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Man and Working Environment
Safety Engineering & Management
Science - Industry - Education

Conference Proceedings

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UNIVERSITY OF NIŠ, SERBIA
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UNIVERSITY OF NIŠ
FACULTY OF OCCUPATIONAL SAFETY

The 20th International Conference "Man and Working Environment"
SAFETY ENGINEERING & MANAGEMENT –
– SCIENCE, INDUSTRY, EDUCATION (SEM-SIE 2023)

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FACULTY OF OCCUPATIONAL SAFETY

Conference Co-organisers:
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Faculty of Engineering, South-West University “Neofit Rilski”, Blagoevgrad, Bulgaria
Faculty of Natural and Technical Sciences, “Goce Delčev” University, Štip, North Macedonia

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FORECASTING SUSTAINABLE STEEL SUPPLY CHAINS: A CASE STUDY

Abstract: *To maintain and enhance competitiveness, organizations must monitor market dynamics, conduct comprehensive analyses, and proactively make informed decisions while continually adapting their business strategies to evolving conditions. In the modern business environment, the implementation of business intelligence plays a key role in improving the decision-making processes of management within organizations. This implementation implies the utilization of processes, technologies, and tools that facilitate the transformation of data into actionable information, information into knowledge, and knowledge into strategic plans, ultimately enabling effective decision-making and management. An essential objective of business intelligence is the identification of trends, patterns, and intentions, which advance the formulation of predictive scenarios for future outcomes. Consequently, the aim of this paper is to present a comprehensive approach to quantitative time series prediction and qualitative Delphi prediction techniques. The specific focus of the study centres on forecasting supply chain dynamics, particularly the estimation of raw material consumption within organizations observing circular economy principles. Supply chain management within the circular economy framework involves detailed planning and management of all system activities with a primary goal of reducing resource utilization during production, reducing the amount of material stocks in the plant, and minimising the amount of generated waste. For this research, a specific production organization X was selected, specializing in the manufacture of bodies for motor vehicles, trailers, and semi-trailers, with steel as the predominant raw material. The choice of this organization is justified by the potential for a substantial impact on climate change mitigation through steel flow planning in the production process. Steel industry is recognized as a significant contributor to CO_2 emissions, accounting for approximately 4-5 % of total emissions. By minimizing the use of the analysed raw material, circular economy objectives can be effectively realized. The study highlights substantial disparities between the actual and predicted figures for steel consumption, specifically hot-rolled steel sheets. These variations are attributed to the exceptional circumstances during the SARS-CoV-2 pandemic. Consequently, the research highlights that the historical data from 2019-2020 utilized as the foundation for this study may not be fully representative due to the fact that operations during that period were carried out under an emergency regime prompted by the SARS-CoV-2 pandemic.*

Keywords: circular economy, quantitative forecasting, qualitative forecasting, time series, Delphi method

INTRODUCTION

Rapid and frequent market changes resulting from globalization demands call for a review of how organizations are managed, all with the goal of achieving a predefined business vision within a specified timeframe. Continuous growth of the global population has a direct impact on the increased consumption of goods and services, which, in turn, drives the global economy. However, this surge in global consumption poses significant economic and environmental challenges, such as imbalanced production and consumption, fluctuating prices, and environmental pollution.

The fundamental issue with the current production and consumption of goods and services lies in their connection to a linear economic model, characterized by a one-way flow of energy and materials. To address these challenges, organizations have increasingly embraced sustainable and green practices, aligning with the principles of sustainable development and circular economy (Manavalan & Jayakrishna, 2019).

Transformation of required economic models can be achieved through the adoption of circular economy principles, emphasizing the importance of repairing, reusing, and improving products during their lifecycle, rather than their permanent disposal. This approach not only conserves resources but also incentivises resource efficiency by connecting industry supply chains.

Effective supply chain management in organizations requires detailed planning to meet customer needs, procure raw materials, manage production, ensure delivery, and facilitate returns of products (Regodić, 2014). According to circular economy principles, managing stocks is a crucial aspect of circular supply chain operations, involving the monitoring of raw materials, semi-finished products, and finished goods. A circular supply chain expands the scope of a closed-loop supply chain by promoting a zero-waste vision, not only within its immediate supply chains but also by collaborating with partner firms in the same or other industrial sectors (Lima & Seuring, 2023).

Accurate forecasting of raw material consumption is essential to proactively address future deviations, enhance raw material management, and adjust business operations when necessary.

