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Evaluating the Efficiency of Leading International Carpet Manufacturing Companies Using the DEA Model

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Abstract

It is reviewed recent research on the efficiency of the top carpet manufacturing companies in the world using DEA, which is one of the leading methods for efficiency analysis. Through a systematic review, we investigated research trends in terms of research purposes, specific DEA techniques, input and output factors used for models, etc. Based on the review results, future research directions are suggested. The results of this paper provide valuable information and guidelines for future DEA research on carpet manufacturing industry.

Keywords: carpet manufacturing, innovations, efficiency, process innovations, Data Envelopment Analysis, DEA model, profitability

Introduction

The experience of the world's leading carpet manufacturers shows that, process innovations - application of new methods of organizing the production process, the use of new production technologies and innovative equipment and support for scientific research are of great importance in increasing the efficiency of the enterprise. At the same time, the establishment of the Ministry of Innovative Development of the Republic of Uzbekistan, In 2018, the decision of the Cabinet of Ministers No. 721 "On measures to further support innovative activities", in 2019 PQ - No. 4453 "Measures for the further development of light industry and production of finished products" The adoption of the decision of the President of the Republic of Uzbekistan "On events" confirms the relevance of this topic at the national level. In this regard, it is important to study the possibilities of applying the experience of Balta Group and Oriental Weavers companies in the light industry of the Republic of Uzbekistan.

2. METHODOLOGY

One of the widely used method of performance evaluation is benchmarking. That is, the indicators of the most successful company operating in a certain field are singled out as a "benchmark" and set as the maximum effective limit that can be achieved using available resources. Thus, the measure of efficiency consists in determining the distance between the investigated enterprises and the efficiency frontier. In the Western literature, the measurement of the efficiency limit is mainly carried out in two ways. The first is by directly constructing the production possibilities function for the most advanced, most efficient enterprises using mathematical statistical methods - the stochastic frontier production function. Secondly,

determining the maximum profitability by comparing the individual efficiency indicators of the use of the resources of this enterprise with the indicators of other enterprises and using the construction of a "data shell" with the method of linear programming. This "data shell" defines the limit of production capacity, that is, the maximum possible level for any combination of resources. This method is called data envelopment analysis (DEA) [1].

M. Farrell was the first to use the DEA method to calculate the efficiency of one final product using one input and one output [2]. However, since it is not possible to represent all the different input and output parameters through a single virtual pointer, this attempt fails. This idea was later refined by Charles, Cooper, and Rhodes using linear programming methods. The basis of this model is the efficiency indicator. The efficiency indicator is equal to the ratio of the sum of all output (result) parameters to the sum of all input parameters. For each decision-making unit (DMU), the efficiency value is determined and then the observations are compared. In the DEA model, the efficiency criterion is to achieve the Pareto optimum. That is, an economic situation is considered 100% efficient if:

- None of the output parameters can be increased by increasing one input parameter or decreasing another output parameter;
- No input parameter can be lowered by lowering one output parameter or raising another input parameter.

The first DEA model is called the Charles, Cooper, Rhodes model (CCR model). It is assumed that the scale effect is constant (constant return to scale, CRS) and has the following form [3]:

$$e_0 = \frac{\sum_{j=1}^{s} u_j y_{j0}}{\sum_{i=1}^{r} v_i x_{i0}} \rightarrow \max!$$ subject to the following conditions:

$$\frac{\sum_{j=1}^{s} u_j y_{jm}}{\sum_{i=1}^{r} v_i x_{im}}$$ 1; for all enterprises m = 1,2 ...., n;

u_j≥0 j = 1,2, 3, …, s

v_i≥0; i = 1,2, 3, ..., r

In this:

e_0= efficiency of the enterprise under study;

n = number of units being compared;

r = number of incoming factors;

s = number of output parameters;

x_i0 = i – the value of the second factor;

y_j0 = value of output parameter j – inchi;

x_im = expression of the i-th input factor of the m-th enterprise, i=1, ..., r i m=1, ..., n

y_jm = the parametric expression of the j-th output of the m-th enterprise, j = 1, ..., s, m = 1, ..., n

u_j = relative weight of the input factor

v_i = relative weight of the output parameter.

