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# Key Performance Indicators for Evaluating the Efficiency of Production Processes in Food Industry

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## ABSTRACT

Most businesses in the industry utilize Key Performance Indicators as performance measurements. Thus it is worth investigating if they are best suited and used effectively. Many businesses assess their performance using what they believe to be Key Performance Indicators and do not differentiate these from other sorts to data. As a result, this study attempted to evaluate performance using a holistic approach of performance measures and then analyze how KPIs should be implemented and employed according to theory.
The program mimics a periodic structure set by the user from among the integral constructive types of a cell. It comprises five unit cell types commonly employed in the modelling of FSS, together with two others explicitly polarized in a single fixed direction of propagation with normal irradiation on the FSS. It therefore considers the reflection transmission spectra of the unit cell, the electric field, typically on the top surface of the unit cell, and the dB-scaled electric field norm shown on a plane cutting across the unit cell domain. This has led to the formulation of a strategy to introduce the use of KPI for benchmarking the effectiveness of the manufacturing processes in the study. In the context of the investigated precision component operation, the number of non-conforming products was presented as a relative percentage for the examined operations (as very thin conductor) and was assessed as an external and internal KPI. Externally, the external indicator, EXTppm, informed on the number of defective items relative to manufacturing. Finally, reasons for not reaching the expected KPI values are identified and suggestions on increasing efficiency and production processes are provided. In order to achieve the company's main goal, that is, to increase profit; it is necessary to determine production process quality and efficiency indicators that should be achieved. The number of product defects, production and technological losses, average and maximum capacity, working hours, energy consumption, number of waste, raw material quality, the time needed to change the production program and the purchase cost of the machine, time to start the process, time needed to execute the production order, work distribution their time intervals, unavailability of production facilities, lack of maintenance and capital maintenance, failure or operating in non-optimal modes of operation, are sufficient to determine the quality of the production process. In this research, all indicators which have been determined will define the efficiency of the production process. The final task of this research is to determine the critical quality and efficiency indicators in order to maximize the production performance in the food industry. The food industry must ensure that it has development, production, processing, and distribution systems that meet the criteria for health and safety, hygiene, quality, and optimal production process speed. Choosing indicators that will become the basis for improving the production process and thus the entire food industry and business was not an easy task. They should be numerically defined based on production parameters and based on business goals and strategies. That is because they evaluate the production process, increase efficiency, productivity, or understandability, and target defined goals.



*Keywords: Key Performance Indicator (KPI), external indicator EXTppm, Food heat perspective, Frequency selective surfaces (FSS).*

## 1 Introduction

Nowadays, it can be stated that the trend is moving from company to chain competition. This proposal is part of a series of scientific contributions to develop new models that the food industry can use. The models we develop and propose can make the structural changes necessary to increase the power of the chains a guiding principle. The companies that belong to these industries must be both recipients and active agents of this evolution. They have to ensure that the model has an evolutionary structure that can adapt to new markets and new scenarios regarding technology and information.

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The research continues with the proposal of a new model based on the SCOR supply chain operations reference model, extended with some additional elements. This model applies to the food industry and serves to interconnect and synchronize a company's core processes with those of its supply chain partners to improve both the individual company performance and the performance of the entire food chain.

The increasing complexity of the competitive environment at the international level, or the conditions created by the process of globalization, requires the establishment of new management systems that take into account everything related to the activities of the food industry. In this context, this research opens with a study of the key performance indicators that are essential and may be implemented by companies in the food industry to monitor and control their production processes in both the short and long term. The purpose of these KPIs is to evaluate the efficiency of the production processes within the food industry. Due to the diversity of activities that occur in this industry, the production process turns out to be complex analyses process efficiency and maintain competitiveness, Thus, it is important to track the individual activity within the system, within the organization. Therefore, it is possible to state that the application of key process performance indicators is considered suitable in this case. These indicators are intended to track particular actions of the firm and ensure the proper functioning of competitive market activity.

Attention should be paid to what is happening around an organization to assess the process's general performance and stay competitive. The determination of key process performance indicators seems appropriate in this respect. They must be applied to track certain firms' actions and ensure efficient and successful market operations.

For both manufacturing and non-manufacturing industries, there are several different KPIs but there is confusion on which ones are the most crucial as each company must create its system of key indicators in terms of importance [1].

The standard STN EN ISO 9004:2010[2] defines the key performance indicators as the aspect of the organization over which the organization has control and or is critically essential. Have to evaluate their performance and determine what their performance measures consist of KPIs are, without a doubt, efficient tools that help evaluate and regulate all organizational activities. These indicators make it possible to evaluate the effectiveness of activities in each operational area and to maximize all the resources employed. They know some aspects of the organizational performance relevant to its current and future achievements. KPIs act as directional pointers for managers, who may use them to identify whether the firm is on the right path to achievement.

KPIs should be aligned with the company's corporate strategy and competitive requirements with emphasis on outcome [3, 4]. Such measures must be reasonable, connected and purposeful and unified in a sense that it enables objective comparisons between different businesses. Many empirical investigations have looked into the definition and discovery of benefits relevant to the implementation of KPIs in company activities [5-7]. We may remark that all writers believe that the most significant contribution of KPI is to increase the efficiency of business operations and product quality via quantitative production indicators [8, 9].

From different literature sources, one can conclude that there are many advantages accruing to the companies that decide to resort to KPI usage.

- They serve to make clear objectives for the employees;
- They improve productivity;
- They enhance the quality of the decision-making process that managers undertake.
- They give work results assessments a more rational and goal-oriented character.
- They enhance the capability and capacity of organizations.
- They enhance the quality of service delivery
- They define objective measures of security [10-13].