Given the rapid technological changes impacting every aspect of modern life, supply chain forecasting aligns with the requirements of Industry 4.0 and facilitates the adoption of a circular economy. This study aims to explore the application of statistical methods in managing raw material supply chains in line with the circular economy principles.

MATERIALS AND METHODS

Today, iron alloys, collectively referred to as technical iron, play an essential role in technical applications. These alloys constitute approximately 95% of the world's total metal production (Jovanović et al., 2003). The widespread use of technical iron is made possible due to significant and easily accessible reserves of iron ore in the Earth's crust, as well as the straightforward processing of iron ore and the diverse physical and mechanical properties of iron alloys (Wondris et al., 2016). Technical irons are classified based on their carbon content into the following categories: pure iron (with very low carbon and other elements), steel (with carbon content typically not exceeding 2%), and cast iron (with carbon content above 2%) (Arsić, 2020).

Steel, available to consumers in various forms, such as hot-rolled, cold-rolled, or cast, has been irreplaceable in societal development for a long time. However, the pressing environmental challenges of the present demand novel approaches and production processes that address climate change and enhance resource efficiency. In order to tackle these challenges, it is imperative to invest in research and development of innovative technologies for producing commonly used resources such as steel. The demand for steel continues to grow, given its fundamental role in society, from infrastructure and construction to transportation. However, steel production is known for its significant energy intensity (World Steel Association, 2012). The steel industry relies heavily on extracting vast quantities of natural materials, such as iron ore (e.g. magnetite) and carbon. Notably, the greenhouse gas most associated with the global steel industry is carbon dioxide (CO_2), with an average emission of 1.41 tons of CO_2 per ton of steel produced (IEA, 2023). The global steel industry is an important emitter of CO_2 and it is considered that it has a 4-5% share in the total emission of CO_2. Consequently, effective management of this raw material is crucial in mitigating climate change.

Long-term reductions in industry emissions require a shift from current production models to new, more environmentally friendly approaches. Steel, being 100% recyclable, can be used repeatedly in a closed loop, aligning with the principles of circular economy. The "4R" concept – reducing the use of steel, reusing it, remanufacturing, and recycling – guides the implementation of circular economy in the steel industry.

Planning and organizing the supply chain for steel are crucial for using this resource in an energy-efficient, environmentally sustainable, and economically viable manner. Given that Serbia ranks 46th among the world's largest steel producers, with 1.9 million tons of steel produced in 2019 (Basson, 2020), and considering steel's suitability for closed-loop management, this research focuses on analysing statistical methods for forecasting the hot-rolled steel (HRS) sheets supply chain in a production organization situated in the city of Kragujevac.

Data collection

To ensure data protection and maintain the confidentiality of the analysed organization, all general information will be anonymised, and the organization will be pseudonymously identified as X throughout this research.

X is a Serbian production organization specializing in the manufacturing of bodies for motor vehicles, trailers, and semi-trailers. Renowned as a leading producer of commercial vehicle bodies, truck enhancements, and specialized vehicles within the Serbian market, X is recognized for its products' quality, innovative design solutions, and long-lasting durability. Within organization X, all products are categorized into two primary groups: the first group comprises cargo boxes with tarpaulin, while the second group includes thermal chambers.

To determine the primary raw material within the organization, which will be the focus of the research, all necessary data was extracted from the company's records to conduct a material flow analysis.

Material flow analysis (MFA) serves as a crucial analytical tool for quantifying materials within a well-defined system, both temporally and spatially, with the objective of achieving a material balance (Brunner & Rechberger, 2017).

Upon analysing material flows within organization X, it was established that the primary input materials encompass steel, aluminium, plywood, insulation materials, tarpaulin, laminate, adhesives, and an input flow of energy. In the production line, the output flows consist of final products, while waste generation and exhaust gases result in emissions.

The MFA reveals that HRS sheets are a frequently utilized raw material in the production process of organization X. This case study focuses on the analysis of HRS sheets, intended for further processing through cold forming and employed in a wide range of industries, including machinery, vehicles, construction, shipbuilding, industrial equipment manufacturing, metal processing, and construction. HRS sheets refer to carbon-manganese steels with guaranteed elasticity, tensile strength, and satisfactory extensibility.

This study focuses on the consumption of the analysed raw material within organization X during the period from July 2019 to December 2020. The data was gathered through a questionnaire distributed to several production organizations operating in the city of Kragujevac. It is noteworthy that the management of the organization X only expressed interest in participating in this research. Figure 1 illustrates the consumption of HRS sheets and their average specific market price during the observed period.

