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Evaluation of the Quality of the Cement Production Process in Terms of Increasing the Company's Performance

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Abstract: This article summarizes the arguments surrounding the scientific discussion of the cement production process at a selected company in Slovakia. (1) The main goal of this article is to evaluate the quality of the cement production process with the intention of increasing the performance and quality of the process and the quality of the cement in various assortments. The object of this research was a selected company in Slovakia which focuses on cement production. (2) The methods of research were focused on using statistical, economic, and financial analyses and instruments of quality management, such as the Ishikawa diagram, regression diagram, correlation, and box plot diagram. The relevance of the decision of this scientific research relating to the innovation of the cement production process focused on Industry 4.0 requirements. (3) This paper presents the results of the clinker CaOF content and LS and their quality. These components are used for cement products and are responsible for the quality of cement. This paper obtained a view of barriers in the cement production process, the most important of which are the people involved and their qualifications. (4) These barriers were minimalized and indicated significant improvements in the quality of entry components in the clinker. We suggest reducing CEM III and replacing CEM I-R, which brings higher profit to the company. These results can be instruments or recommendations for other companies utilizing the cement production process.

Keywords: evaluation; performance; quality; production process

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1. Introduction

The quality of the cement production process is one factor in the level of product quality for customers and one of the key indicators of a company's performance. Due to the high competition in the Slovak market, it is important to pay attention to the quality of Portland cement, which is used mainly in the construction industry, Foreign customers also have demands for the quality of cement with respect to the environment. High-quality cement must meet the required quality characteristics established by the STN standard and, at the same time, meet customer requirements.

The basic component of cement is clinker, which comprises 95–100% of the cement by weight. The rest are additional components that make up the remaining 0–5%: slag, limestone, and gypsum. These are the oxides CaO, SiO_2, Al_2O_3, and Fe_2O_3. In addition, it is important to monitor the degree of carbonation (LS) and the content of free lime (CaO_F) in the clinker.

The novel contribution of this research is to monitor the composition of cement for customers with respect to two factors which have a significant impact on the quality of Portland cement: the degree of carbonation and the lime content.

Process management aims to optimize processes to achieve better process performance and optimal indicators of the company performance, such as an optimal quality of products, new customers, new quality services for customers after purchase, new quality inputs for production, new suppliers, new technologies of production, innovative courses for employees, improved environmental efficiency and sustainable development, higher profit, and other requirements for Industry 4.0. The increasing significance of these processes requires organizational and technical capabilities and a process mindset [1].

The level of quality of mining processes and the monitoring of their performance are basic prerequisites for the improvement, innovation, gain in KPI indicators, and competitiveness of the mining industry. The main goal of this article is to evaluate the quality of the cement production process with the intention of increasing performance process and product quality. Process management systems in Industry 4.0 are required to digitize and automate business process workflows and support the transparent interoperations of service sellers. The critical bottleneck to advancing PM systems are the evaluation, verification, and transformation of trustworthiness and digitized assets [2].

The production process of cement must be improved in relation to two aspects: (1) the high quality of the concrete components and (2) benefits for the company. Tian et. al. (2022) found that an improvement in heating efficiency is crucial for cement-based materials. To be specific, a sample with a higher heating efficiency endows a higher curing temperature when compared to a sample with a lower heating efficiency under the same electric power [3]. Zhang et.al. (2021) commented that cement paste matrices were employed to analyze microstructure and mineral phases. The results showed that coal gangue incorporation degraded the early-age strength of the cement and increased its porosity and water absorption under standard curing conditions, substantially lowering transport behaviors and refining the pore structure with a negligible loss of ultimate strength. Therefore, it was concluded that the combination of a suitable steam-curing regime and proper coal gangue content could realize the production of green concretes with excellent durability, low cost, and substantial environmental benefits [4]. This article consists of the following phases: the collection of data regarding cement process, a description of the production process, an evaluation of the quality of the process and products, and a description of the influence on profit.

The main goal of this article is to evaluate the quality of the cement production process with the intention of increasing the performance and quality of the process and the quality of the cement in various assortments to meet the high demand and requirements of customers.

2. Literature Review

Processes are an important part of a mining company's daily operations. Every process mining analysis starts with the collection of data. In business, is necessary to provide business sustainability with an orientation to Industry 4.0 and Industry 5.0, which refer to the effort to reduce negative impacts in the STTEEP environment in social, technical, technological, environmental, economic, and political areas [5]. V4 countries value the business scene according to the global competitiveness index, and the index of the business environment, the aim of which is to identify obstacles that limit business development [6].

Achieving success in STTEEP area factors is a very important motivational instrument for improvement and change in the companies. The improvement process in mining companies is linked to KPI factors for each company, with specifications for the main process [7]. In addition to the main process, it is also necessary to analyze supporting processes, which are an essential part of business and have an economic impact on the performance of mining companies [8]. With the management of supporting processes, it is also necessary to accept risks associated with the performance of mining activities. For example, risks relating to safety, the reliability of mining machines, the functionality of belt conveyors, the readiness of mining premises, etc. [9,10].