It is also possible to employ a methodology that includes the process analysis, design, implementation, and verification steps to develop an interface to display significant production indices in Industry 4.0 [14]. KPI may be selected using various models, including EAM (the Enterprise Analysis Model) and the Quality Matrix [15, 16]. KPIs are chosen from several sectors of the organization, such as maintenance (see Figure 1). They can also influence sustainability the company's future competitiveness [17, 18].

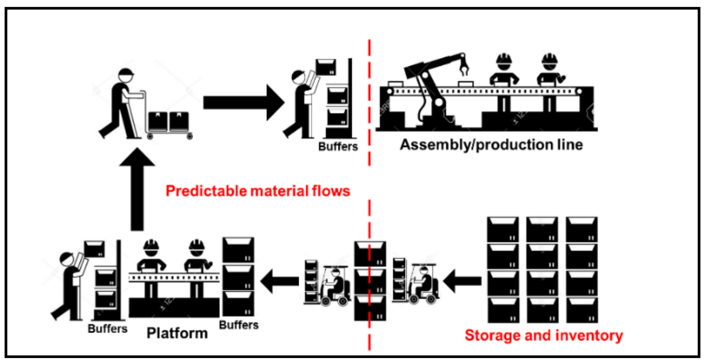


**Figure 1:** Illustrates the area of predictable material flow, and storage and heat together with their responsibilities.

KPIs are essential for using the balanced scorecard, a strategic management system introduced by Robert S. Kaplan and David Norton in 1992. This approach focuses on financial and non-financial indicators to assess how well a business is developing towards its strategic goals.

KPIs are financial and non-financial measures used to evaluate the performance of an organization. They monitor how well companies, business units, projects, etc., are achieving their goals. KPIs can include financial indicators such as profit, revenue, and cost, as well as non-financial indicators like market share, customer relations, and environmental management. They help ensure that the organization's activities contribute to goal achievement.

Key performance indicators (KPIs) are important tools for evaluating the efficiency of production processes in the food industry. They help determine the alignment of process management practices with business strategy, identify solutions for problems, and evaluate performance. KPIs highlight important features of a process when judging its efficiency. They promote individuals and departments within an organization to take responsibility for controlling operations.

### 1.1. Key Performance Indicators in Food Industry

The high degree of risk, the high workload, the significant impact on nature and human health, and significant delays until the product reaches the customer are also characteristic features associated with other sectors (safety, quality and customer responsibility for product supply are important values in the food industry, enormous energy expenses, the use of specific processing equipment, a significant number of personnel for organizing the processes). These factors have a significant impact when determining the appropriateness and applicability of the KPI configuration methods presented in literature in practice in the food industry. Therefore, the main indicators of production-process efficiency were identified, reflecting the performance of the production process with the technological particularity of this process and the influence of the external environment.

The production efficiency, sector belonging, and nature of the manufactured goods play an important role in preparing and researching KPIs for production assessment. These features are manifested in the manufacturing process specificity and complexity, which results in the need for KPIs system. The food industry has both unique technological processes and specific working conditions. The following essential features are typical for the technological processing of plant industry raw materials: low initial quality of raw materials, their natural inconsistency, and the short storage time of raw materials, the process volume, and the operating cycle of the equipment.

### 1.2. Efficiency Metrics

Efficiency indicators have increasingly become the focus. In this particular concern, during the last decade, some scientific publications discussed the factors that may influence efficiency at the enterprise level. Our review identifies a few publications that focused on the influence of at least three of dimensions. However as claimed, when examining the company's state of functioning, to make decisions to eliminate the inefficient aspects that hinder it, managers have to rely indicators meant to inform about results, inputs, and processes. Following, on these existing qualifications, authors claim that obtaining the most efficient output in the activity involves more or fewer inputs.

About performance measurements, our research focuses on effectiveness indicators (showing how well the company is attaining its goals), Image from Pick away but actual use cases are much more centred specific efficiency indicators, clearly positioning and set up real truth points, where the faults in the company operation can be traced .As an overview of production process. In order to make the investigation not all to have measurements, many of productivity indicators have been developed about the various aspects of input-result even managerial-operation [10]. Reflecting formality of these indicators of productivity that can be developed to operate at a specific level of training of the technical staff in several constructs may give the first in the form of a figure of the return.

### 1.3 Production Process Evaluation

The production process is considered to contain all the necessary activities to obtain a certain product. Therefore, the objective of the production process is to create the desired product in the desired quantity, with the desired quality, the shortest possible completion and start-up time to accomplish the planned work. The effectiveness of the production process depends on such objective criteria as quality, quantity, operational time, and attainment of the expected productive results by the actual possibilities. The characteristics selected define the results of the production process by analysing the following: stability assessment of the work process and direct estimates of the production process, the actual results of the operational process, the workforce level, and the corresponding time resources. According to these main criteria, the effectiveness of the production process is analysed. The established quality criteria of the production process can be used to define and evaluate the goals of the food companies.

Evaluating the performance of modern food industry manufacturers is the most important requirement for achieving a high level of production results. It is extremely important for manufacturers to use appropriate criteria to assess the effectiveness of production processes. At a time when open, fair competition requires top performance in all areas, the objective is to be above average in everything. The Quick Measurement of Production Process Efficiency is a key tool for assessing the TQC production process efficiency. Based on KPIs, the required improvements are outlined. The ultimate goal is, in other words, to determine the status of the production process.