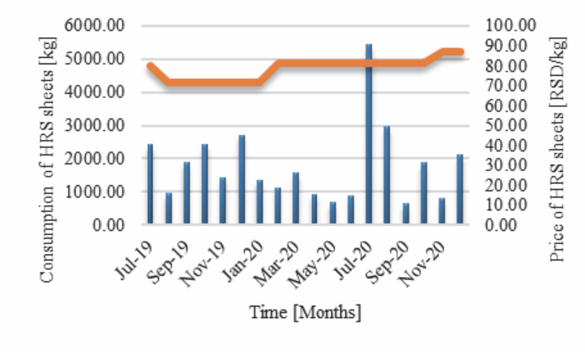


Figure 1. *The influence of fluctuation in the price of HRS sheets on consumption*

Based on Figure 1, it is evident that the price of HRS sheets exerts minimal influence on steel consumption. This assertion can be empirically substantiated using appropriate statistical methods, such as regression and correlation analyses. A comprehensive statistical examination has unveiled a negative (-) correlation coefficient, indicating an inverse, negative relationship. Additionally, the square of the Pearson correlation coefficient, known as the coefficient of determination, quantifies the extent to which variations in one variable can be attributed to changes in another variable. In this instance, the Pearson coefficient showed a value of -0.045. A comparative analysis of this value with literature values (Cvetković, 2015) leads to the conclusion that there exists a weak correlation, often referred to as a low direct correlation, between the consumption of HRS sheets and their price. Specifically, through correlation and regression analysis, it has been established that changes in HRS sheets consumption are only minimally influenced by fluctuations in price.

Forecasting methods

Forecasting can be defined as a systematic and forward-looking participatory process. It facilitates the development and formulation of medium- and long-term policies. Figure 2 illustrates the fundamental components of the basic forecasting model, including input, methodology, and output. This model remains consistent regardless of the specific forecasting technique used.

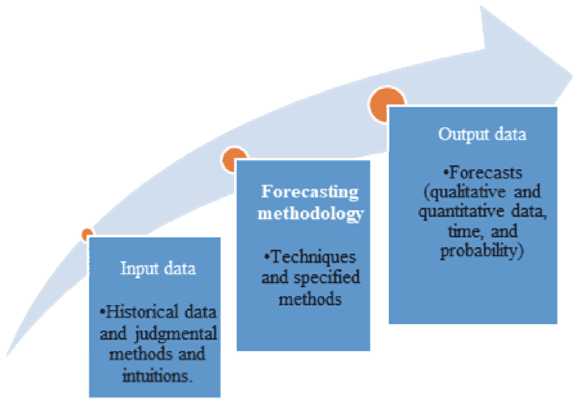


Figure 2. *Forecasting model*

The forecasting process necessitates inputs, specifically data or expert judgment, and the application of specific forecasting techniques. These primary forecasting techniques are divided into three fundamental categories (Walk, 2012):

- Quantitative techniques: These involve the creation of quantitative models based on historical data.
- Qualitative techniques: These rely primarily on non-numerical, descriptive data gathered through expert assessments and opinions.
- Hybrid techniques: These methods combine both qualitative and quantitative approaches using the strengths of both.

In this research, quantitative forecasting methods, specifically time series analysis with a trend component, were employed, alongside qualitative forecasting techniques such as the Delphi method.

Time series analysis has proven to be a valuable tool for forecasting. It allows management to predict the demand for materials for the upcoming months based on historical data, facilitating the planning of production capacities, workforce allocation, raw material stocks, product distribution, and more. It is evident that time series analysis is particularly reliable for short-term forecasting. Most time series data can include several components that contribute to their variations, including trend, seasonality, cyclicality, and random components.

Business intelligence encompasses technologies that empower business users to access, analyse, and utilize data to obtain the essential information required for effective decision-making and management within organizations. Notably, business intelligence technologies also facilitate users in the business to conduct statistical analyses, including forecasting. One of the simplest ways to incorporate business intelligence into the forecasting process in production organizations is by employing various forecasting software solutions. Many forecasters commonly utilize a combination of tools, opting for either Microsoft Excel or specialized forecasting software for their forecasting needs (Syntetos et al., 2016).