The main drawback of this model is that it does not take into account the scale effect. Therefore, the further improvement of the DEA model is characterized by the development of BCC-output and BCC-input models that take into account the variability of the scale effect. As an example,

we will consider the measurement of efficiency for the quality management system of 10 enterprises (DMU - decision-making units) [4]. Incoming factors:

- Quality cost (additional costs of product quality assurance) - x_1
- The number of employees responsible for quality assurance is x_2
- Table of output (result) indicators:

Activity measurements	*Output variables*
Quality performance indicators	Quality products (%) - y_1
	Customer satisfaction level (%) - y_2
Operational activity indicators	On-time delivery rate (%) - y_3
Financial indicator	Income indicator (million USD) - y_4

This information is placed in the form of a table. Enterprises (DMU 1, DMU 2, etc.) are included in the vertical sequence and input and output variables (x_i; y_j) are entered in the corresponding horizontal sequence and applied to one of the above-mentioned basic DEA-models, and which companies are efficient and those of the rest inefficiency levels are determined. It should be noted that for the application of basic DEA-models, the business environments and consumers of the companies should not differ sharply from each other. It is necessary to specially develop and implement modified DEA models for enterprises operating in sharply different conditions [5].

Thus, all the methods of performance measurement considered are of great importance in increasing the effectiveness and efficiency of the company's activities. The development stages of performance evaluation methods include the analysis of financial indicators, value indicators (coefficients such as ROI, ROA, ROS, ROE), economic added value (EVA), shareholder return index (TSP), six sigma, DMAIC and Includes DEA-analysis. The relatively new and most widely used six sigma method is aimed at reducing errors and the percentage of defective products. Currently, the DEA model, which is considered the most effective, helps to identify effective and relatively ineffective units among several decision-making units (DMUs) by optimizing input and output indicators based on a benchmarking system.

The Data Envelopment Analysis (DEA) model developed by Charles, Cooper, and Rhodes is the most widely used method for determining efficiency today. This model is based on the benchmarking system, which distinguishes efficient and ineffective units for several decision-making units (DMUs) and defines target indicators and sample units for ineffective units. Several input and several output parameters are used to determine efficiency.

In order to use this model to evaluate the efficiency of "Oriental Weavers Carpet" and "Balta Group" companies, the ten largest companies (decision-making units) operating in the field of carpet production and 3 input and 2 output parameters were selected for them. The decision-making units (in this case carpet companies) were selected based on www.marketresearchstore.com ranking of companies operating in the carpet and carpet products market.

As input indicators, attention was paid to the selection of indicators that represent the application of process innovations, that is, the total number of employees, the amount of annual costs for raw materials and administrative costs (including employee salaries, retraining and

training and other costs not reflected in direct production and related to the organization of labor activity) were selected.

As output (result) indicators, the indicators representing the competitiveness and efficient operation of the company - the volume of gross annual income (net sales) and the level of profitability (profitability) were selected. All indicators for the initial data table were taken from the official websites and annual financial reports of the relevant companies (Table 1):

Table 1. Initial data for the DEA model

	Decision Making Units (DMU)	**Input indicators**			**Result indicators (output)**	
№	Top ten largest carpet manufacturing companies in the world [6]	Total number of employees	Costs for the purchase of raw materials, thousand USD	Administrative expenses, thousands of US$	Gross income (net sales), thousand USD	Profitability (profitability indicator), in %
1	Oriental Weavers (Egypt)	19000	89,238.5	18,869.2	655,900.0	12
2	Balta Group NV (Belgium)	3926	341,122.2	177,024.0	732,566.3	23
3	Shaw Industries Group, Inc. (USA)	22660	258,616.9	1,228,543.0	6,437,011.0	21.1
4	Tai Ping Carpets Int, Ltd. (Hong Kong)	893	10,292.1	25,477.5	69,838.2	38
5	Brintons Carpets Limited (Great Britain)	1686	16,555.6	34,797.6	109,339.2	12
6	Mohawk Industries, Inc. (USA)	41500	824,956.0	1,848,819.0	9,970,672.0	26.8
7	Victoria PLC (Great Britain)	3042	211,000.0	318,604.0	1,179,000.0	34.2
8	Tarkett S. A. (France)	12500	384,752.9	208,622.8	3,393,280.0	22.4
9	Interface, Inc. (USA)	4110	160,542.0	381,604.0	1,343,029.0	38
10	Suminoe Textile Co., Ltd. (Japan)	3100	133,585.0	155,660.8	896,650.6	19.6

Source: prepared by the author on the basis of the official websites and annual reports of the companies [7].