All processes in the IPO chain must relate to the business model, performance evaluation criteria of mining companies, and ultimately to the creation of added value in business [11–13]. Production activity has a decisive influence on the functioning of the company itself, its position in the market, and the competitiveness of its products. Therefore, it is important to manage production processes in mining companies with respect to the creation of added value. Currently, product quality is the main weapon in the competitive struggle of manufacturing companies. The production process must meet the requirements of sustainable development and accept macroeconomic indicators, such as the current high inflation, unemployment, and low GDP [14,15].

A production process in the era of Industry 4.0 must consider the requirements of optimization, digitalization, automation, and customer orientation. In this direction, the production process begins to carry out innovations and improvements. It is also necessary to evaluate the innovative indicators of the production process in mining companies [16]. Important quality indicators include financial indicators such as cost, revenue, and profit. To manage costs, a cost model is needed, which will allow for the minimization of the types of costs that represent a barrier in the mining company [17].

In addition to financial indicators, it is also necessary to monitor technical, social, technological, economic, and environmental indicators. An important tool for evaluating these indicators are various methods such as the CEDAC method; statistical, economic, financial, technical and logistic principles; and logistic methods [18–20]. Based on the results of the given indicators, it is possible to identify the economic risk for businesses and help them stay on the market [21]. An eco-efficiency assessment of mining production processes enables the integration of the results of evaluating both environmental and economic aspects using a life cycle approach to assess environmental efficiency and the results of operating activities to assess economic efficiency. The comprehensive method of assessing mining production processes is proposed as the Key Performance Indicator (KPI) [22].

Operations management dysfunctions and lost production time are problems of enormous magnitude that impact the performance and quality of industrial companies in addition to their cost of production [23]. Reducing the energy consumption, the energy efficiency of the technological processes, and cost reductions with respect to energy supply are relevant problems for the mining industry which determine the competitiveness of a mining corporation [24]. Except for cost, hazard identification, and risk assessment are of great significance for the safety and efficiency of mining processes [25].

3. Materials and Methods

In this article, we evaluate the quality of the cement production process. The object of this research is cement production company in Slovakia that deals with the production of cement. This company is the most modern cement company in Central Europe and uses high-quality raw materials, modern production technology, and professionally qualified employees, making it possible to produce and sell high-quality Portland cement. This company has a great deal of competition in Slovakia (Figure 1), but it produces and sells cement throughout Europe.

Figure 1. Cement companies in Slovakia. Source: author's own source.

Portland cement is produced by finely grinding clinker and gypsum. It achieves a high strength and is produced without the addition of blast furnace slag. Gypsum acts as a regulator of cement solidification. This type of cement is usually used in the construction of all categories of buildings to produce concrete, which is characterized by a high strength class.

The basic component of cement is clinker, which comprises 95–100% by weight. The rest of the components are supplementary components that make up the remaining 0–5%. Cement contains elements that are mostly expressed as oxides: CaO, SiO_2, Al_2O_3, and Fe_2O_3. In addition to oxides, the degree of carbonation (LS) and the content of free lime (CaO_F) in the clinker are also monitored as they increase the quality of the cement. Cement is characterized by its physical, chemical, and mechanical properties (normalized and initial strength). Complex research was performed according to the algorithm (Figure 2).

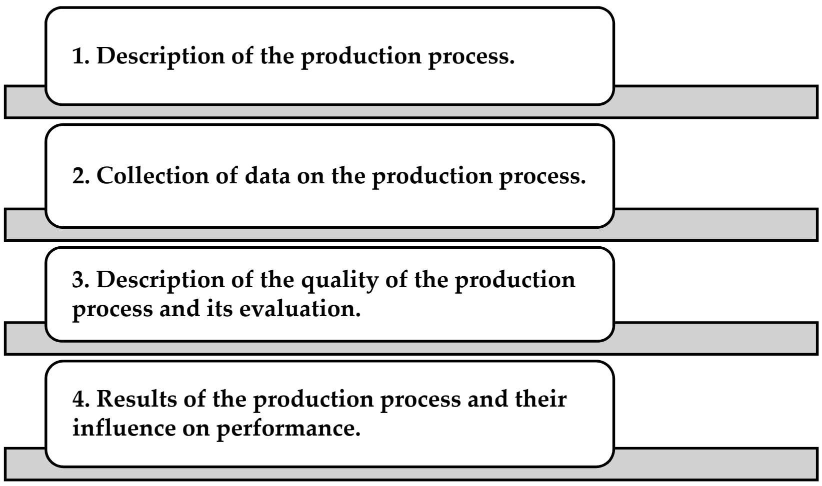

Figure 2. Algorithm of research. Source: own source.

In the first step of the research, we described the production process of cement. The production process of cement creates three phases that are presented in the results.