In this research, Microsoft Excel software was employed because historical data on a specific variable from organization X's records were available. These data were utilized to create a forecast using Excel functions such as “forecast” and “trend”. As part of this research, these functions were used to validate the values obtained from the previous forecasting method.

The last method utilized in this research was the Delphi method. The Delphi method is a specific, qualitative, and systematic approach that involves gathering and processing the opinions of experts on specific forecasting issues (Vujošević, 1997). Its primary objective is to reach a consensus among experts on a defined topic through a series of surveys (Chan et al., 2001). What sets the Delphi method apart from other qualitative methods are its key characteristics, including anonymity, an iterative process involving rounds of research with feedback, statistical analysis of responses, and a predefined questionnaire (Lang, 1995). These advantages make the Delphi method particularly relevant when applied to research topics with a strong social desirability aspect, such as sustainability and circular economy (Gebhardt et al., 2022).

The Delphi method allows for variations in answers, where participants (known as panellists) can respond to a specific question with one or three answers. If three answers are required, the meanings of the given answers are as follows:

O represents the optimistic answer, signifying a high probability of the event occurring, implying the shortest expected time for the activity’s execution.

M corresponds to the expected response, indicating the time when the event is almost certain to take place, representing the most likely time for activity execution.

P stands for the pessimistic answer, suggesting a low probability of the event occurring and representing the longest expected time for the activity to be completed.

In the classical Delphi method, typically only one answer is expected for the corresponding future event or activity. The classic single-answer Delphi method involves panellists providing only the expected response (M). The responses collected from the Delphi questionnaire are predominantly subjected to statistical analysis, which involves the calculation of various parameters, including the median, dispersion, and the probability of the event occurring.

The scheme for forecasting HRS sheets consumption using the Delphi method within organization X is illustrated in Figure 3.

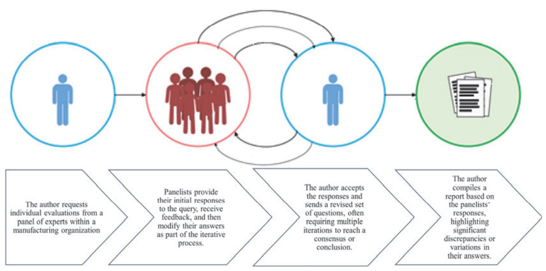


Figure 3. *Forecasting with the Delphi method in a specific organization*

The fundamental steps outlined in the implementation of the Delphi method are in alignment with the recommended methodological framework established in existing literature (Chedi, 2017).

To initiate the Delphi study, experts or respondents were carefully selected to form the expert panel. The number of panellists is a crucial aspect of the Delphi method and typically ranges from 5 to 15 individuals. The selection of these experts for participation in the study was carried out in collaboration with a representative of the production organization X. Once the relevant job positions interested in participating were identified, e-mail addresses were requested from the organization’s contact person to facilitate the distribution of the Delphi survey questionnaire. The Delphi survey questionnaire is a fundamental research tool and the main tool in Delphi forecasting.

Creating the questionnaire involves formulating questions related to the relevant area of prediction and defining possible answers to these questions. It is also possible to quantify the responses in the questionnaire, which facilitates subsequent statistical data analysis. The questions within the questionnaire must be clearly understandable and formulated in a way that ensures all panel members interpret them uniformly and correctly, aiming to create the highest quality questionnaire possible. The questionnaire used in this case was structured into two parts. The first part collected general information about the panellists, including their gender, age, educational level, and years of work experience. The second part contained specific questions related to the consumption of the analysed raw material.

The questionnaire comprised two specific questions, each requiring a distinct response related to the consumption of HRS sheets in the production organization X:

(1) Do you assume that the consumption of HRS sheets sheet will be less, greater, or equal to the forecasted value of 1,791.44 kg for the month of January 2021?

(2) In which month of 2021 do you expect the consumption of HRS sheets in your organization to be 1,791.44 kg, which is the forecasted value?

Given the significance of resource efficiency and waste reduction in the context of the circular economy, the panellists were also asked to assess the productivity of using steel as a critical resource in the production process. The productivity of resources in the analysed organization was not previously determined, but for the purposes of this study, it was considered to be low concerning the use of HRS sheets. Consequently, the panellists were asked to respond to the following question:

In which month of 2021 do you expect the productivity of using HRS sheets in your organization to reach 30 %?