### 1.4. KPIs for Quality Control

Concluding Remarks TQM is then a set of practices aimed at improving the performance of the entire organization. It is to follow quality, productivity, innovation, and mutual responsibility without interruption. It is a weapon to fight against waste, keeps production costs always under control, seeks continuous improvement transparent for all involved, and produces income that brings financial health and survival conditions of organizations. It is a management strategy that requires everyone's commitment, implies that no one is blamed or rewarded and passes no responsibility to one besides willing. TQM thus has the primary objective of being assured that internal and external customer needs are met, in satisfaction and in compliance with legal requirements. These conclusions led to the development of the indicators identified based on the product realization process.

KPIs for Quality Control Rejections and Complaints - According to Liker, the rejection of the final product is considered an internal failure, which can represent up to 10% of the cost of goods. Proven Quality - In the case of the production history of packaged products over a defined period of time, carbon dioxide and nitrogen levels are measured and, or the degree of saturation in sealing the packaging is verified. Broken Label. It is a history of label rupture during transport and, or handling of the packaging made visible, retention by Magnetic Leakage. Attention: the necessary information about the validation of the preservation is kept for future verification of validity and retention at Jordan Test.

### 1.5. KPIs for Cost Analysis

Non-processed goods in the food industry generally have price changes concerning the market. Different market trades or competitions in seasonal cultivation can result in imbalances of prices which affect companies that use that type of goods in production. Besides, changes related to goods purchases may also occur within the company. The reasons for these changes related to increased and reduced costs are multi-faceted. Some of them can be overlooked, unnoticed, which can have significant effects on the company's business. Companies must be focused on regular cost analysis and look for risk-preventive solutions and implement them in order to avoid any risk or damage to their business.

The food industry is specific due to various production processes for achieving a single objective: producing quality foods and satisfying consumer demands. Most companies in this industry are focused on the reduction of production costs. The value drivers are different, and risks that hamper the value creation are various. In that sense, KPIs as value drivers or value inhibitors can also be used for the analysis of the efficiency of particular processes where various risks occur. Traditional KPIs are focused more on measurement, expressed through quantities and relations among them. The developed KPIs are the ones directly affecting efficiency. In this way, a detailed cost analysis is possible. Together with the analysis of the KPIs, the most probable risks can be identified, the means for prevention and reduction of their impact can be defined, and early warning systems can be established.

## 2 Methods

The investigation was carried out in an engineering firm that specializes in machining both metallic and non-metallic items using chip removal procedures [19]. The goods of the analysed firm (see Fig. 2) are used in window system mechanisms, the food sector, hydraulic assembly, and, most notably, the manufacturing of renowned vehicle and heavy truck manufacturers.

The primary research was conducted using a questionnaire survey and focused on using of performance indicators in heat food production enterprises the quantitative section the research aims to characterize the existing status of use of performance indicators and analyse firms' attitudes toward measuring and managing performance. The final sample comprised of 67 manufacturing enterprises from Conductor that were included in the numerical study.

The questionnaires were divided into sections, with one portion focusing on information about the usage of specific measurements, tools, methods, and concepts for monitoring and controlling the heat process, as well as the company's approach to value management. The core study questionnaire was created based on a literature search, prior knowledge and experience, and, most importantly, interactions with manufacturing company personnel. Five firms were requested to review the questionnaire and answer questions to remove incorrect language, ambiguities, and inaccuracies.

The production also encompasses a vast array of elements, with nearly all components being produced through chip manufacturing processes, including turning elements into high-

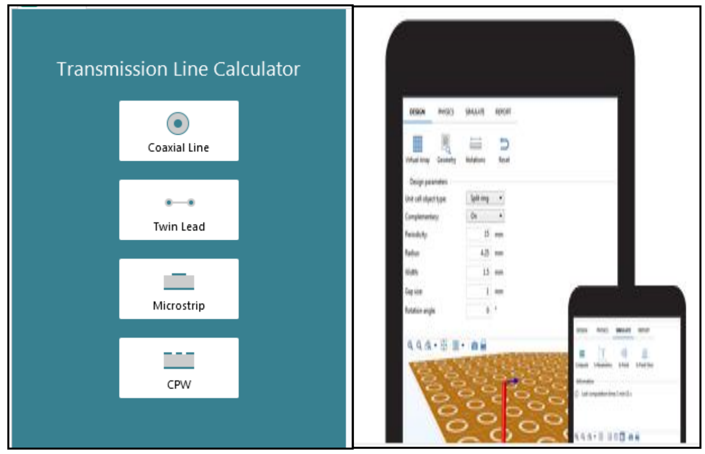


**Figure 2:** Front page Frequency Selective Surface Simulator of produced pieces.

quality milled parts by grinding, rolling or milling. First, attention is paid to the use of numerical control technology for the production of metallic and non-metallic parts. This manufacturing technology comprises two categories of machine tools: machining centres, CNC lathes mostly used in processing bar materials and small horizontal centres.

The organization is mainly committed to preserving financial order, although it states that it is increasingly becoming necessary to incorporate signs suggesting the successful completion of processes into the monitoring system. The usage of key performance indicators inside the investigated firm is divided into phases in this research, stating that each step is crucial for the effectiveness of the KPI. It is important to note the order of these phases, as they affect the KPIs' design and integration process with the organization.

A procedure has been developed to define the various steps of implementing KPI in production operations as a plan.

- Creating a Process Map: Develop a comprehensive map outlining the production processes.
- Determination and Identification of Measured Processes and Process Owners: Identify the specific processes and their respective owners that will be subject to measurement.
- Defining Key Process Performance Indicators (KPIs): Clearly define the KPIs that will be used to gauge process performance.

