MODERN MANAGEMENT REVIEW 2025
MMR, Vol. 30, No. 4(2025), pp. 77-94 October-December

Received: June 2025
Accepted: December 2025
DOI: 10.7862/rz.2025.mmr.24

Marija STANOJESKA[1]

OPTIMIZING PROCESS EFFICIENCY: CASE STUDIES IN BREAD MAKING PRODUCTION

The paper examines the influence of job design on production process efficiency. Although optimization brings significant benefits, it also faces numerous challenges, primarily due to the high robustness of existing technology and workforce needs.
The research methodology treats real-life Case Studies from a bakery plant located in North Macedonia. The data gathered by the pilot period (Case Study 2) was summarized and compared with the data gathered during the regular plant operating (Case Study 1). Both data sets collected in different plant departments were compared regarding relevant operational criteria.
Based on the quantitative data analysis, the operations design of Case Study 2 resulted in a 7% reduction in overall production costs. By analyzing real-life Case Studies, this paper can serve as a valuable guide in striving to enhance overall efficiency and contribute to companies within the relevant industry sector.

Keywords: optimization, task allocation, workforce, process.

1. INTRODUCTION

In today's increasingly dynamic business environment, manufacturing industries are coping with the challenges of producing goods of the right quality and quantity, and most importantly, at minimum cost to enhance competitiveness in the market. The current traditions in the design of production processes may not be adaptable to future challenges that organizations face. Yet, adopting effective concepts brings numerous benefits alongside barriers and difficulties due to the high robustness of the existing technology and workforce availability, especially in emerging economies. Rapid changes in demands and requirements, both internal and external, frequently trigger plans for change in different manufacturing areas, including the food processing industry. Process design, as a core of operations management, ensures that the process runs smoothly and that the goals are met entirely within an organization, and then implements ways to improve it (Wolniak, 2020). It cannot be denied that process design is a critical element of successful optimization in striving to develop efficient and profitable manufacturing operations.

[1] Marija Stanojeska, University American College Skopje, North Macedonia; e-mail: marija.stanojeska@uacs.edu.mk. ORCID: 0000-0002-9070-6036.

Technically, manufacturing process design is a specific and extremely complex activity for any operations manager. Process design is a comprehensive methodology that integrates all essential manufacturing options and relevant aspects and considerations. Since processes are managed at the operational level, process design must cover a more detailed set of objectives, primarily focusing on the flow of operations. These include reducing bottlenecks, delays, and idle time on the one hand, and maximizing resource utilization, inventory, capacity, demand, and product quality on the other.

The necessity of workforce utilization and appropriate task allocation, as one of the factors that influence the total cost of production, is worth emphasizing (Tausch, Kluge, 2022). Each process activity must decide on the balance between workforce utilization. Division of labor or task allocation is the dominant job design model in most mass-produced products, such as mass food production. Task allocation involves a specific and comprehensive analysis of the available workforce. Although machines are designed to perform specific tasks within a production process, employees can perform various tasks based on their skills, availability, and workload (Sheveleva et al., 2023). In that context, it is essential to consider all relevant issues influenced by process duration, the types of tasks, the resource needs, and resource consumption, as well as the available workforce (Galeazzo, Furlan, 2020).

Speaking about the available workforce, the manufacturing workforce shortage has been weighing on the food industry for several years, and it is showing no signs of letting up. The bakery industry, in particular, has been suffering. This industry is deficient in employees in all areas of production with baking-industry-specific technical skills. Automation reduces the workforce requirements and associated costs along the production line. Automated production machinery allows manufacturers to have fewer employees on the line, which is especially advantageous for repetitive tasks. Another important characteristic of manufacturing systems is their variabilities, which lead to complex changes in the functional states of jobs and resources (Suchintita et al., 2023).

This paper aims to analyze the possible variants in selecting the proper bread-making process design. Focusing on this process, task allocation has become one of the design process priorities. In the context of preventing employee overload, it is essential to balance the workload. Operations managers play a key role in distributing tasks among employees and, more importantly, in ensuring that each worker operates at optimal capacity.

This approach can improve overall productivity in the bread-making process because when allocating tasks, operations managers need to consider various factors, such as the type and complexity of the task, the estimated time required for completion, the quality of the products, and the availability of equipment for maintenance. By considering these factors, operations managers can create a balanced workload for employees in the bakery department.

Therefore, the main research question of this study is addressed by investigating how job design and specifically task allocation, influence process efficiency. For that sake, the research in the paper includes the examination of the essential aspects of the design of the process, through two scenarios presented in the form of Case Studies. In this regard, a post-process approach in one food processing company is used, where the outcome of the task allocation towards the efficient execution of the process is mainly analyzed. Additionally, the paper aims to confirm the role of workforce task allocation, through a comprehensive discussion of specific scenarios.

Following this introduction, the rest of the paper is organized as follows. The next section presents a literature review focusing on operations management, process design, and task allocation topics. In the third section, the methodology of the research framework is explained. In the fourth section, a detailed description of the production process is given, where workflow activities are mapped and the cost analysis of consumed resources is presented. In the last section, the Case Studies results are presented and discussed. Lastly, a conclusion is provided, including the suggested further avenues of investigation and research limitations.

2. LITERATURE REVIEW

Numerous researchers confirmed that the transformation role of operations management is directly responsible for many decisions and activities within the organization related to the design (Wolniak, 2020; Peinado et al., 2018; Oladejo et al., 2019; Lewis, 2019; Slack, Brandon-Jones, 2019). According to Gembalska-Kwiecień et al. (2018), operations management is a function integrated into the organization specifically to improve performance and the financial bottom line.