As data on the current productivity of HRS sheets usage was not available, a value of 30 % was chosen in collaboration with the management to initiate the Delphi method and obtain a consensus of opinion among a group of experts within the organization. Many researchers halt the survey rounds of Delphi studies when they achieve a predetermined consensus among the panellists. In this research, a reference value of the variance of 1.2 was established as the criterion for concluding the study. This means that in a given iteration, the variance of a specific response must be less than or equal to the reference value to exclude the question from the subsequent iteration or to terminate the research. This value was chosen based on its frequent use as a benchmark variance value in the literature (Levi-Jakšić et al., 2015).

RESULTS

Fluctuations in the market necessitate organizational management to adapt their approaches in order to attain well-defined business objectives, such as profitability, growth, development, and long-term sustainability. Monitoring business changes is of strategic importance in improving an organization's functioning, allowing for effective analysis and real-time assessment of the current business environment. Consequently, it is imperative to manage organizations effectively, employing activities such as forecasting, organizing, directing, coordinating, and controlling.

Time series forecasting methods

Dynamic analysis is employed in the examination of time series data to ascertain the progression, trends, and rate of change in a variable phenomenon over time. Time statistical series consist of data points gathered and categorized within specific time intervals (Jovetić, 2006). The initial step in time series analysis involves visually representing the data and making a visual assessment. In this research, the consumption of HRS sheets within production organization X is examined over an eighteen-month period (Figure 4). The analysis reveals that this data series displays an impulse pattern.

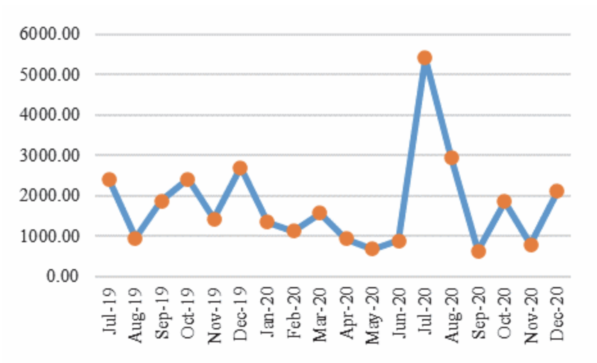


Figure 4. *Time series data characteristics*

This research focuses on analysing the trend component, which is one of the most common variations contributing to changes in time series data. When analysing a particular time series, the application of a linear trend is appropriate if there is a consistent, linear development and movement of the variable.

A key condition for applying a linear trend in time series analysis is that the variable, over the observed time period, should experience approximately the same magnitude of increase or decrease.

Building on the concept of a simple regression function, the linear trend function is defined by Equation 1. In this equation, x represents the independent variable value, which is time in the context of time series analysis, while y_t signifies the trend in the observed phenomenon's value, a indicates the trend's value when x is equal to 0, essentially representing the average of the time series over the observed period, while b is the coefficient indicating the average absolute increase in successive time periods:

$$y_t = a + bx \qquad (1)$$

Given that the observed dataset, specifically the consumption of HRS sheets within production organization X, contains an even number of data points, it is necessary to select two data points from the middle of the time series. To these selected data points, values of -0.5 and +0.5 are added, respectively. To forecast the consumption of HRS sheets in the upcoming month for organization X, it is necessary to continue by adding a value of +1 to the independent variable x and repeat this process until it reaches the desired forecasted month. The trend in the consumption of HRS sheets for production organization X can be graphically represented, as shown in Figure 5, with the yellow line on the graph denoting the projected consumption of the analysed raw material for the next 6 months (January 2021 – July 2021). In the first following month of the analysis, the expected consumption (y_{t19}) is projected to be 1,791.44 kg.

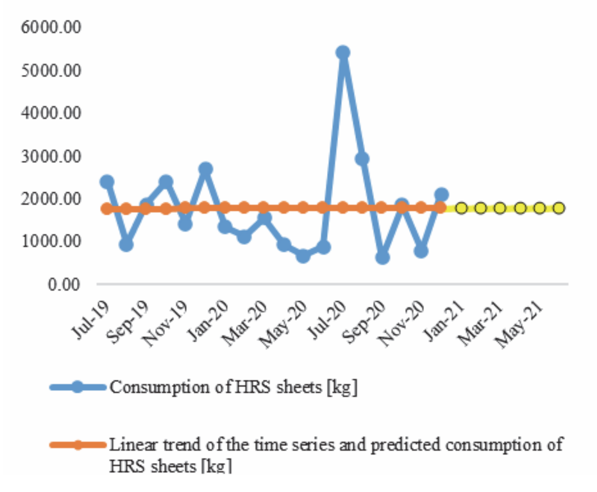


Figure 5. *Linear trend of the time series and predicted consumption of the analysed raw material*

When the central tendencies of a time series do not follow a straight-line pattern, a linear trend may not accurately represent the long-term movement of the phenomenon. In such cases, it becomes necessary to employ alternative trend models, such as parabolic or exponential trends, to better capture and describe the behaviour of the data.