- Data sources and measurements for selected KPIs: Identify relevant data sources and establish a method for measuring values associated with selected KPIs.
- Analyzing and Reporting Current Process Performance: analyze of the current performance of the processes and generate comprehensive reports.
- Evaluation of the Fulfillment of Process Performance Goals: Assess the extent to which process performance goals have been achieved.
- Determining measures to optimize process performance: Identify and establish measures to enhance process performance.
- Iterative data collection and analysis, as well as verification of measure, compliance: Verify the implementation of measures, and repeatedly collect and analyze data to ensure ongoing compliance and improvement.

After the “Defining Key Process Performance Indicators” it was suggested that Key Performance Indicators (KPIs) be used to explain the examined production. The other measures of product quality include customer complaints, plan completion, areas of non-compliance, total efficiency, and production time for each product. Our analysis was based on the following KPI proposals: Complaints, the items the customer realizes did not conform to requirements, and the other non-conforming products, which are realized not conforming through production control activities. Due to this fact, the ratio indicators of Ext and Int ppm were developed to describe, in a precise manner, this KPI, which is representative of the total non-conformity of the month to the total amount of delivered or manufactured items within the same month. The following text is an arithmetic representation of the indicated indicators:

The study also has a monthly Key Performance Indicator (KPI) for assessing customer-related procedures concerning the number of goods complained about. The result is given in terms of the value set in parts (as in Very thin conductor) per million (ppm), referred to as external ppm over one month. This calculation involves the number of parts supplied within one month and the total number of faulty parts. Here is the formula used to estimate external ppm over one month.

$$EXTppm_{\mathrm{monthly}} = [O_n / O_c] * 1000000 \qquad (1)$$

Where:

$O_n$ … the number of reported non-conformities during one month [pcs],

$O_c$ … Total number of items delivered in a month [pcs].

In other words, for the aspect of internal process quality for the component and orders, the performance was evaluated – no of non-conforming items coming out in the process. The final calculated result is the internal ppm for the element A in question for each particular order. It is always checked when the manufacturing time of a particular order is through. The inputs are the number of order units of products manufactured and the number of scrap items manufactured during one order.

$$INTppm = [V_n / V_c] * 1000000 \qquad (2)$$

Where:

$V_n$ … volume of non conforming products in the order [pcs],

$V_c$ … total volume of products produced in the stated order [pcs].

### 2.1 literature review KPI (Key Performance Indicator)

Metrics provide insights by focusing on companies' key goals. They can be developed in finance, operations, business development, and human resources. In process areas, companies of all sizes must monitor certain indicators to understand the potential risks that may occur. These indicators include productivity rates, reliability rates, overall equipment efficiency (OEE), return on total assets (ROTA), asset utilization index (AUI), return on capital (ROCE), net present value (NPV), contribution margin (CM), supply chain cycle time, material flow completions, inventory turnover (IT) [22], demand variability, and demand accuracy. What is desired in the evaluation of process performance is the chosen set of KPIs, technical teams such as reliability, project, maintenance, and production. Each parameter must have its predefined bounds, and these boundaries depend on each piece of equipment and its operational skills. In the case of process performance, technical teams understand the indicators. Understanding overall performance and its risks through the chosen indicators is the foundation of various studies that can act as knowledge transfer tools, drawing critical knowledge to prevent failures [23].

Despite the significant number of works dealing with the modelling of different food industry processes and using machine learning-based algorithms, we did not find any demonstration of a successful application that allows simultaneously monitoring and forecasting a large number of different parameters at different times. A complex manufacturing process can involve hundreds of parameters, and forecasting is mandatory in order to avert undesired utilization, poor product quality, and failures. The performance evaluation of the manufacturing process also includes predictive maintenance. Many models have addressed individual indicators or have used data from very specific scenarios, which prevent a broader application. Entrepreneurs in different sectors of the economy, including the food industry, need metrics and tools to better understand how their process is and how they can use and analyse data to improve processes to increase efficiency and agility. Using 28 high-quality KPIs, industries can better achieve their goals, reduce costs, reduce waste, and maximize efficiency [24].

## 3. 3 KPI evaluation

### 3.1 The number of faulty products via EXTppm per month

The original phase of the research was aimed at the reviewing and testing of the manufacturing processes, especially the quality of a final product. It was devised which meant a monthly analysis of the proportion of negative elements, labelled as EXT-ppm (external parts per million per month). As the past year's data was used for the retrospective study to help offer a demonstrative depiction of the upcoming trend, results of monitoring this Key Performance Indicator (KPI), we arrived at a desirable outcome at the year end point.

The data collection outcomes on the specific key performance indicator were illustrated by summing up the accumulative of external ppm per month with the formula (1). The EXT-ppm values per month are between 30–105. The company's defined expat ppm external value at the studied firm was realized in conformance with the firm's quality Objectives to keep the external ppm below 300 ppm. The reported findings show that the obtained EXTppm values are lower than the threshold goal values, which is a good sign for assessment. Regarding the quality of components (Very thin conductors) provided to consumers, customer complaints account for less than 0.0. The first phase of the investigation focused on reviewing and testing manufacturing processes, particularly the quality of a finished product. It was arranged to designate a monthly breakdown of the percentage of negative constituents, referred to as EXT-ppm (external parts per million per month). Using data from the past year for a retrospective study to illustrate the trend that is expected to occur, this study came up with a desirable outcome of monitoring this Key Performance Indicator (KPI) at the end of the year point.

The data collection results on the specific KPI were summarized by adding the accumulative of the external PPM for every particular month with the formula I mentioned before: The EXT-ppm per month is as follows: Between 30 and 105. The company’s defined expat PPM external value at the studied firm conformed to the firm’s quality objectives of achieving an external PPM of below 300 ppm. The presented research results prove that the obtained EXTppm values are below threshold goal values, which can be considered advantageous for assessment. Regarding customers’ satisfaction with the quality of components (Very thin conductors) offered to consumers, the percentage of complaints is less than 0. The specialty stores accounted for 03% of the total order volume and 3% of the total order volume.