Task allocation, as a fundamental aspect of operations design, plays a critical role in determining the efficiency, adaptability, and overall performance of production processes (Wang et al., 2024; Wieland, Hammes, 2014; Tausch, Kluge, 2022; Zandieh, Adibi, 2010). In this sense, Hacker and Sachse (2014) confirmed that task allocation is normally a preparatory task carried out during the planning activities and aligned with the process design. Task allocation determines the overview of the full task as well as how free one feels in fulfilling the own tasks (Akyazi et al., 2020; Van den Broeck, Parker, 2017; Agnetis et al., 2014; Maman, 2017; Parker et. al., 2017). In line with Fast-Berglund and Stahre (2013), task allocation should be seen as complementary between man and machine rather than dividing tasks solely to one resource. According to Dvorak and collaborators (2023), a task description is provided based on which a standardized time for operations is considered and the link between the task description, and the product state must be created. Numerous researchers, such as Sheveleva et al. (2023), Joo et al. (2022), Petzoldt et al. (2022), and Calzavara et al. (2024), stated that the task allocation problem is of critical importance in the manufacturing industry, and determines the effectiveness and efficiency of advanced manufacturing systems. Moreover, Cheng and collaborators (2019) argued that the proper task allocation approach can give an optimized arrangement of existing resources, and enable the manufacturing system's flexibility, thus improving both economic performance and social benefits. Generally speaking, the performance of process execution is highly related to the effective allocation of task resources, and inappropriate allocation can lead to low resource utilization, high cost, time delay, and low equality (Goel et al., 2023; Stanojeska, 2022; Zhao et al., 2020; Huang et al., 2022; Arias et al., 2018; Sedighi, 2017; Pufahl et al., 2021).

According to Goryńska-Goldmann and collaborators (2021), the baking industry is deficient in employees in all areas of production with baking-industry-specific technical skills. Automation reduces the workforce requirements and associated costs along the production line (Kumar, 2019). Automated production machinery allows manufacturers to have fewer employees on the line, which is especially advantageous for repetitive tasks (Hecker et al., 2010; Naegele Inc. Bakery Systems, 2019). Drozd and collaborators (2023) stated that in the contemporary business environment, growing competition in the baking industry causes an ever-growing demand for solutions that would increase the reliability of all manufacturing processes. Additionally, the manufacturing workforce shortage has been weighing on the food industry for several years, and it is showing no signs of letting up

(Drozd, 2020; Patel et al., 2019; Babor et al., 2021). In the same context, Clark (2009) and Martin and collaborators (2020) argued that the workforce is always important, especially in circumstance when an expansion is considered and when workforce supply may be tight and costs may have increased.

It can be concluded that the issue related to job design, and specifically task allocation in the baking industry, is still a vague area worth researching. More importantly, this issue is expected to become more critical given the ongoing trend of decreasing the workforce, especially in developing countries.

It can be concluded that the issue related to job design, and specifically task allocation in the baking industry, is still a vague area worth researching. More importantly, this issue is expected to become more critical given the ongoing trend of decreasing the workforce, especially in developing countries.

Yet, there exists no similar review in the domain of process optimization through task allocation in the bread-making production process, utilizing automated production lines. By investigating real-life Case Studies, this research brings unique value in the current domain. The identified gap in the literature sources of knowledge was the major trigger to conduct this manuscript's research. In that direction, the hypothesis of this research is:

H1: Optimally designed task allocation has a significant impact on cost reduction and process efficiency improvement in bread-making production.

3. RESEARCH FRAMEWORK

The type of research conducted in the paper is descriptive, aimed at analyzing the different organizational approaches in the bread-making process. The study relies on primary data**,** collected through two qualitative methods: observation and documentation**.**

The documentation method involved the analysis of internal records and formal documentation obtained from five key departments: Production, Maintenance, Procurement, Human Resources (HR), and Finance. These sources provided required information related to operational procedures, workforce allocation, resource consumption, maintenance schedules, and cost structures.

The observation method was applied through direct monitoring of activities in the production process under different organizational setups. Two case studies were examined:

- Case Study 1: *The production process is carried out on parallel production lines operated within a single shift*.
- Case Study 2: *The production process is carried out on a single production line operating over two shifts*.

This two-case approach provides a basis for comparative examination of task delegation, utilization of resources, and process performance across different production configurations to build a pragmatic ground for identifying opportunities for improving job design and production planning.

The period of research conducted by observation was January to March 2025. Actually, the onsite observation method was accomplished in the pilot period of 30 days, while the production process was organized as it is explained in Case Study 2. Data gathered in the pilot period specific to Case Study 2 was summarized, and compared with data from the regular production operations of in Case Study 1, during the previous 30 days.

Both data sets were compared regarding the relevant criteria, like workflow, total throughput time, costs, quality, time for preventive maintenance, available workforce and workload, efficiency, warehousing capacity, and other relevant factors. Those data were carefully analyzed, and based on them, the right managerial decisions were made. In general, the research methodology applied in the paper encompasses qualitative analysis and comparative quantitative analysis.

For the purposes of this research, the bread-making process is described in detail, including a flowchart; workflow activities are mapped, and the needed resources are outlined in the following sections.

3.1. Description of the bread-making process

Food processors typically expect automation to be a key driver of throughput increasing and achieving industrial-scale production volume (Ahmed, Rahman, 2012). Boosting process throughput and reducing the risk of workforce turnover are influential reasons many bakery plants are looking to automate their production lines. The research in this paper was conducted in a food processing company, consisting of bread-making plants, milling plants, and pasta production plants. Specifically, this research is focused on the bakery plant equipped with two automatic production lines with the same capacity and performance properties. The capacity of each of those production lines is 1400 loaves of bread/hour. Actually, the capacity of the production line is determined by the capacity of the baking tunnel oven.