As input indicators, attention was paid to the selection of indicators that represent the application of process innovations. That is, as noted above, process innovations are manifested in the optimization of business management, in the facilitation and automation of production, in the reduction of costs associated with improving the skills of employees, and in the increase of the productivity of the use of raw materials. Taking this into account, as input indicators, the total number of employees, the amount of annual costs for raw materials and administrative costs (including employee salaries, retraining and training of employees, and other direct costs) costs that are not reflected in production and related to the organization of labour activities) were selected.

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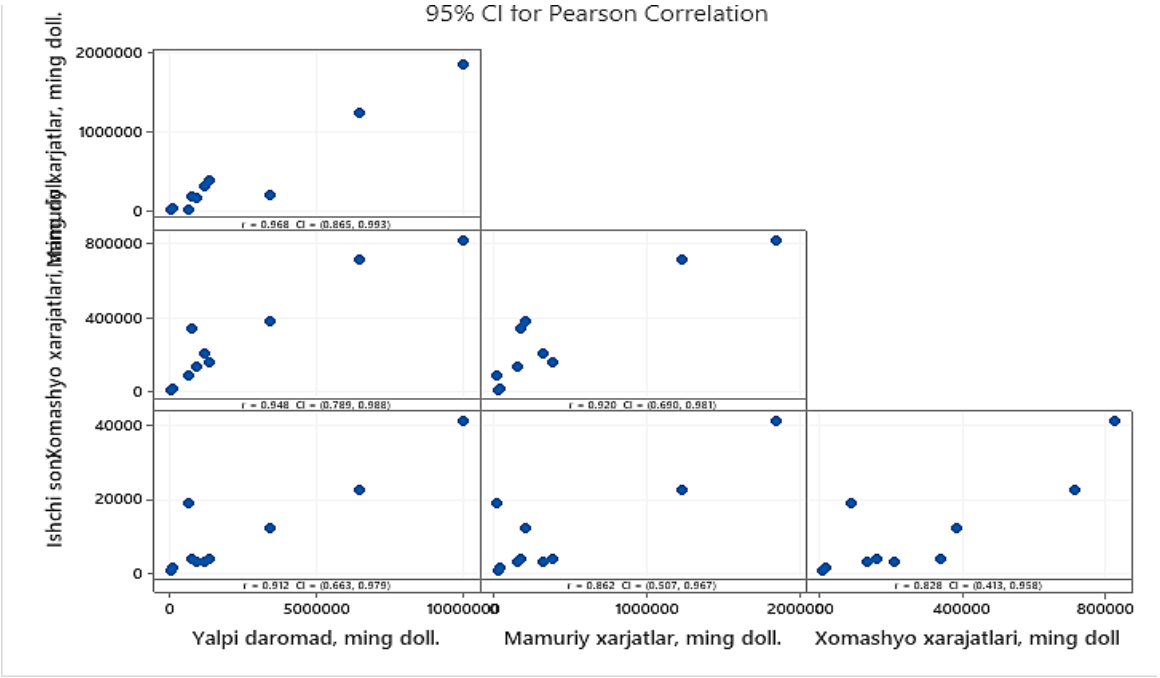
3. RESULTS

As output (result) indicators, the indicators representing the competitiveness and efficient operation of the company - the volume of gross annual income (net sales) and the level of profitability (profitability) were selected. All indicators for the initial data table are taken from the official websites and annual financial reports of the relevant companies (Table 1). Before using the DEA model, a correlation-regression analysis was performed in order to determine the relationship between the input and output parameters. For this purpose, the indicator of gross annual income in thousands of US$ was selected from the output indicators. Below is a correlation matrix graph of these four parameters (number of employees, raw material costs, administrative costs and gross profit) (Picture 1):



Picture 1. Correlation matrix graph of input and output parameters

Source: Prepared by the author based on correlation analysis performed in Minitab.

In the above graph, we can see that the points representing the relationship between the parameters are located mainly in the lower left corner based on linear or quadratic relationship. This is because most of the selected companies have a gross revenue between six hundred million and one billion US dollars, and only three - Tarkett S. A. (France), Shaw Industries Group, Inc. (USA) and Mohawk Industries, Inc. (US) with gross revenues of more than US$3 billion, US$6 billion and US$9 billion respectively. These high-yielding companies are located in the upper right part of the graph.