## 3.2 Performance Indicators for the HEAT Food Industry

To answer research issue 1, 16 literatures on performance assessment systems used in the food sector were evaluated. There are 37 metrics described in the literature, including customer query time, order lead time, service flexibility, responsiveness to urgent deliveries, delivery lead time, effectiveness of delivery invoice methods, delivery reliability, effectiveness of distribution planning schedule, achievement of defect free deliveries, customer response time, delivery flexibility, order fill rate, market share, distribution performance, customer satisfaction, level of customer perceived value of product, accuracy of forecasting techniques, order entry methods, purchase order cycle time, planned process cycle time, effectiveness of master production schedule, product safety and health, capacity utilization, manufacturing lead time, inventory accuracy, total profit, total inventory cost, range of products and services, level of information sharing, return on investment, variations against budget, cost per operation hour, number of training per year, the flexibility in units of volume, time taken to develop new products, sensory qualities and durability and the ease of use/convenience of products.

• Designing it for small screens – cellophane, for instance.

• Website construction with a top menu used to manage the user interface.

• Geometry components and parameterized geometries:

• Explaining the periodicity of a shape through materialization/articulation.

• This is followed by icons that give warning messages when their properties have not been updated.

• Upon computation being effected, send an email with the report as an attachment [20].

FSS are periodic structures that allow only a specific frequency range to pass through or stop. They categorically or selectively attenuate RF, microwave, and electromagnetic wave frequencies. For instance, it will be possible to observe those selective surfaces on microwave oven doors by which one can watch their food cooking without burning their fingers. You may change the polarization, connectivity, enter frequency, substrate thickness and material properties, number of frequencies, unit cell type (circular, ring, split ring, and so on), and geometric characteristics such as periodicity (cell size), as shown in Figure 3.

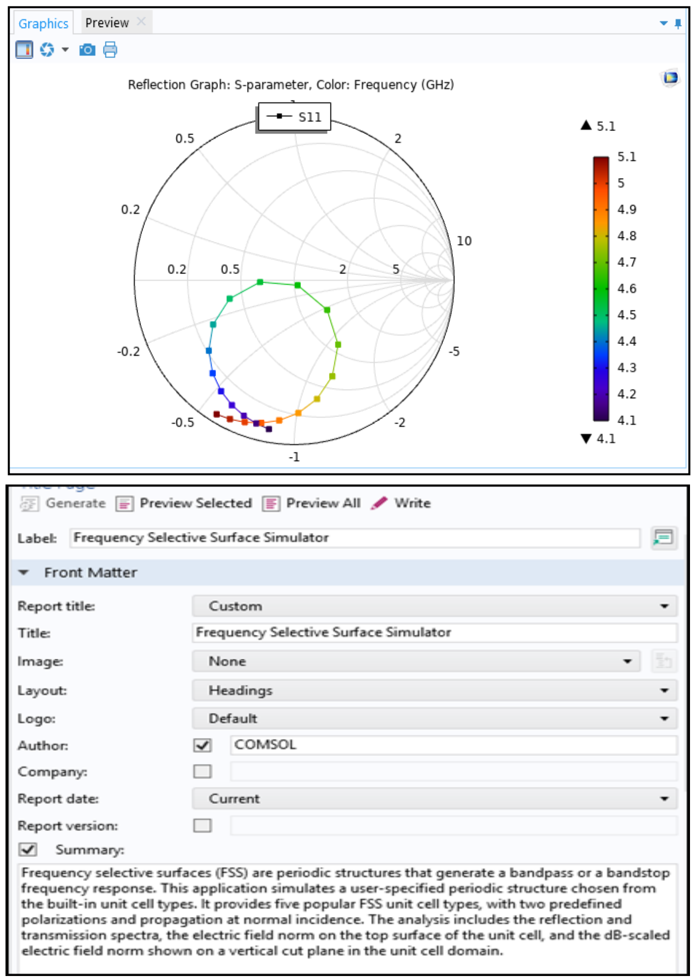


**Figure 3:** Evaluating the quantity of delivered units Frequency selective surfaces (FSS).

## 3. 3 KPI assessment: non-conforming products, INTppm

The performance was determined and rated as part of an order based on the number of non-conforming units. The result is the externalization of the internal ppm for the specified portion a created for each order (Table 1). After the manufacturing of an order is complete, how much time it consumes is continuously analyzed. The first input is the number of items produced per order, and the second is the number of non-sibling items made within a particular order. The INT ppm indication (2) is intactottage overall – steady production for one order during the analyzed period.

**Table 1:** Assessment of food heat process through a conductor for the evaluated period.

| Number | **Yes, we measure the indicator** | **No, we are planning to implement** | **Material consumption 100 % Number of completed products** | **Internal ppm INTppm** |
|---|---|---|---|---|
| 1 | Quality expressed by line symbol | | 5 | 3310 |
| 2 | Automatic digital scale | | 0 | 0 |
| 3 | | Optional offset of the label for point feature | 1 | 651 |
| 4 | Curve labels according to line feature | | 2 | 868 |
| 5 | | Optional offset of the label for point feature | 29 | 12587 |
| 6 | Curve labels according to line feature | | 3 | 1500 |
| 7 | Automatic digital scale | | 22 | 9549 |
| 8 | Quantity expressed by line symbol | | 14 | 6076 |
| 9 | Automatic digital scale | | 12 | 5576 |
| 10 | | Optional offset of the label for point feature | 5 | 2170 |
| 11 | Quantity expressed by line symbol | | 8 | 8989 |
| 12 | Automatic digital scale | | 16 | 10417 |

The collected information sources within the case firm were also analyzed to assess the challenges and possibilities of the product and process range management relevant to the case study's environment (see Figure 4).

