conditions of this industry to be unstable. In this regard, one of the best and most appropriate ways to compete with other countries is to reduce production costs and, consequently, reduce product prices. This factor includes various variables, including weavers' wages. Unfortunately, there is no definite and elaborate program for determining the wages of handmade silk carpet weavers in Iran according to the standard. In fact, in some cities, the weavers' wages determine based on the texture conditions, texture parameters, economic conditions of the country, and other parameters by carpet wage boards that consist of several carpet experts. In this way, there is the possibility of mistakes and the loss of the rights of weavers or producers due to the entry of personal opinion and the failure to classify the effect of different parameters on the final point.

The main purpose of this study is to collect various parameters affecting the wages of handmade carpet weavers in Iran. According to a collection of statistical data obtained from the country's most popular producers, the effects of different parameters were investigated through the Design of Experiment (DOE). Finally, the effect of each parameter was expressed as a percentage using Taguchi Approach (TA). The most important achievement of this research is that the obtained results can be used to prevent the loss of rights of

the people by providing an appropriate formula and detail table.

**Keywords**— Handmade Carpet, Carpet Weavers' Wage, Carpet Expert Council, Carpet Association, Design of Experiment, Taguchi Method

## I. INTRODUCTION

There are several parameters in determining carpet weavers' wages that the carpet expert council collects as the initial information from the workers. They arrive at a joint summing up to determine the salary based on input data, involvement of personal opinion, and presentation of different opinions. Based on existing documentation as well as many complaints, this method has drawbacks that cannot be seen and touched alone, but the problems can be clearly identified by comparing two carpets with similar characteristics alongside each other. Therefore, in this research, the authors have attempted to extract the percentage of the effective parameters on the final price announced by the expert council, so that the people's rights could be determined in the future with fewer problems. The initial information collected to determine the wages of the handmade carpet weavers are:

1. Carpet sizes (i.e., longitudinal and transverse directions), which is considered as the area in the calculations.
2. Duration of carpet weaving (based on the dimensions of the carpet and the complexity of the design), a certain time frame for its weaving should be considered. Then, people who are quick-weavers will be encouraged by increasing final wages and vice versa.
3. Pre-paid money for carpet weavers. Since manufacturers make a huge contribution to creating jobs in the area and apply a lot of initial capital, the most favorable way for manufacturers

is to pay the lowest prepayments for carpet weaving. In other words, paying the minimum wage to finish the carpet weaving. Therefore, to prevent the violation of rights of both sides, for each carpet, depending on the size and difficulty of the design and other parameters, it is possible to pay the money until the end of the carpet in an appropriate interval. Eventually, those who receive more money must be different from those who receive less money until the end of the carpet weaving, which can be made as a coefficient smaller or larger than the one for the final price of the wage.

4. Workshop distance from raw materials warehouse.
5. The number of colors: the final price announced for weavers' wages should increase by increasing the number of colors.
6. Complexity of the carpet design.
7. Weaving quality (based on excellent, very good, good, medium, and poor grades). However, artistic carpets cannot be priced using the relationship and the price table, but it can be solved by agreement between the sides or judged by someone who has the art of mastering and experiencing enough.
8. The premise of using this information is that the carpet is without defect and damage, and the amount paid for the safe carpet. Therefore, if there is a failure and defect in the carpet, the total price obtained should be fully compensated for the defect and, in some cases, half of it should be deducted from the short default of the duties of each party.
9. In this research, it is assumed that the woven carpet density is normal and the effect of the density is ignored. Of course, the density factor ( $\alpha$ ) can also be introduced as a tabulation to be multiplied at the final price of the wage.

## II. AN OVERVIEW OF THE HISTORY OF IRANIAN CARPET

The oldest Iranian handmade carpet was discovered in 1949 in the second stage of the Russian archaeological excavation, Rudenko, in the Pazyryk region, called the Pazyryk carpet. On the occasion of these discoveries in Russia in 1953, Rudenko described a detailed description of the discovered carpet in a book and explicitly expressed it as an Iranian work and the oldest Iranian carpet in the world. He wrote: "It is a great fact that we can definitely say this carpet is one of the territories of Mad-Parth (old Khorasan) or Pars, the history of the carpet and the fabrics discovered in Pazyryk is detected in the

fourth or early fifth century BC". Also, he said: "The history of this carpet is evident from the shape of horse riders. The manner in which the warhorses are shown on their back instead of the saddle of the carpet and the cloth on the horse's chest is from the Assyrian features. But on the Pazyryk carpet, various details and the manner of knotting the tail of the horses are also featured in the impressive designs of Persepolis".