Below are the correlation indicators between each parameter (Table 2):

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Table 2. The degree of correlation between parameters

Correlation	Gross income, thousand dollars.	Administrative expenses, thousand dollars.	Raw material expenses, thousand dollars
Administrative expenses, thousand dollars.	0.968		
Raw material costs, thousand dollars	0.948	0.920	
Number of workers	0.912	0.862	0.828

Source: calculations made in Minitab based on initial data.

From the table above, we can conclude that there is a problem of multi correlation, although high correlation values are noted between the output indicator (gross income) and input indicators, in particular administrative costs, raw material costs and the number of employees. Because the correlation between some x variables - raw material costs and administrative costs, labour and administrative costs is high (0.92 and 0.86, respectively). Therefore, three input parameters cannot participate in the regression model at the same time. In this case, it is appropriate to create a separate regression model for each parameter. At the same time, taking into account that the correlation index between the number of workers and the cost of raw materials is relatively low (0.82), it is possible to conditionally propose a regression model in which these two variables participate. Below are the results of the regression model (Table 3). From the results of the regression model, we can conclude that the p-value for both x variables - raw material costs and the number of workers - is at the limits of acceptance, that is, less than 0.05 (0.005 and 0.031, respectively). Therefore, we accept the hypothesis H1.
The coefficient of determination (R-sq) is 95%, which means that 95% of the gross profit can be determined by the cost of raw materials and the number of employees.

Table 3. A regression model involving the variables of raw material costs and the number of employees

The regression equation					
Gross income, thousand dollars. = - 698596 + 7.08 Raw material costs, thousand dollars + 100.7 Number of employees					
Coefficients:					
Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	-698596	384693	-1.82	0.112	
Raw material costs, thousand dollars	7.08	1.74	4.07	0.005	3.17
Number of workers	100.7	37.5	2.68	0.031	3.17
Model Summary (conclusion)					
S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**		
827828	95.00%	93.57%	78.18%		

Source: Compiled by the author based on the results of calculations made in the Minitab program based on initial data.

It is appropriate to build a separate one-variable regression model for the parameter of administrative costs. Given that administrative costs represent the result of process innovation, optimization of production processes, employee training, insurance, rent, etc., this model is important. The model results are presented in Table 4. From the regression results presented below, we can conclude that the H1 hypothesis is accepted in this model, that is, the p-value for administrative costs is 0, which means that there is no multi correlation problem. The coefficient of determination (R-sq.) is equal to 93%, which means that with the help of this regression equation, it is possible to explain 95% of the gross income through administrative expenses.

Table 4. The results of the regression model in which the volume of administrative expenses as the variable X and the volume of gross income as the variable Y participated

The regression equation					
Gross income, thousand dollars. = 198678 + 5,184 Administrative costs, thousand dollars.					
Coefficients:					
Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	198678	346759	0.57	0.582	
Administrative expenses, thousand dollars.	5.184	0.477	10.86	0.000	1.00
Model Summary (conclusion)					
S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**		
872687	93.65%	92.85%	91.53%		

Source: Compiled by the author based on the results of calculations made in the Minitab program based on initial data.

4. DISCUSSION

Unlike regression models, the DEA model allows working with several output parameters at the same time. This model is run in Excel using the custom macro "DEAfrontierFree". This DEA model is "input-oriented", i.e. it is aimed at optimizing input parameters, and it is built on the basis of "CRS - constant return on scale" - constant return on scale. The DEA model is built using this macro by entering the initial data into the Excel program. The following efficiency results were obtained for the companies selected as initial data and their related parameters (Table 5). From the results presented in the table, we can conclude that among the shortlisted companies are 6 - Oriental Weavers (Egypt), Shaw Industries Group, Inc. (USA), Tai Ping Carpets International Ltd. (Hong Kong), Victoria PLC (Great Britain), Tarkett S. A. (France, Interface, Inc. (USA) are effective, and the remaining 4 companies are Balta Group NV (Belgium), Brintons Carpets Limited (Great Britain), Mohawk Industries , Inc. (USA) Suminoe Textile Co., Ltd. (Japan) is relatively ineffective.