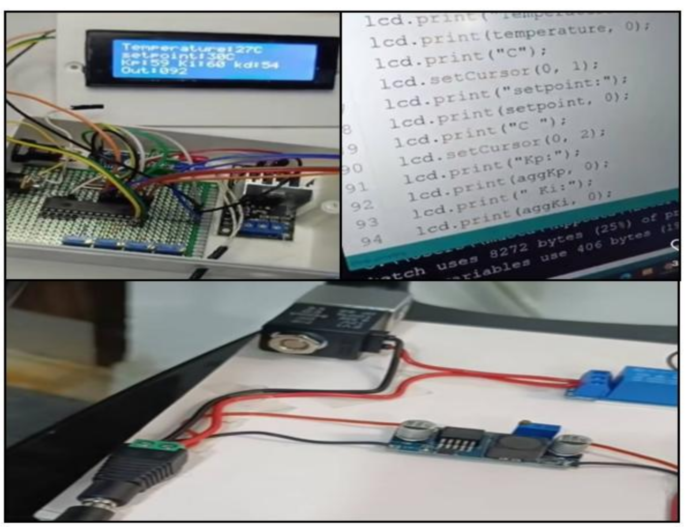


**Figure 4:** Control of temperature.

The case-study was studied at a heating manufacturer, such as cheese and pastry. The management project explored in this study focuses on heating manufacturing lines in a plant.

## 3.4. Perfect Electric Conductor

Depending on the detailed model, there may be better alternatives to modelling the thin conductor as a three-dimensional component. The AC/DC Module, for example, has these capabilities: Modelling Thin Structures Shell formulas for direct currents, electrostatics, magnetostatics, and induction simulations can be used to describe very thin structures. Electromagnetic shell modelling allows replacing a thin solid's thickness with a surface's physical attribute in a CAD model, resulting in a considerably more efficient representation, as shown in Figure 5.

## 3.5. Mesh 1

Mesh simulation of a very thin Conductor (5 mm) with lateral dimensions ranging from 100 mm (for stationary COMSOL 6.2 AC/DC magnetic and electric field simulation), as shown in Figure 6.

When attempting to construct a tetrahedral mesh, I receive a "face is substantially smaller when compared to the specified smallest element size" warning; nevertheless, if I manually increase the most diminutive element size to 0.1 um, the geometry becomes overly meshed.

## 4 Results and Discussion

The above-presented eight-step algorithm was used to apply the analysis to the specified company to identify and design the KPI implementation procedure. After the procedure was implemented, the S-parameter ($m_{ew}$) of Plot Groups found from the virtual array view and various miscellaneous factors were evaluated using the collected data and their corresponding KPIs.

| Perfect Electric Conductor | $\mathbf{n} \times \mathbf{E} = \mathbf{0}$ | |
|---|---|---|
| Geometric entity level | Boundary | |
| Name | **PEC** / Periodic Condition Equations | |
| Selection | $\mathbf{E}_{dst} = \mathbf{E}_{src} e^{-i\mathbf{k}_F \cdot (\mathbf{r}_{dst} - \mathbf{r}_{src})}$ <br> $\mathbf{H}_{dst} = \mathbf{H}_{src} e^{-i\mathbf{k}_F \cdot (\mathbf{r}_{dst} - \mathbf{r}_{src})}$ <br> $S = \frac{\int_{\partial\Omega} (\mathbf{E} - \mathbf{E}_1) \cdot \mathbf{E}_1}{\int_{\partial\Omega} \mathbf{E}_1 \cdot \mathbf{E}_1}$ <br> $S = \frac{\int_{\partial\Omega} \mathbf{E} \cdot \mathbf{E}_2}{\int_{\partial\Omega} \mathbf{E}_2 \cdot \mathbf{E}_2}$ <br> $\mathbf{n} \times (\nabla \times (\mathbf{E})) - jk\mathbf{n} \times (\mathbf{E} \times \mathbf{n}) = 0$ | |
| | **Settings** | |
| | **Description** | Value |
| | **Maximum element size** | 4.4970 |
| | **Minimum element size** | 0.018200 |
| | **Curvature factor** | 0.2 |
| | **Maximum element growth rate** | 1.3 |
| | **Predefined size** | Extremely |
| | **Custom element size** | Custom |

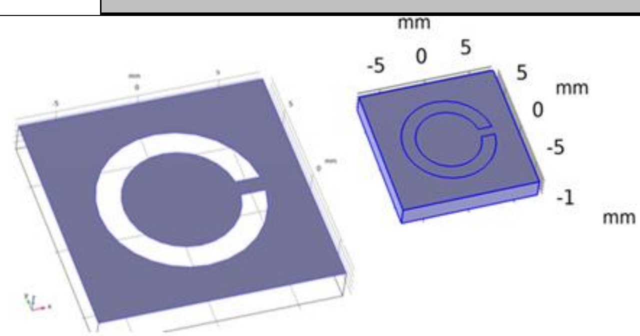


**Figure 5:** Electromagnetic Waves, Frequency Domain (Perfect Electric Conductor).

However, for information that has been processed to be understood and enhance the evaluation of process performance, it must be presented in a proper format. Moreover, the data has to be arranged deliberately to easily be compiled into future development trends from the collected information. See fig 7 .

The data about non-conforming items during the production of goods was gathered using the company-wide information application Dialog to evaluate the efficiency of manufacturing processes for long-term use to the number of non-conforming goods. The data on non conforming items were gathered once every shift and covered the whole product's production time.