In the second step, we collected data for economic, statistical, and quality analyses of the performance indicators in the production process in the selected company. We obtained data from the management information system, SAP (Tables 1 and 2), from individual departments in the company.

An evaluation of the quality of the cement production process by the statistical, economical, and qualitative methods is presented in the chapter results.

The statistical analysis was oriented around the indicators of basic statistics—descriptive statistics, and the following indicators were monitored in the post: mean, mode, median, MAX, MIN, range of variation, variance, standard deviation, kurtosis coefficient, and skewness coefficient. We used data from Tables 1 and 2. A statistical analysis was used for the content of the CaO_F and the LS in the clinker as base substances of cement. The lower and upper limits (Table 3) represent the limits for CaO_F and LS set by the company, which are based on Slovak technical standards for the content of substances in the clinker. A box plot was used for comparing measured values. A box plot is a type of chart that depicts a group of numerical data through their quartiles. It is a simple way of easily comparing characteristics of data between categories. The box plot identified the Min, Max, Medium, quartile 1, and quartile 3.

The economic analysis of the CaO and LS substances in the clinker was expressed as an index as a proportion of defective samples and the total number of samples.

$$I = Xf/Xc \times 100\% \quad (1)$$

where Xf represents the failure samples of substances in the clinker, Xc represents the total number of samples of substances in the clinker, and the percentage expression represents the structure of the substances in the clinker according to the established criteria MIN and MAX.

Table 1. Measured values—degree of clinker carbonation (LS) (%).

Measured Values (%) October	Measured Values (%) November	Measured Values (%) December
98.37	97.89	103
97.85	97.17	97.99
100.2	97.42	99.56
99.61	98.99	97.58
99.69	99.47	96.53
101	100.3	96.15
96.17	100.4	96.04
97.91	102.3	98.63
98.05	102.2	96.5
98.97	100.4	97.31
97.37	99.02	96.58
97.22	98.13	96.17
97.66	98.33	97.2
96.01	99	97.95
96.37	100.4	97.82
96.19	99.91	97.53
96.26	98.58	96.27
96.16	96.68	97.48
96.8	98.38	97.88
97.17	102.2	97.29
96.43	104.2	96.04
97.18	101.1	91.99
96.88	96.95	
97.44	97.96	

Measured values are clinker carbonation values (LS)—(%).

Table 2. Measured values—free lime content in clinker (CaO_F)—(%).

Month	Measured Values CaO_F (%)											
X.	0.98	0.98	1.94	1.51	1.58	2.17	0.5	1.06	1.17	1.31	0.68	0.78
	0.9	0.71	0.7	0.66	0.72	0.56	0.96	0.99	0.66	0.78	0.88	0.96
XI.	1.21	0.88	1.07	1.5	1.58	1.92	2.07	2.95	2.88	1.81	1.17	1.4
	1.01	1.22	1.8	1.66	1.18	0.46	1.1	3.01	3.78	2.31	0.93	1.16
XII.	3.53	1.03	1.66	0.9	0.68	0.27	0.48	0.93	0.81	0.72	0.8	1.07
	0.9	1.15	1.05	0.77	0.73	0.71	1.1	0.95	0.61	0.19		

Table 3. Measured values—free lime content in clinker (CaO_F).

(%)	MIN	MAX
CaO_F	0.6	2.1
LS	95	100

The total number of samples was 70. Failures in samples of the clinker was calculated through a percentage expression involving the index, number of defective samples per piece, and a graphic representation of the samples with limits.

An Ishikawa diagram was used to determine the causes of defects in the clinker samples. This provided a clear representation of the causes and the consequences of the detected defects. An Ishikawa diagram is a diagram that shows the causes of an event which is often used in manufacturing and product development to outline the different steps in a process, demonstrate where quality control issues might arise, and determine which resources are required at specific times. We monitored the dependence of the clinker components based on a correlation analysis with respect to the important causes of errors.

The main goal of this article was to evaluate the quality of the cement production process with the intention of increasing performance by improving the quality of the process. The area of performance were solved by an assortment analysis and economic indicators (Formulas (2)–(5)).

1. Return on costs (unit) (%):

$$Rn = \frac{Zj}{VNj} \times 100 \tag{2}$$

2. Return on sales (unit) (%):

$$Rt = \frac{Zj}{Cj} \times 100 \tag{3}$$

3. Gross margin (unit) (EUR):

$$Hr = Cj - Nprj \tag{4}$$

4. Gross profit margin (unit) (EUR):

$$P = 1 - \frac{Nprj}{Cj} \tag{5}$$

where *Zj* represents the unit profit, *ÚVNj* represents the total number of direct and indirect costs for unit, *Cj* represents the unit price, and *Nprj* represents the direct cost for unit.

Return on cost is a return metric used to understand the profitability of an investment. It is a great measure of how much you can expect to make on an investment in comparison to how much it cost you to invest.