During the reign of the Mongols (thirteenth and fourteenth centuries), carpet weaving reached a very high level of beauty and technique. The prosperity of this industry may have coincided with the empire of Ghazan Khan (1295-1307 AD). But the peak of Iranian classical carpet, which is referred to as the Renaissance of Iranian carpets, dates back to the time of the Safavid Sultans (1499-1722 AD), especially during the reign of Shah Tahmasb I (1524-1587 AD) and Shah Abbas (1587-1629 AD). From this era, there are about 3000 carpets stored in the world's museums or in personal collections. During this period, besides the kings' palaces, carpet weaving workshops were built and various centers previously existed in Tabriz, Isfahan, Kashan, Mashhad, Kerman, Yoghaz, Yazd, Astarabad, Herat, and the northern provinces such as Shirvan, Garabagh, and Gilan developed and prospered more.

In the 19th century, Iranian carpets, especially the carpets of Tabriz, came to Europe. Delegates were sent to all the eastern countries from the European countries and collected all antique carpets in a very tight competition and sent to Constantinople, which was still the most important market for Oriental carpets. With the end of the old carpets, the British and German companies (Ziegler, 1883) unlimitedly established workshops in Tabriz, Sultan Abad (Arak), and Kerman. This process continued until World War I, where carpet production increased significantly.

When the great Cyrus conquered Babylon in 539 BC, he introduced the industry and art of carpets to his country. It was said that in the cemetery of Cyrus, which was buried in Persepolis, the most expensive carpets were covered. Even before him, the desert people had information about knitting carpets. Also, they took good and durable wool from their flocks of sheep and goats.

The first evidence of carpet existence in the Chinese writings related to the Sassanid Dynasty, from 224 to 641 AD. In 628 AD, Emperor Heraclitus, after the victory, brought some carpets to the city of Ctesiphon, the capital of the Sasanians. When the Arabs overcame the city of Ctesiphon in 637 AD and looted the city, there was a considerable amount of carpet, one of which was the famous garden carpet known as the "Spring of Khosrow Carpet". This carpet has been the most precious carpet in history.

Carpets that were woven 90 square feet during the reign of Khosrow I (571- 531), Arabic historians have

described it in this way: its corners are magnificent beds of blue, red, white, yellow, and green flowers; its background color is a copy of the earth to a golden color, its stones are as clear as crystals which is a false impression of water, plants with silvery and fruits are formed with stone color, but unfortunately, Arabs cut this precious carpet into small pieces and sold separately.

After the reign of the Arab caliphs, one of the Turkic tribes, called Seljuk, conquered Iran. The Seljuk dynasty (1194-1038) is important in relation to the history of carpet in Iran. In this regard, Seljuk women had a particular experience in carpet weaving with Turkish knots. Hence, in the Azerbaijan and Hamedan cities, which were much influenced by the Seljuk, Turkish knots were used during this period.

Perhaps the most important date in the carpet industry of Iran is related to the era of Safavid rulers (1799-1499). Almost 1500 preserved works are available in museums and collections around the world. In Iran, trade and art flourished during the reign of Shah Abbas (1679-1571). Shah Abbas encouraged people to call and exchange with Europe and made his capital, Isfahan, one of the most luxurious and enormous cities in Iran. Moreover, he created a large workshop for working artists to weave the finest and most magnificent examples of carpets. Most of these carpets were woven from silk with gold and silver filaments decorating them [1-4].

Recently, carpet weaving has become the most extensive handicraft in Iran and is well known abroad. Persian rugs today have a special reputation due to their color and diversity and their various patterns and designs.

### III. HISTORY OF QOM CARPET

The carpet industry has long been popular among nomads and villagers of Qom. Carpet weaving history in Qom in the current mode dates back to the last decades of the 19th century, about 134 years ago; in fact, when the Kashan masters (i.e., great ancestor of Kashizadeh) moved the carpets loom to Qom and started work on a limited scale. In less than 20 years, carpet weaving has been expanded to a large extent in the form of massive commercialization. This industry quickly flourished in the city of Qom, and over time, it spread to surrounding villages. However, it should not be forgotten that carpet weaving among nomads in the Shah-Savan district has already been mentally weaving.