Business intelligence and forecasting

When applying the aforementioned functions within Excel software to forecast the consumption of HRS sheets in the 19th (January 2021) month of analysis, a value of q_{t19} = 1,789.18 kg is obtained. This reveals certain discrepancies in comparison to the value derived from the time series with a trend component.

Given that the first derived value of 1,791.44 kg for the forecasted consumption of HRS sheets is slightly higher than the Excel-generated value of 1,789.18 kg. The first value is adopted for further analysis. It is essential for further research that the forecasted consumption value, represented as y_{t19} = 1,791.44, belongs to the set of real numbers. However, it is important to note that the model used for this forecast may have limitations because real-world situations are often complex and may not be precisely described with available data. A comprehensive description of a real system frequently requires more detailed data than can be gathered at a single point in time (Zimmermann, 2001). Hence, when defining forecasted consumption values, it is crucial to express the analysed variable using linguistic terms or a language variable. In this particular case study, the expressions used to describe the variable over time are rooted in human reasoning. The terms are defined by the organization's management team on a scale of 1-9, where 1 represents the lowest value (extremely small) of the variable, and 9 signifies the highest value (extremely large) of the variable. The management team has associated specific values with each point on the 1-9 measurement scale, reflecting the range from extremely low to extremely high. The interval size is determined by the range of data and the nature of the feature set. In this instance, the maximum consumption of HRS sheets in the analysed period, y_{max} is 5420 kg, and the minimum consumption y_{min} is 629 kg. With a total of 18 data points n, the interval size i is calculated as 927 kg using Equation 2.

$$i = \frac{y_{\max} - y_{\min}}{1 + 3.322 \cdot \log_n} \qquad (2)$$

To gain a deeper understanding of the current consumption of the analysed raw materials within the organization, it is necessary to map the forecasted value y_t to one of the five listed outcomes from Table 1.

Table 1. *Linguistic terms of consumption of the analysed raw material*

Definition	Interval
Extremely low value	[629-1556)
Low value	[1556-2483)
Middle value	[2483-3410)
High value	[3410-4437)
Extremely high value	[4337 <

Based on the comparison of the forecasted value y_{t19} = 1,791.44 kg for the first following month and the intervals shown in Table 1, it is concluded that the forecasted value has a low value.

Forecasting using the Delphi method

Forecasting using the Delphi method in the specific production organization X, which operates in the city of Kragujevac, was carried out following the steps shown in Figure 3.

The Delphi survey questionnaire was transmitted to the panellists via the Internet. One of the significant advantages of using modern media is the expedited feedback process, which is a crucial factor in the Delphi technique. This accelerated communication allows for more rapid iterations and consensus-building among the experts involved in the Delphi process.

In the initial Delphi iteration, the questionnaire was distributed to seven employees at the production organization X, resulting in an initial response rate of 71.43 %. As previously emphasized, the first part of the questionnaire in the initial Delphi round gathered information about the panellists' general data. The general data of the panellists are presented in Table 2.

Table 2. *General data of the panellists*

Feature		Frequency	Percentage of panellists [%]
Gender	Male	3	40
	Female	2	60
	Total	5	100
Feature		Frequency	Percentage of panellists [%]
Age	18-25	1	20
	26-35	1	20
	36-45	2	40
	46-55	1	20
	Over 55	0	0
	Total	5	100
Education level	High School	0	0
	Vocational college	3	60
	Bachelor	2	40
	Master	0	0
	Total	5	100
Years of work experience	Up to 2 years	1	20
	3-5	2	40
	6-15	1	20
	Over 15	1	20
	Total	5	100

The distribution of answers related to the question of whether the consumption of HRS will be less, equal, or greater than the predicted value is illustrated in Figure 6.