Return on sales (ROS) is a ratio used to evaluate a company's operational efficiency. This measure provides insight into how much profit is being produced per dollar of sales. An increasing ROS indicates that a company is improving efficiency, while a decreasing ROS could signal impending financial troubles.

The gross margin is the amount of money a company has left after subtracting all direct costs of producing or purchasing the goods or services it sells. The higher the gross margin, the more money the company can contribute to its indirect costs and other expenses like interest.

The gross profit margin is a metric used by analysts to assess a company's financial health by calculating the amount of money left over from product sales after subtracting the cost of goods sold.

For economic analysis, we collected data from the SAP management system of the company's financial accounting department (Table 4).

Table 4. Data for economic analysis of product—cement.

Type of Cement	CEM I-R	CEM I-N	CEM II-N	CEM II-R	CEM III
Cost (EUR/1 tonne)	43.18	41.94	38.85	35.40	32.88
Direct cost (EUR)	39.6	38.36	35.27	31.82	29.3
Profit charge (EUR)	32.06	29.74	25.52	24.33	20.21
Calculation price (EUR /1 tone)	75.24	71.68	64.37	59.73	53.09

A description of the results of the cement production process and their influence on performance is presented in the chapter results and discussion. Type of cement implies the type of cement product, which depends on the structure; the cost is the unit for production of the cement product; direct cost is the cost of materials and salaries; profit charge represents the benefit for the company; and the calculation price is the limited price with profit.

4. Results

In the first step of this research, we described the production process of cement. The production process of cement creates three phases: (1) mining, (2) processing raw sources, and (3) cement production, packing, and expedition. The first phase is mining. This phase consists of three activities (Figure 3): **(1) Quarry**—The basic raw materials for cement production are limestone and clay, which are mined in the company quarry and subsequently sorted to produce white cement and to produce gray cement. **(2) Crusher**—The excavated excavated mass limestone, which can be up to 120 cm in size, must be adjusted. It is prepared by pre-crushing in a crusher to a size of 1 to 8 cm. **(3) Conveyor**—After pre-crushing, the limestone is transported from the quarry to the production organization using belt conveyors to the homogenization hall. 2. The phase of processing raw sources consists of six activities (Figure 4):

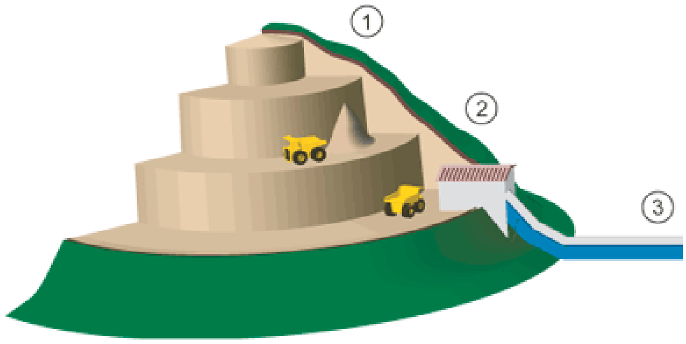

Figure 3. The first phase is mining. Source: own source.

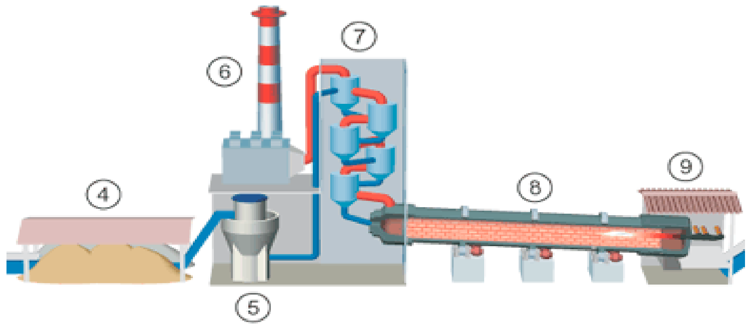

Figure 4. The second phase is the processing of raw sources. Source: own source.

4. Homogenization—The homogenization process is the mixing of the limestone with clay, which takes place in the homogenization hall. **5. Grinding**—The production of raw material flour is the first stage of cement production. The raw material mixture—perfectly homogenized limestone with clay—is transported by conveyor to the mill, where it is ground to the required fineness. The resulting product is raw material flour. **6. Filter**—The produced raw material flour must be filtered. **7. Preheating**—Before entering the rotary kiln in the heat exchangers, the raw material flour must be preheated. This increases the energy efficiency of the kiln. **8. Rotary kiln**—Clinker is a product of high-temperature processing of raw material flour in a rotary kiln. At a high temperature (approximately 1450 °C), the oxides present react with each other and, subsequently, clinker is formed from the minerals. **9. Cooling of the clinker**—The produced clinker is cooled with air in a cooler to a temperature of approx. 100 °C and then stored in clinker silos. The used air for cooling the clinker is then fed into the furnace as combustion air.