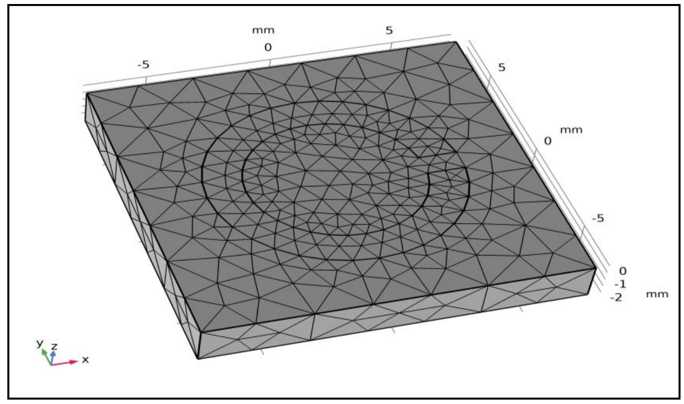


**Figure 6:** Mesh Size.

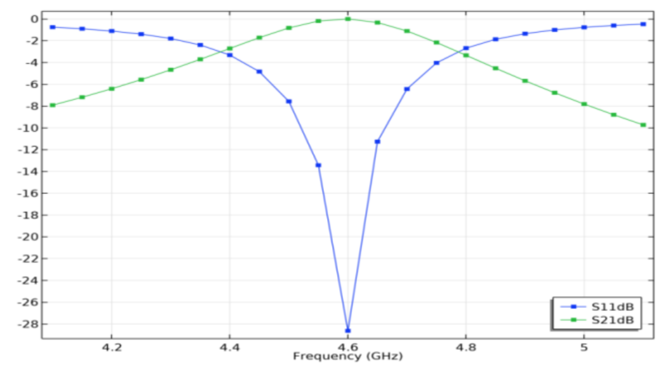


Figure 7: Plot Groups S-parameter (mew) and Virtual Array View.

When evaluating the efficiency of the manufacturing process, the measures that defined the ratio of defective/faulty products to the total amount addressed key performance indicators. In particular, the group focused on the effectiveness of two factors related to the ppm type: EXTppm, which stands for Non-conforming products pointed out by the customer, and INTppm, which stands for Non-conforming products found within control in production. Regarding the detailed form of the KPI were created, proportional indicators to express the monthly overall number of non-conformities in relation to the overall number of products delivered/produced in one month.

Controllable meta-films offer promise for broadband applications, since they transcend the limitations of traditional meta-materials. However, a homogenous magnetic field is more difficult to apply than electrical voltage or current across a broad working area. The active frequency selective surface (FSS) loaded with pin diodes was combined into a single microwave low reflection layer, with reflectivity as a function of diode bias current.

Figures (8 and 9) indicate that the variable normE is defined by the expression:

$$Sqrt\ [realdot(Ex,Ex) + realdot(Ey,Ey) + realdot(Ez,Ez)] \quad (3)$$

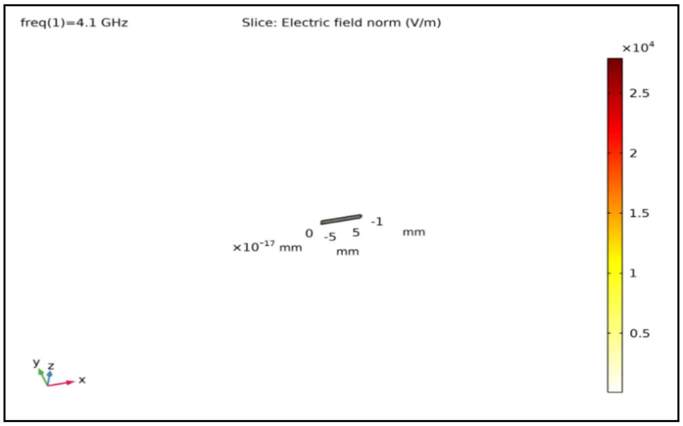


**Figure 8:** Slice: Electric field standard (V/m Electric field norm (horizontal).

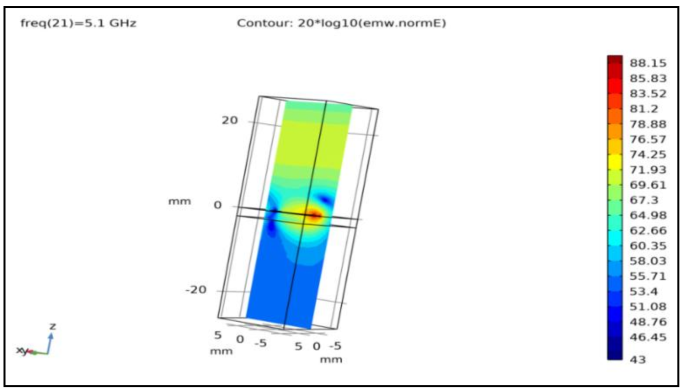


**Figure 9:** Electric Field Norm (Vertical, dB) Contour: 20*log10 (emw.normE).

Where the operator real dot (a, b) treats complex numbers $a$ and $b$ as if they were real-valued vectors of length 2 and returns their dot product (similar to a shorthand form of real (a*con*j* (b)), except with respect to its partial derivatives).

From the point of view of external ppm evaluation, we can state that EXT ppm are considerably lower than limit target values of the company (300 ppm), which is a positive result. In contrast to previous years when EXT ppm rose to the climax or crossed the set limit of 300 ppm, the assessed parameter is rather better. There was a rise in the number of consumer complaints, and many attempts were made to tackle this issue.