The rest of the equipment integrated into the production lines is sized to meet the continuity of the production flow and allow a continuous flow of the process. In essence, if the specified capacity of the tunnel oven is to bake 1400 units per hour, the capacity of the machines connected in the line must be matched to the capacity of the tunnel oven. Synchronization of the workflow eliminates the risk of non-value-added effects such as defects, bottlenecks, and downtime. The discussion presented in the following part of the paper refers to the stated production line capacity of 1400 units/h.

The automated production line is supported by the pressure-type pneumatic conveying system that utilizes positive-pressure gas as the driving force to transport flour through pipelines. The main raw material used in the production process is wheat flour, which is obtained in the Mill plant. The conveying system allows efficient, safe, and reliable transport from the Mill plant facility located on the same site, overcoming issues faced by traditional mechanical conveying methods. The dosing and weighing systems provide precise weighing, individual dosing parameters, and reliable functioning. The compact design of storage and weighing systems can be customized according to production needs. Flour silos offer many unique benefits for the indoor storage of bulk flour and numerous dry bulk materials. The weighing of different ingredients is carried out as per the formulated recipe in appropriate ratios. The formulation for bread varies from bakery to bakery, depending on factors such as the cost of ingredients and consumer preference concerning the quality of bread (Stanojeska, Cepujnoska, 2014). The remaining raw materials (yeast, salt, flour improvers, and other ingredients for different types of products) are added directly to the batch after prior weighing on the scales. The water is dosed automatically in the mixers for dough formation. Dough kneading enables the main ingredients to be dosed and improves efficient homogenization in the dough. The mechanical-physical process of mixing and kneading triggers chemical and microbiological processes, resulting in high-quality dough for further processing (Muscalu et al., 2017). Kneading is performed in mixing bowls of an industrial mixer, under operating conditions (number of revolutions, mixing time) following the product specification. A dough ball divider is one of the most important pieces of baking equipment used in commercial bread-making setups (Alam, 2020). Its primary role is to separate prepared dough into equal-sized pieces. When the dough piece exits the divider, it is irregular in shape, having sticky cut surfaces through which gas can easily diffuse (Trinh et al., 2016). The function of the rounder is to shape it into a ball and impart a thick continuous surface skin that will retain the gas and ease the handling or machinability of the dough. Dividing and rounding dough causes a drop in its pliability, elasticity, and extensibility, and thus, the dough may tear easily. It is necessary to let the dough piece rest while fermentation proceeds to restore these properties so that it recovers from strains and stresses caused by previous operations (Bhatia, 2016). This is known as intermediate proofing, which is a short rest period between dough dividing and the final moulding. Dough moulding is the terminal step of the dough makeup stage. It is a continuous operation, where the moulder receives pieces of dough from the intermediate proving and shapes them according to the bread variety. A dough piece that has undergone the processes of sheeting and moulding appears degassed and lacks volume. The loaves travel to a second prover that is set at a high temperature and with a high level of humidity. Dough rising is a complex microbiological process, tightly connected with the chemical and physical characteristics of raw materials (Mondal, Datta, 2008). Dough fermentation causes a dough volume increase and also affects the bread structure and flavor. Here, the dough regains the elasticity lost during fermentation and the resting period. From the prover, the loaves enter a tunnel oven. The temperature and speed are calculated so that when the loaves emerge from the tunnel, they are completely baked and partially cooled. During bread baking, due to the CO_2 thermal expansion, bread volume still increases a bit, a crust is formed on the surface, bread gets its final shape and volume, it is colored, and gets additional flavor through the baking process (Williamson, Wilson, 2009). On the other side, steam boilers for bakery tunnel ovens have been installed in the production department, both in the air conditioning of the fermentation chambers and in the supply of equipment to provide clean steam to the ovens. Cooling takes place at ambient temperature (Purlis, 2012). The cooled products (29–31°C) are sent for further processing in the packaging department. Bread has to be cooled before slicing and wrapping to facilitate slicing and prevent condensation of moisture in the wrapper. The desirable temperature during slicing is 30°C. Cooling facilitates in redistribution of moisture from the center to the crust, softening this layer. The internal temperature of the bread should be reduced to 35–40°C towards the end of the cooling cycle and this is normally achieved by applying an external air temperature of 24°C at a relative humidity of 85%, with an air movement. Bread is normally packaged at the legal limit of 38–42% moisture (Bhatia 2016). The process of packaging of final units is executed through the semi-automated process equipment. Therefore, the packed units are warehoused and arranged in special storage containers according to the distributor's orders. The products are shipped to the retailer to fulfil the client's demands.

The discussed process steps are present in the flowchart (Figure 1). The monitoring and control of the quality is covered throughout the entire process. The positions for taking samples and quality control in the laboratory are presented by the acronym QC (quality control).