3. The cement production, packing, and expedition phase consists of three activities (Figure 5): **10. Completion of the process**—The basic component of cement is clinker,

and additional components (mine slag, and limestone) and are ground together with a certain amount of natural or industrial gypsum. By grinding all cement components in ball mills, the cement is obtained. **11. Packing**—The cement is packed into bags according to customer requirements. **12. Expedition**—The shipping process is carried out based on supply contracts in the form of truck transport.

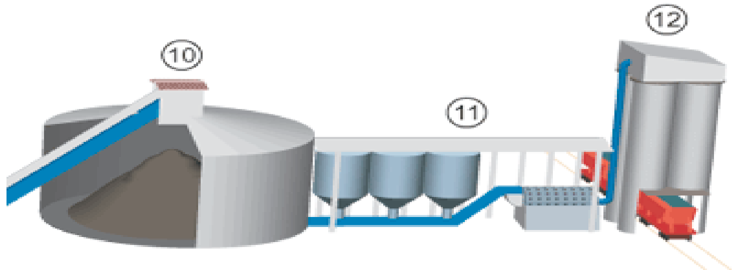

Figure 5. The third phase completion of cement production. Source: own source.

The evaluation of the cement production process was followed by basic statistics—descriptive statistics (Table 5) for the basic component of cement, which consists of clinker (95–100% by weight) and supplementary components that make up the remaining 0–5%. Clinker is produced by burning raw material flour. It contains elements that are mostly expressed as oxides, e.g., CaO_F. It is important to monitor the degree of clinker carbonation (LS) and the content of free lime (CaO_F) in the clinker, which should be observed according to the prescribed criteria.

Table 5. Statistical analysis—statistical indicators for CaO_F, LS. Source: own source.

Statistical Indicators	CaO_F	LS
$\overline{x}$	1.217714	98.13957
$\hat{x}$	0.9	96.17
$\widetilde{x}$	1	97.835
MAX	3.78	104.21
MIN	0.19	91.99
RV	3.59	12.22
s2	0.515853	3.972642
s	0.7182229	1.993149
γ_3	1.737614	0.589682
γ_4	3.189647	1.557602

All statistical indicators recorded positive results, indicating that the content of CaO_F and LS in the clinker is technically acceptable for cement quality.

Results were compared with the lower and upper limits (Table 3): the limits for CaO_F and LS set by the company based on Slovak technical standards for the content of substances in the clinker. A box plot was used to compare the measured values (Figures 6 and 7).

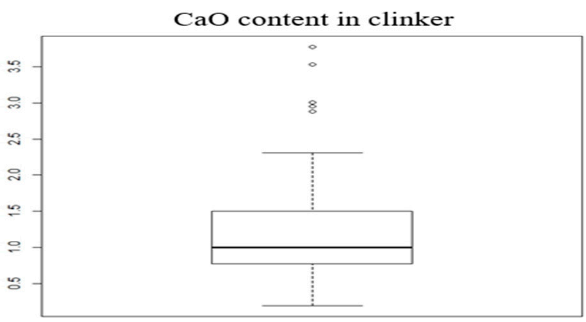

Figure 6. CaO_F content in clinker. Source: own source.

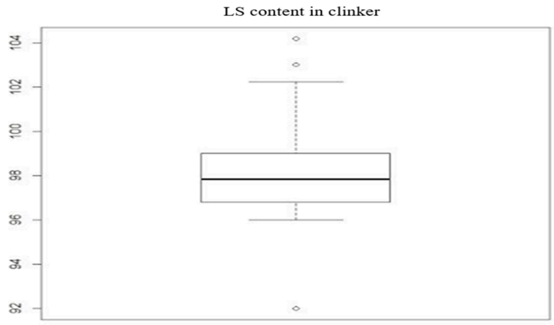

Figure 7. LS content in clinker. Source: own source.

In conclusion, the content of CaO_F in the clinker was outside the limits at values of 2.07, 2.95, 2.88, and 3.53. More CaO_F in the clinker can affect the cement quality. The LS clinker carbonation values should be within the limit of 95–100; however, we found that seven data did not correspond to the limit and were in the range of 100.4 to 103.

Based on the economic analysis of failure findings in a sample of CaO_F and LS in the clinker, the main proportions of findings above and below the limit were determined. The economic analysis of CaO_F and LS substances in clinker was performed using Formula (1). The results of the economic analysis are presented in Table 6. Based on the results, we can see that the components of CAO_F and LS in the clinker samples were also failures of samples, which can have consequences for the formation of the cement and affect its quality. More failures of the samples were over the limit.

Table 6. Economic analysis—index of failures for CaO_F, LS. Source: own source.