Table 5. Performance indicators of companies (based on the DEA model)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Sum of lambdas	RTS	Optimal Lambdas with Benchmarks	
1	Oriental Weavers (Egypt)	1.00000	1.000	Constant	1.000	Oriental Weavers (Egypt)
2	Balta Group NV (Belgium)	0.63915	0.681	Increasing	0.308	Tai Ping Carpets International Ltd. (Hong Kong)
3	Shaw Industries Group, Inc. (USA)	1.00000	1.000	Constant	1.000	Shaw Industries Group, Inc. (USA)
4	Tai Ping Carpets International Ltd. (Hong Kong)	1.00000	1.000	Constant	1.000	Tai Ping Carpets International Ltd. (Hong Kong)
5	Brinton's Carpets Limited (Great Britain)	0.56942	0.337	Increasing	0.023	Oriental Weavers (Egypt)
6	Mohawk Industries, Inc. (USA)	0.83954	2.323	Decreasing	1.000	Shaw Industries Group, Inc. (USA)
7	Victoria PLC (Great Britain)	1.00000	1.000	Constant	1.000	Victoria PLC (Great Britain)
DMU No.	DMU Name	Input-Oriented CRS Efficiency	Sum of lambdas	RTS	Optimal Lambdas with Benchmarks	
8	Tarkett S. A. (France)	1.00000	1.000	Constant	1.000	Tarkett S. A. (France)
9	Interface, Inc. (USA)	1.00000	1.000	Constant	1.000	Interface, Inc. (USA)
10	Suminoe Textile Co., Ltd. (Japan)	0.93114	0.607	Increasing	0.007	Shaw Industries Group, Inc. (USA)

Source: Compiled by the author on the basis of initial data and the results generated using the special macro "DEA frontier Free" in Excel.

The main reason why most companies are considered effective is that these companies are ranked among the top 10 largest carpet manufacturers in the world. That is, these companies are the most competitive and successful manufacturers in the world market. In particular, the main reason why "Balta Industries" company has a relatively low efficiency index (0.63915) is that the company is currently investing in a number of projects for 5-10 years, in order to increase production capacity and improve the mechanism of waste processing. increasing additional administrative and other costs. It is expected that these investments will bear fruit within 5-10 years and lead to a significant increase in income [8]. Mohawk Industries, Inc. has the highest gross revenue volume. The main reason why the (USA) company also has a relatively low efficiency (0.83954) is that the profitability indicators are low compared to the effective units. In this basic BCC model, the relative weight (importance level) of all input and output parameters is assumed to be the same. Modified DEA models have the ability to change this and assign more importance to some parameters than others.

Below are the optimal target (target) values of input and output parameters for each relatively inefficient company (Table 6):

Table 6. Optimal values of Input and Output indicators

	Efficient Input Target			*Efficient Output Target*	
DMU Name	***Number of employees Profitability, in %, thousand US$***	***Raw material costs, thousand US$***	***Administrative costs, thousand US$***	***Sales volume, thousand US$***	***Profitability, in %, thousand US$***
Oriental Weavers (Egypt)	19000	89238.5	18869.2	655900.0	12.0
Balta Group (Belgium)	2509	103188.8	113145.2	732566.3	23.0
Shaw Industries Group, Inc. (USA)	22660	258616.9	1228543.0	6437011.0	21.1
Tai Ping Carpets International Ltd. (Hong Kong)	893	10292.1	25477.5	68538.2	38.0
Brinton's Carpets Limited (Great Britain)	960	9427.1	19814.5	109339.20	12.0
Mohawk Industries, Inc. (USA)	34673	692587.1	1552165.5	9970672.0	55.8
Victoria PLC (Great Britain)	3042	211000.0	318604.0	1179000.0	34.2
	Efficient Input Target			*Efficient Output Target*	
DMU Name	***Number of workers***	***Raw material costs, thousand USD***	***Administrative expenses, thousand USD***	***Sales, thousand USD***	***profitability, in %, thousand USD***
Interface, Inc. (USA)	4110	160542.0	381604.0	1343029.0	38.0
Suminoe Textile Co., (Japan)	2886	124386.4	144942.1	896650.6	19.6

Source: It was compiled by the author on the basis of initial data and the results generated using the special macro "DEAfrontierFree" in Excel.

We can conclude from the table that all relatively inefficient companies can optimize input parameters to a certain extent based on this model (reduce labor force, reduce raw material and administrative costs) and, in some cases, increase efficiency by improving output indicators. For example, Mohawk Industries (USA) can improve efficiency by optimizing output parameters (increasing profitability by 55%) and reducing the workforce from 41,000 to 35,000. Balta Group (Belgium) has the opportunity to reduce the number of employees from 3,200 to 2,509, reduce annual raw material costs from $341 million to $103 million, reduce administrative costs from $177 million to $114 million, and increase efficiency.