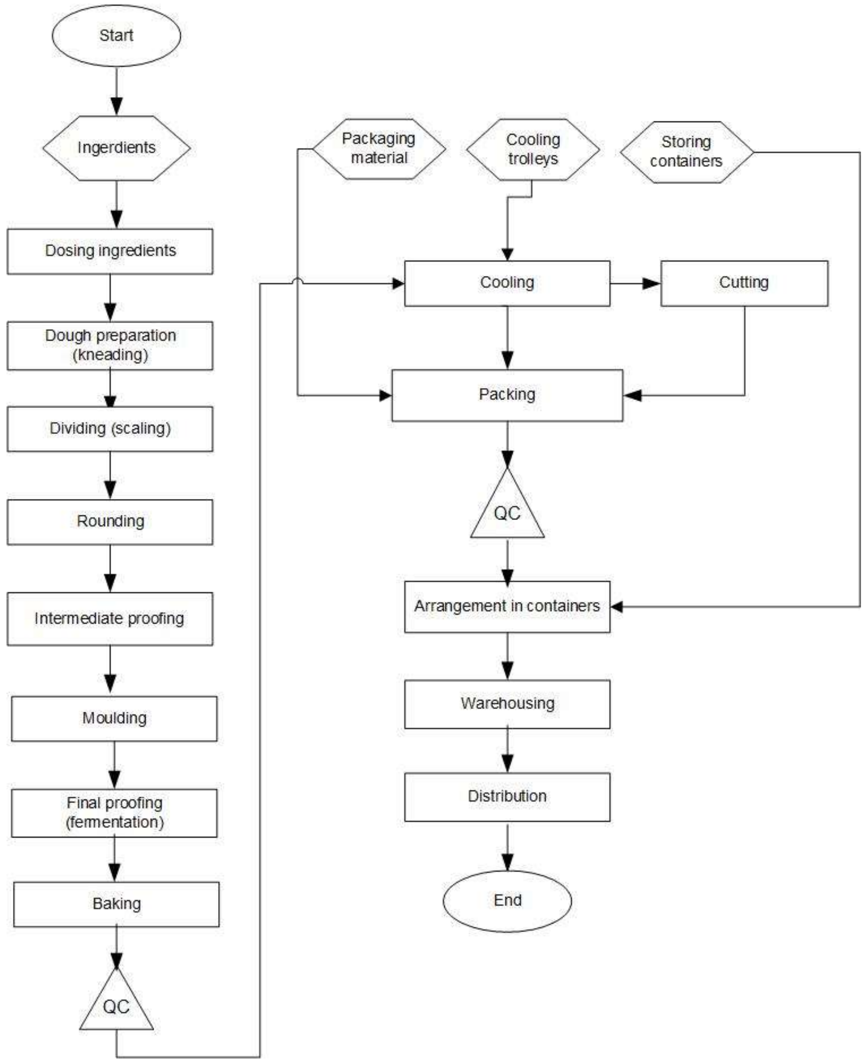

Figure 1. Flowchart of the bread-making production

Source: Author's work based on general bread-making process phases.

3.2. Mapping workflow activities

According to the demand, the current capacity of the plant is 19.600 units/ day. The question is how many hours are needed to produce the required products using the available resources, equipment, energy, and stuff. For that sake, a mapping of the process activities is provided. The mapping aimed to show the duration of each of the every single process activities in the workflow. According to the presented flowchart (Figure 1), the initial activities like dosing flour in chambers, preparing the other ingredients, and reaching the required working conditions (temperature, pressure, humidity), take place before the production process starts. The reaching of required working conditions includes the generation of steam by the boiler house. As shown in Table 1, the duration of the process performed on the single production line is 2 hours and 23 minutes.

Table 1. Duration of process activities performed on the production line

Type of process activity	Type of equipment	Start time (min)	End time (min)	Activity duration (min)
Dosing ingredients	Dosing and weighing systems	00:00	00:15	15
Dough preparation	Mixing bowls	00:15	00:17	2
Dough resting	Mixing bowls	00:17	00:27	10
Dough dividing	Divider	00:27	00:37	10
Rounding	Conical rounder	00:37	00:52	15
Intermediate proofing	Intermediate proofing chamber	00:52	01:04	12
Long loaves moulding	Moulder	01:04	01:12	8
Final proofing	Fermentation chamber	01:12	01: 55	43
Baking	Tunnel oven	01:55	02:23	28

Source: Production Department data compiled and analyzed by the author.

After baking is complete, activities such as cooling, cutting, packaging, and storage follow, which are performed on several semi-automatic machines, and the estimated duration is given in Table 2.

Table 2. Duration of process activities performed out the production line

Type of process activity	Type of equipment	Start time (min)	End time (min)	Duration of activity (min)
Cooling	Cooling trolleys	02:23	02:53	30
Slicing	Cutting machines	02:53	03:27	35
Packing	Packing machines	03:27	03:52	25
Units crate stacking	/	03:52	03:53	1
Arrangement in containers	/	03:53	04:13	20
Distribution	Vehicles	04:13	...	

Source: Production Department data compiled and analyzed by the author.

However, the duration of the process performed on the single production line is 2 hours and 23 minutes, while the duration of the activities after baking completion is 1 hour and 51 minutes. To notify, the distribution time is not subject to analysis because the distribution of the products is the responsibility of external companies. If the necessary time to fulfill the required working conditions of 1 hour is added to the total time of 4 hours and 13 minutes, the length of time needed to complete the process is obtained, which is 5 hours and 13 minutes. Regularly, to fulfill the targeted capacity, the production process is taken on the single production line, in two working shifts, continuously and without downtime, which means that over 14 hours (the duration of one work shift is seven hours), the production cycle is repeated a few times.

3.3. Key resources for production execution

For the needs of the production process, specifically for the fermentation and baking activities, the steam produced in the boiler house is used. Moreover, the electricity is used for other equipment integrated into the production line. The third resource is water, which is included in the composition of the products. The consumption of those basic resources necessary is given in Table 3. The consumption of resources is calculated for a production capacity of 1400 products/hour, when the line operates in two shifts (14h/day), throughout the year.

Table 3. Annual consumption of required resources and cost distribution

Type of resource	Annual consumption	Cost distribution
Electricity	634831 KWh	84 %
Fuel for steam boiler house	405 t	15 %
Water	1240 m^3	1 %

Source: Production Department data compiled and analyzed by the author.