- Focusing on Process Quality and Machine Reliability: Place emphasis on the work process and machine reliability.
- Every worker conducts a random 10% check on individual pieces of merchandise before finishing a shift.
- Mentoring for New Employees: Offering assistance to new employees facilitates their first employment and prepares them to become good employees.
- Creating a Training Plan with Skill and Knowledge Checkpoints: Finalizing the training plan with checkpoints to evaluate the skills and information.
- Stabilizing the Workforce Team: Make efforts to strengthen the workforce team, possibly through morale-boosting efforts, structured communication or other issues that may affect the internal environment of the team.

All these were done to address and manage the effects of the undesirable trends in customer complaints, especially during difficult periods caused by the pandemic years. From the analysis of internal ppm, its high values were compared to the target value of 2000 ppm internal – average values of 5136.5 ppm were attained, and it is possible to conclude that the production activities lacked efficiency and generated numerous non-conforming outputs.

- clamping error – short, mismatched units were produced;
- Used cutting plate, time to replace the cutting plate – damaged units was made.

According to prior studies, the company adjusted its strategy to alter the disadvantageous position. To eradicate all the causes responsible for clamping errors during turning, the technologist directed changes in the clamping mechanism, stopped the change, and reversed the movement of the soft jaws of the chuck. The stop, on which the part lies at one point during clamping, has to be regulated such that the part lies on several points, and hence, the possibility of the part being held crooked in the chuck is excluded. The causes of a worn cutting insert in the turning operation and the right time to replace the insert are still functions of adequately identifying the problem and providing proper care for the machine. Suggesting an appropriate time to replace the cutting plate is the way to prevent the wearing off of the cutting plate and, consequently, the development of a defective unit.

A key part of the investigated process's overall effectiveness is the mill's performance on the loaf. The efficiency of the specific milling process is associated with the technical parameters of operations. The methods used so far require intervention with external influences on the technological process, further studies, calibrations, etc. The digital relation that is used in the proposed KPI method for determining the efficiency of the mill on the obtained flour consists of a technological factor (by setting the number and construction of the cylinders of the break system and the sifting elements in the plan sifter), and an expression for obtaining the digitally calculated production efficiency by applying extrusion pressure within the 2.17 MPa range.

When applying the method of determining the KPIs based on Overall Equipment Effectiveness (OEE) in the food production processes of a cereal milling/crushing conglomerate, several challenges and limitations were experienced and detected. The main problems are the restricted access to certain production data due to specific characteristics of the processed agro-materials (certain cereals), the energy used in production, and the difficulties linked to the different modes of registration and presentation of information. In addition, the processed products are characterized by determining specific quality parameters and performance at the final stages of the production process. The systems for monitoring and automation of some key stages are underdeveloped, and the number of variables that affect the OEE can be high.

The analyzed company is characterized by a high sensitivity to the solution for removing non-conforming products in the first place because of the satisfaction of the customers' requirements, then the removal of complaints and, finally, the improvement of the company's economic performance. These findings from external and internal ppm comparisons suggest that while many non-conforming products in production were discovered, most of the faulty products never reached the customers. This can be considered as a favourable indication in external ppm.

## Conclusion

As with any other area of operation, the measurement of performance in a production organization through the use of KPIs requires time and effort to set up. To ensure the process is fruitful, the support of top management, senior–staff, and the people involved in the position related to the KPIs that have been set are vital. Managing KPIs offers business with a systematic approach of enhancing process performance via identifying-goal-establishment. The content of this article explained a study that was geared towards establishing the focal parameters that may help in framing up and evaluating the manufacturing performances. As a result, the suggested performance measuring system for the food business includes the following perspectives: customer, financial, operation/ internal business process, knowledge/learning, and product/service quality (food quality). Therefore, regarding the quantitative measurement of the KPI, the ratio indicators are offered as follows: EXT ppm and INT ppm, which represent the total non-conformity per month plus the total volume of products shipped/delivered per that month. Accordingly, the study findings reveal that while the EXT ppm indicator anchored on positive values, it was still below the level of the quality targets, though the INT ppm was well above the stipulated ppm target values. The proposed method addresses some of the most critical characteristics of nonlinearities, high dimensionality, and redundancy of information in industrial processes. In the study, the KPI-oriented feature extraction approach is effective in identifying relationships between process variables and KPIs. Along with the construction of monitoring statistics and control limits, the detection of faults is made in real time. The divergence of the sliding window selective surface and the simulator holds a promising future for operating performance assessment. Adoption of the application of heat processing of food reveals efficiency of the adopted method and all food industries reveal the different level of efficiency in their numerous operations. There is a general upward trend of efficiency, which could be attributed to getting lean in their operation. Thus, they are the principal factor superior to company competitiveness in direct application. In an environment like ours, where efficiently produced, competitive products are crucial for company profit, it is necessary to direct the company's management with defined goals, given a certain timeframe and a special technology platform. KPIs also enable this, considering that they have the necessary tools to measure efficient production and demonstrate the main drivers of creating value in the food industry.

The final business result of a company, which can reflect the success or failure of the business, is the existence of profitability and efficiency in operation, which has to be observed by all stakeholders. Here, the role of Key Performance Indicators (KPIs) adjusts to the reality of the activity, indicating the achieved results and showing, through this set of relevant indicators, the ability of managers to successfully achieve the primary goals. Its complexity essentially draws a parallel between the sufficient physical inputs and the resources established for company operation in the form of achieved results previously targeted.

## Conflict of interests

None.

## Author's contribution

As evidence of the collaborative atmosphere, each author contributed equally vital ideas. The researchers carefully crafted and executed the research framework, conducting extensive data analysis and incorporating their findings into a unified manuscript. Their seamless collaboration and collective knowledge fuelled each stage of this endeavor, establishing this work as a veritable testament to our shared commitment.

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