It can be concluded that "Oriental Weavers Carpet" and "Balta Group" companies are major manufacturers of carpets and carpet products. These companies have 19,000 and 3,926 employees, respectively, and their products are exported to more than 15 countries of the world,

such as the USA, Russia, Canada, China, England, France. These companies located in Egypt and Belgium have production lines in several countries of the world (Turkey, China, USA).

The results of the conducted research showed that these companies use a number of process (technological) innovations in order to increase efficiency in their activities and achieve competitive advantage. For example, "S&OP" (sales and operational planning), an innovative management method based on sales volume and operational activity planning, high-precision, quick and easy carpet coloring technology using special Chromo JET equipment, "single material construction" aimed at reducing waste and simplifying the production process. ” (using one type of raw material) production technology, innovative "cost optimization", "balanced scorecard" methods of labor organization aimed at cost optimization, etc.

In order to evaluate the efficiency indicators of Oriental Weavers Carpet and Balta Group companies, the resulting indicator of the company's activity (net sales volume) according to the results of the correlation-regression analysis conducted among the ten largest carpet manufacturing companies and two different regression models that incorporate the results of process innovation with administrative costs, raw material costs and headcount, and determine net sales using headcount and raw material costs and separate net sales using administrative costs was invited. The DEA (data envelopment analysis) model of efficiency evaluation showed that 6 of the 10 largest carpet manufacturing companies selected, including Oriental Weavers Carpet, were efficient units, and the remaining four companies, including Balta Group, were relatively identified as an ineffective unit. The main reason for this is the high administrative and raw material costs, and the relatively low level of profitability. Such high cost indicators are connected with the fact that the company invests in long-term projects.

5. CONCLUSION

According to the results of the analysis carried out using the DEA model, the company "Oriental Weavers" recorded the highest efficiency among the 10 largest carpet manufacturing companies. "Balta Group" has a relatively low profitability (0.63915), and the main reason for this is the large volume of administrative and other expenses due to the fact that the company invests in a number of long-term projects.

From this point of view, we can conclude that the implementation of the following technological innovations introduced in the practice of "Oriental Weavers" and "Balta Group" companies in the activity of "SAG" company will serve to achieve higher efficiency:

1. Developed a development program based on the method called "S&OP" (sales & operations planning) - sales and operations planning. This method used by "Balta Group" company allows to minimize additional costs by forecasting the volume of sales and planning all operational issues according to it. Taking into account seasonal changes, trends in the field of housing construction and peculiarities of consumer behaviour, the use of the "S&OP" method is relevant for the SAG company in today's business conditions.

2. "The single material construction" - that is, production technology from the same material. This technology makes it possible to reduce waste in the production process, simplify the production process and optimize costs. It should be noted that today carpets of the SAG company "Isfahan" collection are made of 100% acrylic raw materials and are high-quality products in great demand among the population.

3. Chromo JET carpet colouring technology. This technology of colouring with special Chromo JET equipment allows you to create more clear, vivid colour combinations and unlimited shades and colour combinations from only 16 primary colours, there is no need to wash these equipment when changing designs or colours, high It will be possible to download patterns with resolution (from 400 x 400 to 400 x 1600 dpi). It is known that SAG carpets incorporate various complex patterns, and Chromo JET technology allows them to be easily, quickly and more clearly laid out on the carpet.

4. Cost management system, SCM - cost management system. This method of enterprise budget control includes strategic cost management, balanced scorecard, cost calculation by activity type, cost analysis during the life cycle, economic added value, etc. includes such instruments and is considered one of the main factors of increasing efficiency and serves to increase profit by optimizing production processes, minimizing the percentage of unusable products and increasing labour productivity.

5. Mechanism of waste processing established in "Balta Group" company. For example, 3% of waste in the company is directed to internal recycling. Polypropylene polymer waste, which is the main raw material, is used for the production of non-woven textile coverings, woven yarns and staple fibres. In cases where internal reuse is not possible, external partners are turned to, which currently accounts for 68.7% of production waste. 28.3% of waste is used for energy, due to the lack of recycling options for all types of waste. The use of this technology in the practice of the "SAG" company helps to increase the efficiency, reduce the percentage of unusable products and optimize the additional costs related to waste, and makes the company more competitive in the world market.

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