According to the presented data (Table 3), it can be concluded that the consumption of fuels accounts for the highest percentage of total costs (84%), followed by electricity costs (15%).

4. JOB DESIGN IN THE BREAD-MAKING PROCESS

Within the limits of available production and demand levels, the process of job design is established according to the operational requirements of each stage of production. Job positions are designed based on the technical specifications and functional interdependences of the equipment, rather than upon the details of a single production line. In automated manufacturing processes, not every machine requires constant monitoring by employees. Actually, employees' roles are more focused on supervision, process coordination, and quality assurance. Peripheral activities such as cutting, packaging, boiler operation, and warehousing remain non-automatic and thus require sole manual posts.

From a job design perspective, the whole process, starting from the preparation of raw materials to the delivery of the product, requires a combination of monitoring, control, and maintenance functions distributed among various operator posts. These job positions reflect the higher task specialization and process integration principles characteristic of automated manufacturing systems. Consistent with this, job positions such as Supervisor, Operator on flour silos, Operator on kneading mixer, Operator on divider, Operator on fermentation chamber, and Operator on tunnel oven reflect the primary activities of the automated line, whereas job positions in the boiler house, packaging, and warehouse comprise supportive, non-automated work. Yet, the further research addresses only the job positions related to the automated production line. For purposes of analysis, two scenarios are used to determine efficiency and the utilization of the workforce:

- Two parallel production lines operated within a single shift - Case Study 1.
- One production line operating over two shifts - Case Study 2.

4.1. Case Study 1

In the context of the first scenario, when the production process is performed on a single line in two work shifts, the task allocation is organized by the needs of the operation. As stated above, the production process consists of several operations, for the execution of which the required number of employees is: one operator responsible for dosing the raw materials, one operator responsible for carrying out the mixing process of the ingredients, one operator for dividing the dough into pieces of a certain weight, one operator responsible for monitoring the fermentation process, one operator for monitoring the baking process and one responsible for controlling the entire process and for recording the relevant data. This means the total number of operators required to execute the working tasks on one production line and in one shift is a total of six operators. The layout of the job design and task allocation is presented in Figure 2.

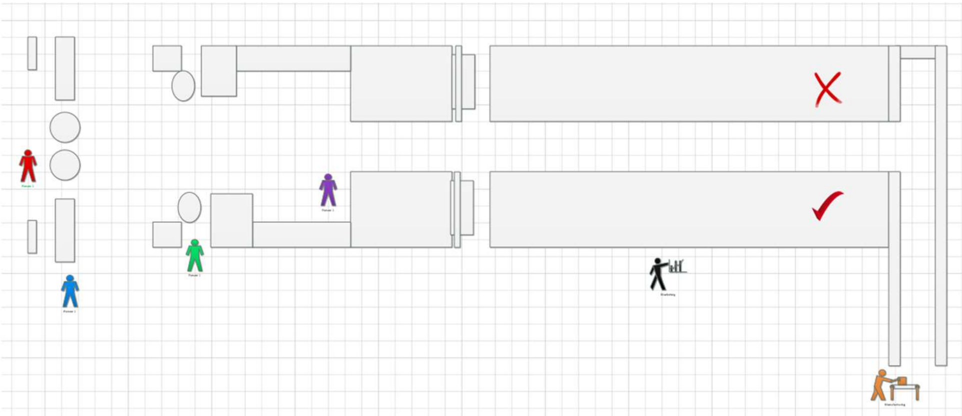

Figure 2. The layout of task allocation for a single production line operating in one shift

Source: Author's illustration.

To fulfill the requested capacity, it is necessary to organize production in two shifts, which means that the number of operators must be doubled, or 12, with six of them carrying out the process in one shift, and the remaining six operators being responsible for carrying out production in the second shift. The layout of this scenario is presented in Figure 3.

To analyze the production costs and in the direction of optimization, in the next step, an analysis of oil consumption was performed. Namely, if the process is carried out on one production line in two shifts, oil consumption is 10% lower compared to production carried out on two production lines. This is quite expected because, during the initial start-up of the two burners with which the two automatic lines are equipped, oil consumption is the highest. Guided by this conclusion, the production process in the bakery products production department regularly takes place on one line in two shifts.

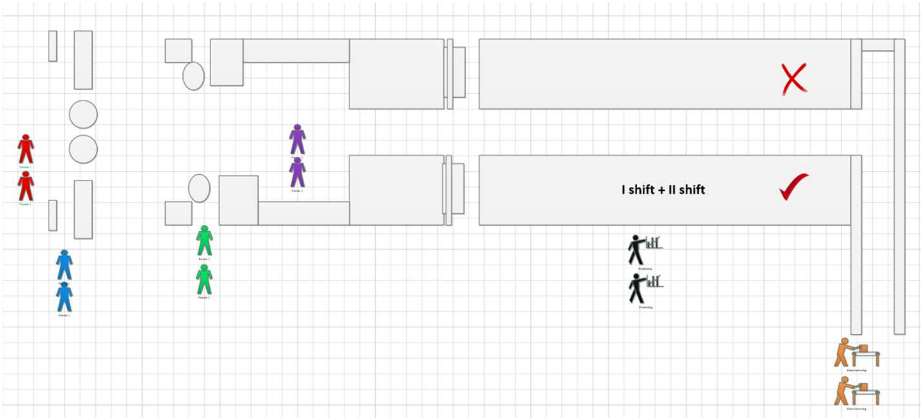

Figure 3. The layout of task allocation for a single production line operating in two shifts
Source: Author's illustration.