	Failures CaO_F	**Structure (%) CaO_F**	**Failures LS**	**Structure (%) LS**
BELOW LIMIT	6	8.6	1	1.4
ABOVE LIMIT	7	10	11	15.7

A suitable tool for choosing the optimal structure of the product assortment is the assortment analysis, which monitors the assortment of the products of the given company and its optimal representation and evaluates the preference, elimination, and reduction of the product assortment. However, the customer's needs and requirements are also decisive criteria for choosing a suitable production range. In addition to basic indicators such as quality, price, safety, and environmental reliability, specific customer requirements are also important. These are reflected in the cost calculation, i.e., the value of the given product without accepting the profit margin and value-added tax. We performed the assortment analysis based on Formulas (2)–(5) and the data collected from the company's SAP management system in Table 4. These indicators are important for determining the production range from the point of view of the company's financial performance and achieving profit for the company. The results are presented in Table 7.

Table 7. Assortment analysis for product—cement. Source: own source.

Cement Product	**CEM I-R**	**CEM I-N**	**CEM II-N**	**CEM II-R**	**CEM III**
Profitability of costs (%)	74.25	70.91	65.69	68.73	61.47
Profitability of sales (%)	42.61	41.49	39.65	40.73	38.07
Payment contribution (EUR)	35.64	33.32	29.10	27.91	23.79
Gross margin (EUR)	0.47	0.46	0.45	0.46	0.44

Based on the calculation of the economic indicators, we can conclude that excluding the CEM III product from the production program could be considered to reduce the production range because all the recalculated indicators clearly determined that it demonstrated the worst values in terms of profitability and in terms of the contribution to the payment of fixed costs and production profit. The most suitable product in the given product range is the CEM I-R product, which the company produces in a sufficiently large volume. Therefore, if we were faced with the decision of which product to eliminate from the production program and which product to continue, the answer based on the above-mentioned characteristics would be clear. We prefer the continuation of the CEM I-R product and would eliminate the production of the CEM III product. However, even this decision does not have to be final because we can also calculate the company-wide profit from individual products.

Focusing on the main goal of this article, which was to evaluate the quality of the cement production process with the intention of increasing performance, we calculated the amount of company-wide profit at the planned volume of production and at the set selling prices of individual products based on the information from Table 7. The results are presented in Table 8.

Table 8. Calculation of profit for company with assortment. Source: own source.

Indicators (EUR)	CEM I-R	CEM I-N	CEM II-N	CEM II-R	CEM III
Production (tone)	136,846	42,969	41,354	250,818	146,059
Revenue (EUR)	10,296,293	3,080,018	2,661,957	14,981,359	7,754,272
Direct costs (EUR)	5,419,102	1,648,291	145,856	7,981,029	4,279,529
Indirect costs (EUR)	489,908	153,829	148,047	897,928	522,891
Profit in company (EUR)	4,387,283	1,277,898	1,055,354	6,102,402	2,951,852

With the original structure of the production range, we would have achieved a company-wide profit of EUR 15,774,789 (the sum of partial profits for individual products). If we look at the company-wide profit from the point of view of individual products, we see that the highest profit was achieved in the production of the CEM I-R product. However, in the case of the CEM III product, which we planned to eliminate from the production program, we found that its company-wide benefit was higher than that of the CEM product I-N and CEM II- N. Based on this finding, we can conclude that the decision to exclude the CEM III product from the production program in relation to the other products would be unjustified.

5. Discussion

It is important to understand the process to perform research on the cement production process. We described the production process of cement. The production process of cement creates three phases: (1) mining, (2) processing raw sources, and (3) cement production, packing, and expedition. A statistical analysis was realized for the quality of the product—cement—from the company's production process. All statistical indicators recorded positive results, which indicates that the content of CaO_F and LS in the clinker is technically acceptable for cement quality. Based on the economic analysis of failure findings in a sample of CaO_F and LS in the clinker, we evaluated samples according to the limits in Table 3. We analyzed the errors in the samples of the cement components using graphic methods, which revealed values below and above the required limits (Figures 8 and 9).

From the graph for CAO_F, we can see that there were six values below the limit and seven values above the limit from the total number of measured data. From the graph for LS, some values were outside the prescribed limits set by the organization. There was one value below the lower limit and up to eleven values above. All values outside the limits can affect the quality of the cement. It is the main source of the quality of the cement structure. Samples that do not meet the specified limits provided by the organization must be selected from the file and modified. An Ishikawa diagram (Figure 10) was used to determine the causes of defects in the clinker samples, which provided a clear representation of the causes and the consequences of the detected defects.