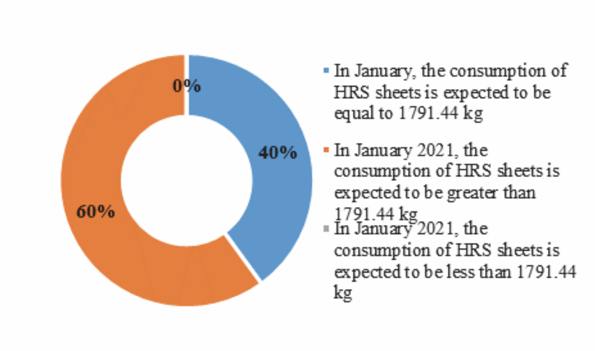


Figure 6. *Distribution of answers regarding the consumption of HRS*

The responses of the panellists to the question regarding the forecasted month in 2021 when the productivity of using HRS sheets will reach 30 % are depicted in Figure 7.

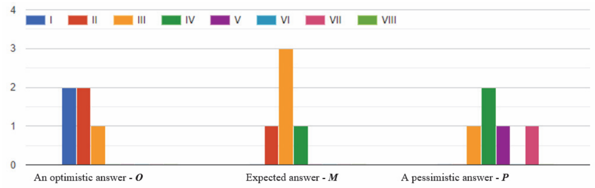


Figure 7. *Distribution of answers regarding the productivity of using HRS sheets*

The panellists were asked to provide answers for the month when there is a high probability of the event occurring, the month when the event is almost certainly expected to occur, and the month when there is a low probability of the event occurring (O, M, and P answer). In such cases, the average time of realization (t_n) of an event is determined according to mathematical relation 3.

$$t_n = \frac{1}{n} \sum_{i=1}^{n} t_i \qquad (3)$$

The individual time (t_i) provided for each panellist is determined on the basis of weights, which are always equal and obtained using the PERT method, while n indicates the total number of panellists.

Based on the answers of the panellists in the first iteration, the productivity of the use of raw materials at 30% in the analysed organization is expected to occur in approximately 2.07 months, which is in the first half of March 2021. A consensus was reached for the said question, as indicated by the received variance value, which is lower than the reference value. Since a consensus has been reached, this question can be omitted in the next iteration.

The panellists were asked to provide their expected answer regarding which month of 2021 (January-August) the consumption of HRS sheets in the organization will be 1,791.44 kg, which is the forecasted value. In this case, where only one answer was required from each panellist, the average time of realization (t_n) of an event is statistically determined using mathematical relation 4:

$$t_n = \frac{1}{n} \sum_{i=1}^{k} t_i f_i \qquad (4)$$

In Equation 4, fi represents the frequency, which indicates how often the same answer is repeated within a given unit of time. The other parameters in this equation are the same as those in Equation 3.

In the first iteration, the answers were diverse, and no consensus was reached, as the variance exceeded the reference value. Therefore, two additional iterations were conducted (Questionnaire 2 and 3), until the variance matched the reference value. The diversification of responses in all three iterations is shown in Figure 8.

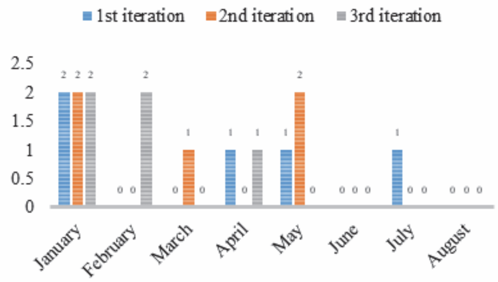
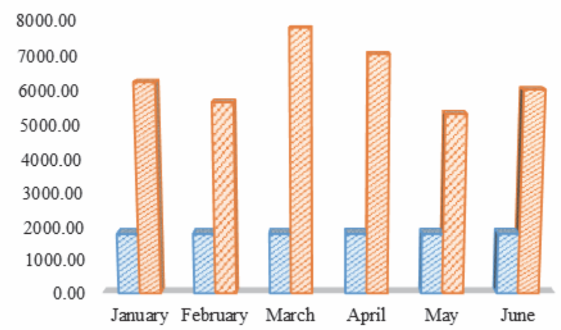


Figure 8. *Distribution of responses in three iterations*

In the initial iteration, based on the responses of the panellists, it was anticipated that the consumption of HRS sheets within the organization would reach 1,791 kg in approximately 2.6 months. Subsequently, in the second iteration, a consensus among the panellists indicated that the forecasted consumption would occur within 2 months. Finally, in the third and concluding iteration, an even stronger consensus was obtained, highlighting that the consumption is expected to reach 1,791 kg in just 1 month. This iteration met the criteria for a satisfactory consensus, as the variance for this question equalled the reference value, emphasizing the conclusion of the Delphi research process.