4.2. Case Study 2

The second scenario, which means using both production lines and working in one shift, is not practiced precisely because it requires an increased oil consumption of 10%, due to the use of two burners to start the two tunnel ovens. However, a test period was conducted in which the second scenario was applied, which is working with both production lines in one work shift. In this regard, a detailed and separate analysis of the required work positions was conducted. As in the previous case, the same job positions previously listed were considered, but in this case, it was taken into account that the production machines on both lines are in operation simultaneously.

For each job position, the possibilities for performing job tasks in parallel on both production lines have been considered. Starting from the very beginning of the process, only one operator can be in charge of dosing raw materials. In fact, the dynamics of dosing raw materials allows for the simultaneous execution of tasks, and accordingly, one operator can meet the requirements of both lines efficiently. Regarding the second job position, due to the continuous flow of mixing dough batches, two employees are required to perform the tasks on both machines for mixing the ingredients. The next job position is dividing the dough into pieces of a given weight. An operator is required on each of the machines that are part of the production lines. This means that two operators are required for the smooth execution of this operation. The next phase is fermentation. Given that the operator responsible for controlling the quality of fermented products and monitoring operating parameters can independently monitor both chambers in parallel, only one employee is sufficient for this activity. Next comes the final process phase, which is the baking phase, which takes place in a tunnel oven. The ovens are equipped with sensors for operating parameters (temperature, pressure), and the quality of the baking process is monitored visually through special openings for that purpose, in all three baking zones. At the end of baking, the final products emerge and are collected in special baskets for that purpose. Since this is a fairly large capacity, two employees are required for efficient collection of the products, who are dedicated to each of the conveyor belts that serve to transport the baked products from the two ovens. The production supervisor has the task of controlling the operation of the production line, collecting data, and, of course, recording it in the form of a report. Regarding the physical distance between the two production lines, such control can be effectively carried out by only one supervisor.

Generally speaking, the total number of employees required to carry out the production process on two lines simultaneously in one shift is nine operators. The layout of the task allocation in the second scenario is presented in Figure 4.

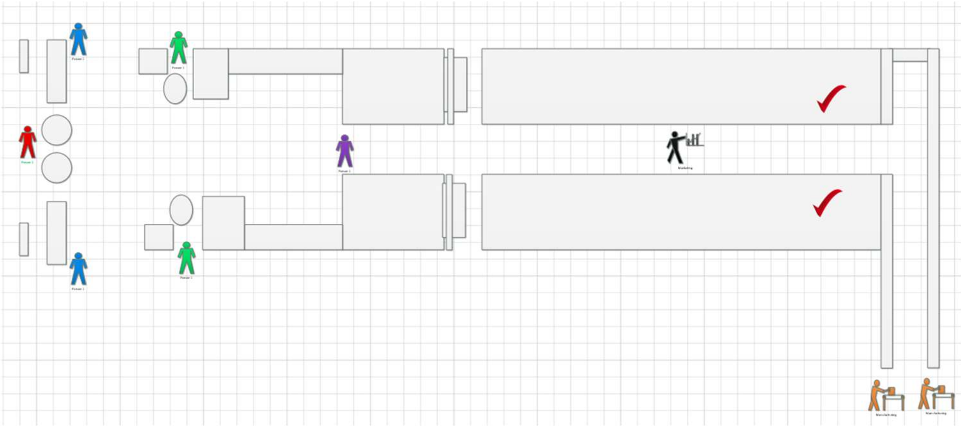

Figure 4. The layout of task allocation for both production lines operating in one shift

Source: Author's illustration.

4.3. Comparative analysis

An explicit overview of the comparison of the required number of employees in both scenarios is presented in Table 4.

Table 4. The comparison of the required number of employees in both scenarios

Job position	Number of employees	
	Case Study 1: Using of 1 production line in 2 shifts	Case Study 2: Using of 2 production lines in 1 shift
Operator on flour silos	2	1
Operator on kneading mixer	2	2
Operator on divider	2	2
Operator on fermentation chamber	2	1
Operator on tunnel oven	2	2
Supervisor	2	1
Total no. of operators	12	9

Source: Production Department data compiled and analyzed by the author.

It is clear that the Case Study 2 - operating two lines in parallel in a single shift, utilizes less employee and has nine employees, unlike twelve employees to operate two lines within two shifts. This variation in numbers indicates the potential for increased optimization of workforce utilization by proper scheduling and concurrent operation of the production capacities. This type of task allocation facilitates productivity among the employees by concentrating surveillance and operational duties in a single shift, minimizing downtime and replicated effort. The surplus employees may be transferred to other sections, enabling more effective and adaptable use of human resources. Before this reorganization may be put into effect, certain other operational factors need to be considered, like equipment maintenence and fuel consumption.

Regarding equipment maintenance, the responsible manager from the maintenance department stated that operating two production lines simultaneously eliminates the possibility of transferring production in the event of a defect from one production line to the other production line. In fact, the attitude of the responsible manager is that one line should be in operation, and the other line should serve as a backup option in the event of a defect or downtime. But on the other hand, operating two production lines simultaneously leaves the possibility of preventive and regular maintenance of the machine equipment within the lines, precisely because production, instead of lasting 14 hours in two shifts, takes place in 7 hours in one shift. Thus, the maintenance department has more time to control the correctness of the equipment, perform preventive maintenance, or possibly intervene. However, the convenience of transferring production to the backup line in the event of a defect is lost. After a detailed analysis of the facts and arguments, the position of the equipment maintenance department is that the option of running out production on both lines simultaneously is completely acceptable.