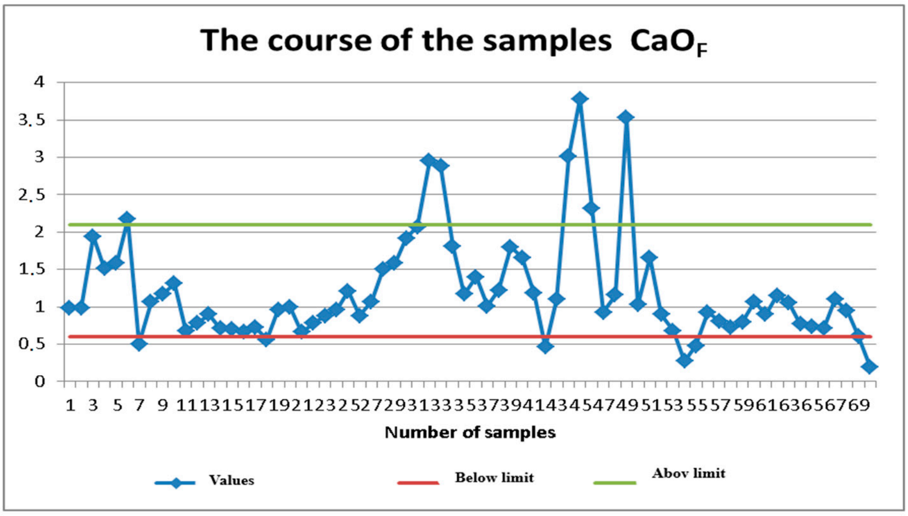

Figure 8. CaO_F content in clinker with the limits. Source: own source.

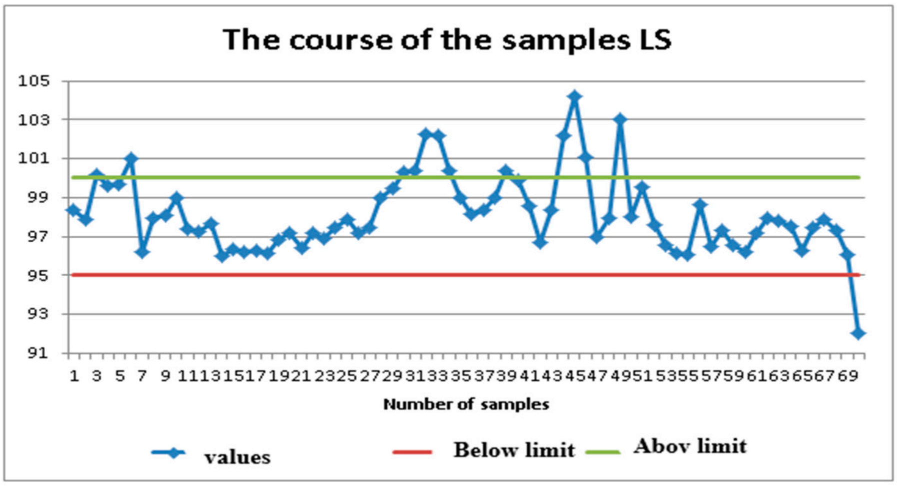

Figure 9. LS content in clinker with the limits. Source: own source.

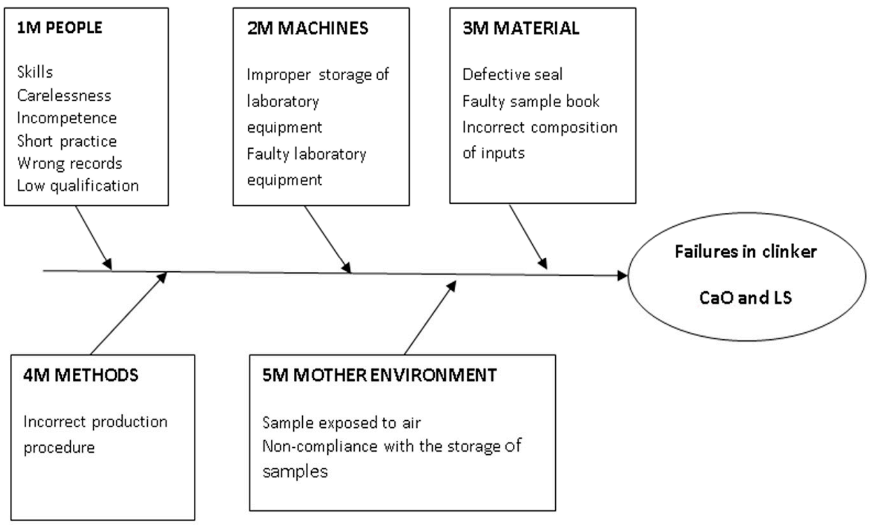

Figure 10. Ishikawa diagram for failures in clinker. Source: own source.

An Ishikawa diagram was used to reveal the key cause. We investigated the causes from the point of view of the 5 M approach, and we monitored deficiencies in the human factor, materials, methods, environment, and equipment. The 5 M process refers to men (people), material, methods, machines, and mother environment. These areas are critical parts of all processes in the company. The main reason for the errors was the incorrect determination of the content of free lime and carbonation in the clinker, i.e., processing technology. From the analysis of the diagram, it follows that the cause to which the greatest attention must be paid is "people", i.e., the human factor. From the point of view of corrective and preventive measures, we suggest carrying out training on the preparation of samples for chemical analysis at regular intervals; this will probably eliminate inexpertness and erroneous recording of values. Due to the fact that the product—cement—is delivered to customers, it is necessary to monitor the dependence of the clinker components—CaO_F and LS—for the production the cement. Its quality, which depends on components, can be improved and adjusted in the process of preparing the input raw materials. We monitored the dependence of the clinker components on the basis of the correlation analysis (Figure 11) with respect to the important cause of errors.