The Qom carpet was entered into the market using non-softened wool and generally with knot density 40. In the following years, carpet weaver artists in Qom perfected carpet weaving and, with special techniques and ability, they proceeded to fabricate the entire silk carpets with a very high knot count. Designs of Qom carpets, like the colors used, are very diverse. The designs of the old

Qom carpets were made up of designs known as Medallion-Corner, Palmette flower (Shah Abbasi), Stripped, Prayer-niche, and hunting grounds. These designs, adapted from the designs of Kashan and Isfahan, quickly evolved with the creativity of the designers of Qom, and a new style of carpet weaving was formed in Iran. This style becomes famous for its features such as elaborate design, harmony of designs, and colorful extras as "Qom Carpet Style" and "Silk Carpet Style". This art in the city of Qom has progressed rapidly in comparison with other cities of Iran and even other countries to the point where international brands such as Kashizadeh, Jamshidi, etc. can be named as the world's finest carpet of silk handmade.

### IV. TAGUCHI DESIGN

Extensive research suggests that the Taguchi method can be well used to detect the effect of various factors on the response as well as predict the results in various issues, both industrial and academic [5-13]. In the present research, Taguchi method was used to determine the effect of different parameters on the final price of silk carpet weavers' wages. In this regard, calculations were performed to assess the final cost of weaving of a one-meter carpet (size of 100 \* 155 cm), taking into account six different parameters with 3 different levels in each of them (for creating the Taguchi algorithm). All data was extracted from the documentation published by the expert council on handmade carpets of Qom or the famous Qom producers. The most and least effective parameters based on Taguchi's analysis [14-15], along with the percentage of each parameter, were determined at the weavers' wages. Given the need to reduce the expense of the product, a smaller term is best was used for data analysis as following [16-17]:

$$S/N = -10 \log \left[ \frac{1}{n} (y_1^2 + y_2^2 + \dots + y_n^2) \right] \quad (1)$$

where  $y_1$ ,  $y_2$ , and  $y_n$  represent the measured bent angles in the bending process, and each bending condition is repeated  $n$  times [12]. Afterwards, the main influences of S/N ratios at every level of parameters were analyzed and plotted.

### V. RESULTS AND DISCUSSION

Variable parameters considered in Taguchi algorithm with their different levels are reported in Table 1.

**Table 1:** Characteristics of variable parameters considered in the Taguchi algorithm

Variable	Label	Level 1	Level 2	Level 3
Duration of weaving	A	Quick weaver	Suitable	Slow weaver
Money received until the end of the carpet weaving	B	High	Average	Low
Workshop distance from raw materials warehouse	C	Intra-urban	Intra-province	Other province
Number of colors	D	High	Average (normal)	Low
Design difficulty	E	Hard-worker	Average (normal)	Slacker
Weaving quality	F	Excellent	Good	Average

The Taguchi orthogonal matrix with the characteristic L27 (3 ^ 6) was used to create the Taguchi test plan, as in Table 2.

**Table 2:** Layout of orthogonal matrix L27

Experiment No.	Factor					
	A	B	C	D	E	F
1	1	1	1	1	1	1
2	1	1	1	1	2	2
3	1	1	1	1	3	3
4	1	2	2	2	1	1
5	1	2	2	2	2	2
6	1	2	2	2	3	3
7	1	3	3	3	1	1
8	1	3	3	3	2	2
9	1	3	3	3	3	3
10	2	1	2	3	1	2
11	2	1	2	3	2	3
12	2	1	2	3	3	1
13	2	2	3	1	1	2
14	2	2	3	1	2	3
15	2	2	3	1	3	1
16	2	3	1	2	1	2
17	2	3	1	2	2	3
18	2	3	1	2	3	1
19	3	1	3	2	1	3
20	3	1	3	2	2	1
21	3	1	3	2	3	2
22	3	2	1	3	1	3
23	3	2	1	3	2	1
24	3	2	1	3	3	2
25	3	3	2	1	1	3
26	3	3	2	1	2	1
27	3	3	2	1	3	2

This technique is efficient and cost saving due to the small number of experimental samples in comparison with the full factorial design method [17]. Different tests were performed for different DOE cases to study the effect of various parameters on the worker's fee who weaved the handmade silk carpet as shown in Table 3. Of course, it should be noted that a lot of data was collected and some of them were selected and used based on the data matching with the proposed Taguchi modes.