In terms of fuel consumption, a comprehensive analysis was carried out by monitoring fuel consumption during the pilot period when operating two lines in one shift (Case Study 2). The data obtained in terms of oil consumption were compared with data from existing records generated from operating one line in two shifts (Case Study 1). As expected, the calculations indicate an increased fuel consumption of 10% when operating with two production lines (Case Study 2) compared to operating with one production line (Case Study 1). However, as previously stated, in Case Study 2, three fewer operators were engaged. If we compare the costs related to salaries for 12 and 9 employees, of course, we have a difference of 25% higher costs if the production is organized according to scenario 1. In that context, if we compare the sum of fuel costs plus employee salary costs in Case Study 1 with the sum of the same costs in Case Study 2, it is determined that the difference is 7%, in favor of Case Study 2. Specifically, the production costs using both lines in one shift, with nine employees and higher oil consumption, are 7% lower than the costs of production utilizing a single production line in two shifts, with 12 employees.

In general, these results confirm that optimizing task allocation and aligning human resources with technological capabilities can yield significant improvements in efficiency. In other words, the stated hypothesis is confirmed.

5. CONCLUSION

The research in this paper is focused on bread-making process optimization from the perspective of job design and adequate task allocation. For that sake, the two real scenarios in the specific baking plant located in North Macedonia were analyzed. The plant is equipped with two fully automated production lines with identical performance features and capacity. Case Study 1 refers to running a process using a single production line during two shifts, but Case Study 2 refers to the utilization of both production lines during one shift. In both scenarios, the quality of the produced units and the production volume are equal. The dilemma, of which one of the presented scenarios should be accepted, is put under question. For this purpose, a deeper analysis was conducted in terms of resource consumption costs and engaged workforce costs. In that context, a comprehensive explanation of the process workflow was enabled due to the close relation with a treated issue. In that context, a comprehensive explanation of the process workflow was enabled due to the close relation with a treated issue. Moreover, the mapping of the time intervals in terms of the duration of any single activity contained in the process was identified. In further, the analysis of the resources was provided and the impact of the main energetic resource was discussed regarding both scenarios.

Based on the collected data generated from different departments in the factory, one can conclude that running operations on both production lines in one shift leads to decreased costs for salaries and increased costs for fuel consumption. The total cost calculations indicate that the scenario discussed in Case Study 2 is more cost-effective than the scenario discussed in Case Study 1.

This research highlights that job design, particularly task allocation, is a critical factor in optimizing production processes. Studying this aspect is valuable for developing more efficient and successful production processes. By analyzing real-life Case Studies from a bakery plant in North Macedonia, this paper can serve as a valuable guide in striving to enhance overall efficiency and contribute to companies within the relevant industry sector.

5.1. Research limitations

The few limitations of this research are underlined.

First, due to company confidentiality requirements, principally on compensation levels of employees and cost of resources, they were not exposed to public presentation. For reporting in this paper, data were provided only for computation in percentages. Although this ensured respecting organizational procedures, it limited the level of quantitative analysis.

Second, the analysis is limited to two case study scenarios, which represent real alternatives in the company, and both are applied in a single industrial environment. The applicability of research findings to other production environments with different structures is limited.

Third, the study does not utilize advanced modeling techniques, which would confirm the proposed perceptions into task allocation strategies and job design.

5.2. Further avenues of investigation suggested

Future research can build on the current research by expanding the sizes of the datasets, crossing a range of industries, and utilizing sophisticated analysis techniques. With the dynamic nature of the production costs and the constant need for adaptive workplace design and task assignment, the future research can engage sophisticated modeling techniques like simulation, which would also confirm the proposed insights into task assignment strategies and work design.

Acknowledgements

The author would like to acknowledge the food processing company, including its bakery plant, located in North Macedonia, for their support during the research and for providing access to the necessary data.

Declaration of AI: The author declares that no AI or AI-assisted tools were used in the preparation of this manuscript.

Author Contributions: All subsections, including the Introduction, Literature Review, Research Framework, Results and Discussion, as well as the Conclusion and Recommendations, were prepared solely by the author of this Manuscript. The operational

data were obtained from the relevant departments of the bakery plant. I would like to express my sincere gratitude for their openness and cooperation.
Funding: The author declares that there was no sponsorship, scholarship, grant, support funding and no financial support from agencies.
Data Availability Statement: The author declares that the data used for the analysis of the study were obtained from the bakery plant located in North Macedonia.
Conflicts of Interest: The author declares no conflicts of interest in this paper or study.

The author has read and agreed to the published version of the manuscript.

REFERENCES

Agnetis, A., Murgia, G., Sbrilli, S. (2014). A job shop scheduling problem with human operators in handicraft production. *International Journal of Production Research, 52*(13), 3820-3831. https://doi.org/10.1080/00207543.2013.831220

Ahmed, J., Rahman, M. S. (2012). *Handbook of food process design*. Blackwell Publishing Ltd. https://doi.org/10.1002/9781444398274

Akyazi, T., Goti, A., Oyarbide, A., Alberdi, E., Bayon, F. (2020). A guide for the food industry to meet the future skills requirements emerging with Industry 4.0. *Foods, 9*(4), 492. https://doi.org/10.3390/foods9040492

Alam, S. T. (2020). Automated bread maker: Implementing techniques of product design process. In *Proceedings of the International Conference on Industrial & Mechanical Engineering and Operations Management*, Dhaka, Bangladesh, December 26-27. IEOM.