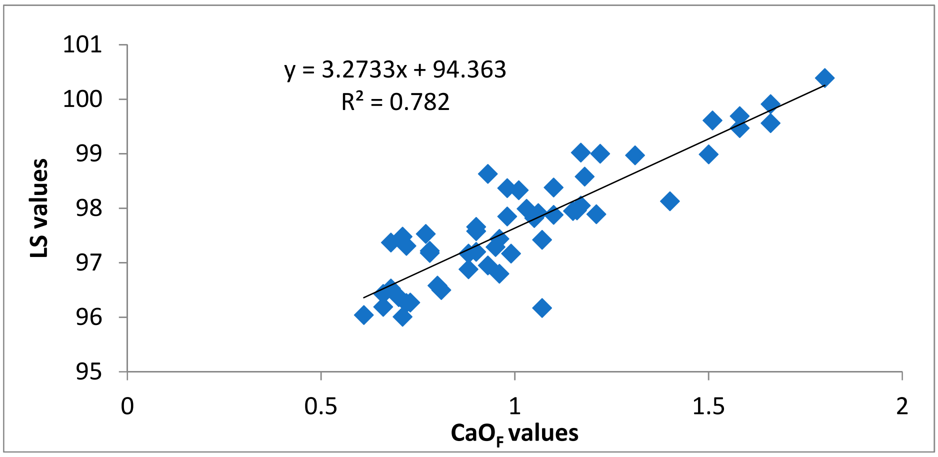

Figure 11. Correlation analysis for the components for clinker. Source: own source.

We can see the direct linear dependence (Figure 11) provided by the point estimate or by the model Y = 3.273X + 94.363 between the dependent variable Y, i.e., by the degree of carbonation (LS) and between the independent variable X, i.e., the free lime (CaO_F). It is clear from the graphical course between the LS and CaO_F parameters that as the value of LS increases, so does the CaO_F. The coefficient of determination is $r^2 = 0.782$, indicating that the coefficient takes values from the interval <0; 1>. It can be concluded that the coefficient is close to (1), which means a close dependence on both measured parameters.

All the findings in the cement production process point to an error in the input, in the preparation of the clinker from which cement is produced. This production process problem must be solved by the company in view of the quality of the product: cement. The scientific contribution of this research demonstrates the errors in cement process with respect to the material structure of the cement product. A very important part of cement production is its use in industry, which changes the structure of cement. Tian et al. (2022) found that an improvement in the heating efficiency is crucial for cement-based materials, and Zhang et al. (2021) commented that the cement pastes containing coal gangue demonstrated a degraded early-age strength and increased porosity and water absorption under standard curing conditions [3,4]. For these reasons, the structure of the cement very important.

The proposed approach to the structure of cement depends on the requirements of customers for a cement product for the construction industry.

In view of this fact, we proceeded with a recalculation of the company-wide profit after the exclusion of the CEM III product from the production program. We transferred this production to the CEM I-R product, with the understanding that we can ensure the sale of this product on the market. All calculated prices of cement products include the environmental protection costs related to the CO_2 emissions of the cost item (Table 9).

Table 9. Profit calculation of the company with new assortment. Source: own source.

Indicators	New Assortments
Revenue	42,009,106
Direct costs	15,194,278
Indirect costs	2,212,603
Profit	24,602,225

We decided to eliminate the product CEM III from the production range and moved the production volume to the product CEM I-R due to its best indicators. With the same volume of production and the same level of fixed costs, the company would achieve a profit in the amount of EUR 24,602,225, which represents an increase in the volume of sales by EUR 8,827,436.

6. Conclusions

Process management aims to optimize processes to achieve better process performance and optimal indicators in the company performance, such as an optimal quality of products and company profit as a financial indicator. The cement production process in the selected company was analyzed by various methods such as statistical, economic, and financial analyses using instruments of quality management such as the Ishikawa diagram, regression diagram, correlation, and box plot diagram. The main goal of this article was to evaluate the quality of the cement production process with the intention of increasing the performance and quality of the process and the quality of the cement product in various assortments. We suggested an alternative assortment to reduce CEM III and replace CEM I-R, bringing a higher profit to the company. This paper presents the results of the components CaO_F and LS of the clinker and their quality, which are critical for cement products. These components create the base of the clinker for the preparation of cement. By evaluating the quality of the sample CaO_F and LS, we obtained failures under the limits required by the company. This was a very important fact for the quality of the clinker because the clinker creates the material for the cement. The relevance of the decision of this scientific research with respect to the innovation of the cement production process focused on the requirements of Industry 4.0. The results of the research can be instruments or recommendations for other companies that are involved in the cement production process. This section is not mandatory but can be added to the manuscript if the discussion is unusually long or complex.

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