**Table 3:** Results for different conditions based on the Design of Experiments (Taguchi algorithm)

Experiment No.	Price coefficient
1	320
2	290
3	275
4	320
5	290
6	280
7	325
8	285
9	275
10	280
11	260
12	265
13	305
14	270
15	280
16	310
17	285
18	315
19	270
20	265
21	260
22	275
23	260
24	255
25	305
26	300
27	285

Taguchi sensitivity analysis was performed in every level. Thus, the plots of means and S/N ratios for different effective parameters are presented in Figure 1 and Figure 2, respectively.

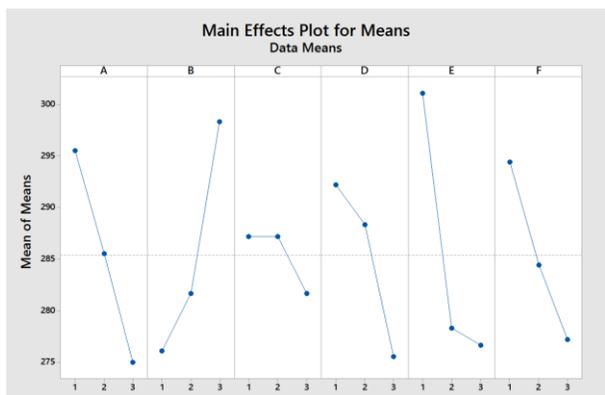


Figure 1: The effect of different parameters on the price coefficient of weavers' wages based on mean value

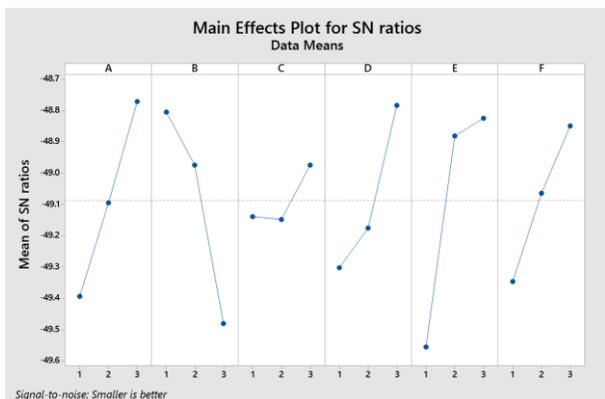


Figure 2: The effect of different parameters on the price coefficient of weavers' wages based on signal to noise ratio

As shown in Figure 1 and Figure 2, in each variable, the maximum data in a graph is the minimum on the other graph and this indicates the sufficient number of tests and there is no need to collect more data [6, 12, 17].

Next, Figure 3 demonstrates the percentage of the effect of each parameter on the value of the final price announced as the wages of handmade carpet weavers.

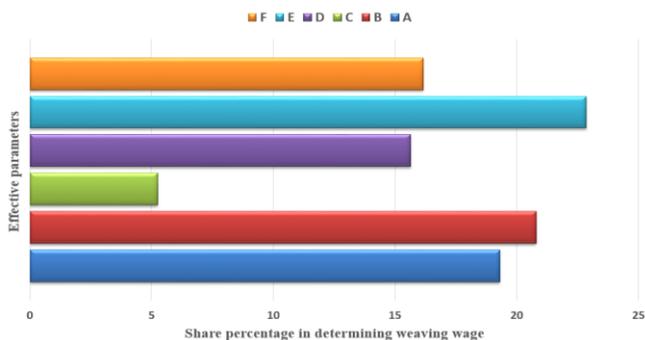


Figure 3: The effect of the studied parameters on determining the wages of handmade carpet weavers based on Taguchi analysis

From figure 3, it is clear that the most effective and least effective parameters in determining the wages of carpet weavers are the design difficulty and the distance of the workshop from the stock of raw materials, respectively. Also, the parameters can be ranked, in which case the three important rankings are according to the design difficulty, the amount of money received up to the end of the carpet, and the duration of weaving.

## VI. CONCLUSION

In the present research, the effect of different parameters on determining the wages of handwoven carpet weavers was investigated. For this purpose, Taguchi analysis was used. In this analysis, 6 different parameters with 3 levels, were evaluated. All data were extracted from documentation published by the carpet association or information received from some of Iran's famous manufacturers. All ties are for carpet with dimensions of 100 \* 155 cm (the so-called one-meter carpet) with a healthy weaving with no defect. The results revealed that the highest and the least effect was related to the carpet design and the distance of the workshop from the raw materials warehouse, respectively. Moreover, the most important and practical achievement of this research is that the most important factors in determining the wages of weavers were the difficulty of the carpet design, the amount of money received from the beginning to the end of the carpet, and the duration of the weaving, respectively.

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