Evaluating forecast accuracy

To assess the accuracy of the forecasts, it is crucial to calculate the deviation errors between the actual and predicted consumption values of the analysed raw material. As previously noted, quantitative forecasts were made for the period from January to June 2021. Hence, real consumption data for HRS sheets for this specified time range was obtained from the organization's records. A comparison of the actual and predicted consumption of HRS sheets in organization X during this timeframe is presented in Figure 9.



	January	February	March	April	May	June
Forecasted consumption of HRS sheets [kg/month]	1791.44	1792.62	1793.80	1794.97	1796.15	1797.32
Actual consumption of HRS sheets [kg/month]	6241	5665	7787	7042	5327	6029

Figure 9. *Actual and forecasted consumption values*

From the information presented, it is possible to calculate the Mean Absolute Percentage Error (MAPE), which represents the average of the absolute differences between actual and predicted values expressed as percentages (Equation 5).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \quad (5)$$

In Equation 5, A_t represents the actual value of the variable, while F_t represents the predicted value of the observed variable. Using this equation, the resulting MAPE of 71.27 % suggests substantial differences between the actual and predicted consumption values of the analysed raw material.

The variance between forecasted consumption of HRS sheets and the actual consumption within production organization X can be attributed to a range of factors, including demand fluctuations (in response to economic conditions, market trends, or seasonality), supply chain disruptions (caused by delays in raw material deliveries), production variability (resulting from machine breakdowns and operational issues), challenges within inventory management (involving overstocking or understocking), quality issues, and economic factors (such as inflation and currency exchange rates). Notably, the COVID-19 pandemic emerges as the most prominent factor during the analysed period. With the spread of SARS-CoV-2 at the end of 2019 – economic, social, commercial, communication, and tourism restrictions were applied in many countries around the world. On 30 January 2020, the World Health Organization declared the COVID-19 pandemic, which was followed by the lockdown of countries. Lockdown has led to disruptions in supply chains and a drop in industrial production. For instance, the steel sector experienced decreased demand in 2020 due to the halt in automotive production, which consequently led to reduced steel consumption compared to 2019. This global trend also affected the specific production organization X under analysis, so it is considered that the increased actual consumption of HRS sheets in the first half of 2021 year is the result of the industry recovery in general.

CONCLUSION

Due to the evident negative environmental outcomes of economic activities, the management of production organizations is under increasing pressure to reduce the harmful effects of their operations on the environment. The costs of prevention and remediation of environmental pollution affect the total costs, and management organizations seek to improve their economic and environmental performance simultaneously. Economic activities heavily rely on natural resources, which are limited. The rising global demand for resources has led to price volatility and the risk of resource scarcity. Addressing these challenges can be achieved through the adoption of a circular economy. Transitioning towards a more sustainable, greener, and circular economy involves reduced resource consumption, investments in environmental practices, and innovation, and can yield significant advantages in terms of competitiveness and job creation.

In line with the principles of circular economy, the goal is to keep raw materials within the economy for as long as possible and minimize waste generation. To achieve this, efficient supply chain management is crucial. Following the circular economy concept, it is essential to plan the quantity of raw materials used in the production process effectively. This can be accomplished through various predictive methods, which can be both qualitative and quantitative. Excessive consumption of metals can disturb the implementation of circular economy. Therefore, this paper focused on a specific case study of production organization X, which specializes in manufacturing bodies for motor vehicles, trailers, and semi-trailers. One of the primary raw materials used in their production process is HRS sheets. To forecast the consumption of HRS sheets in this organization, both quantitative methods (Time series method with a trend component) and qualitative methods (Delphi) were employed.

In the comprehensive analysis conducted in this case study, it was determined that the combination of qualitative and quantitative methods employed was not entirely suitable for forecasting supply chains in alignment with the principles of the circular economy. It is important to note that the historical data used for this analysis may not be fully representative, as the organization was operating under an emergency regime during the specified period. Therefore, this may have affected the accuracy and adequacy of the forecasting methods.

It is imperative to conduct a comprehensive analysis of the aforementioned factors that may contribute to consumption deviations. This analysis is crucial for enhancing forecasting accuracy and aligning supply chain and production processes with the principles of circular economy. While acknowledging the significance of COVID-19 pandemic as a potential driver of observed variations in the analysed period, it is equally vital to account for the broader contextual factors in future research.

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