Aljohani, K. (2023). Optimizing the distribution network of a bakery facility: A reduced travelled distance and food-waste minimization perspective. *Sustainability, 15*(4), 3654. https://doi.org/10.3390/su15043654

Arias, M., Munoz-Gama, J., Sepúlveda, M., Miranda, J. C. (2018). Human resource allocation or recommendation based on multi-factor criteria in on-demand and batch scenarios. *EJIE, 12*(3), 364-404. https://doi.org/10.1504/EJIE.2018.092009

Babor, M., Senge, J., Rosell, C. M., Rodrigo, D., Hitzmann, B. (2021). Optimization of no-wait flowshop scheduling problem in bakery production with modified PSO, NEH and SA. *Processes, 9*(11), 2044. https://doi.org/10.3390/pr9112044

Bhatia, S. (2016). *Food biotechnology*. CRC Press.

Calzavara, M., Faccio, M., Granata, I., Travisani, A. (2024). Achieving productivity and operator well-being: A dynamic task allocation strategy for collaborative assembly systems in Industry 5.0. *International Journal of Advanced Manufacturing Technology, 134*, 3201-3216. https://doi.org/10.1007/s00170-024-14302-3

Calzavara, M., Faccio, M., Granata, I., Travisani, A. (2024). Achieving productivity and operator well-being: A dynamic task allocation strategy for collaborative assembly systems in Industry 5.0. *International Journal of Advanced Manufacturing Technology, 134*, 3201-3216. https://doi.org/10.1007/s00170-024-14302-3

Cheng, Y., Sun, F., Zhang, Y., Tao, F. (2019). Task allocation in manufacturing: A review. *Journal of Industrial Information Integration, 15*, 207-218. https://doi.org/10.1016/j.jii.2018.08.001

Clark, J. P. (2009). Process and equipment selection. In *Practical design, construction and operation of food facilities* (pp. 85-122). Academic Press, Elsevier Inc.

Drozd, R., Wolniak, R., Piwnik, J. (2023). Systemic analysis of a manufacturing process based on a small scale bakery. *Quality & Quantity, 57*, 1421-1437. https://doi.org/10.1007/s11135-022-01408-7

Drozd, R. (2020). Functional model of the impact of factors on product quality in the baking industry. *Science Didactics Equipment, 3*, 173-180.

Dvorak, J., Wurster, M., Carl May, M., Lanza, G. (2023). A systematic approach to task assignment and production planning in disassembly with employee skills. *Procedia CIRP, 120*, 958-963. https://doi.org/10.1016/j.procir.2023.09.107

Fast-Berglund, Å., Stahre, J. (2013). Task allocation in production systems – Measuring and analysing levels of automation. *IFAC Proceedings Volumes, 46*(15), 435-441. https://doi.org/10.3182/20130811-5-US-2037.00032

Galeazzo, A., Furlan, A. (2020). Developing operational problem solvers: The role of job design decisions. *Total Quality Management & Business Excellence, 32*(15-16), 1768-1785. https://doi.org/10.1080/14783363.2020.1771176

Gembalska-Kwiecień, A., Skotnicka-Zasadzień, B., Wolniak, R., Bujna, M. (2018). Creating participation of employees in improving work safety in enterprise. In *XV International Conference Multidisciplinary Aspects of Production Engineering (MAPE 2018)* (pp. 689-694). Wydawnictwo PANOVA.

Goel, K., Fehrer, T., Röglinger, M., Wynn, M. T. (2023). Not here, but there: Human resource allocation patterns. In C. Di Francescomarino, A. Burattin, C. Janiesch, S. Sadiq (Eds.), *Business Process Management. BPM 2023. Lecture Notes in Computer Science* (Vol. 14159). Springer, Cham. https://doi.org/10.1007/978-3-031-41620-0_22

Goryńska-Goldmann, E., Gazdecki, M., Rejman, K., Kobus-Cisowska, J., Łaba, S., Łaba, R. (2021). How to prevent bread losses in the baking and confectionery industry? Measurement, causes, management, and prevention. *Agriculture, 11*(1), 19. https://doi.org/10.3390/agriculture11010019

Hecker, F., Hussein, W., Becker, T. (2010). Analysis and optimization of a bakery production line using ARENA. *International Journal of Simulation Modelling, 9*(4), 208-216. https://doi.org/10.2507/IJSIMM09(4)4.175

Hacker, W., Sachse, P. (2014). *Allgemeine Arbeitspsychologie: Psychische Regulation von Tätigkeiten*. Hogrefe, Göttingen.

Huang, E. Y., Paccagnan, D., Mei, W., Bullo, F. (2022). Assign and appraise: Achieving optimal performance in collaborative teams. *IEEE Transactions on Automatic Control, 68*(3), 1614-1627. https://doi.org/10.1109/TAC.2022.3156879

Ihde, S., Pufahl, L., Lin, M. B., Goel, A., Weske, M. (2019). Optimized resource allocations in business process models. *International Conference on Business Process Management* (pp. 55-71). Springer. https://doi.org/10.1007/978-3-030-26643-1_4

Joo, T., Jun, H., Shin, D. (2022). Task allocation in human–machine manufacturing systems using deep reinforcement learning. *Sustainability, 14*(4), 2245. https://doi.org/10.3390/su14042245

Kumar, P. P. (2019). Goal programming through bakery production. *International Journal of Scientific & Technology Research, 4*, 3722-3725.

Lewis, M. (2019). *Operations management: A research overview*. Taylor & Francis Group. https://doi.org/10.4324/9781351034982

Maman, Z. S., Yazdi, M. A. A., Cavuoto, L. A., Megahed, F. M. (2017). A data-driven approach to modeling physical fatigue in the workplace using wearable sensors. *Applied Ergonomics, 65*, 515-529. https://doi.org/10.1016/j.apergo.2017.02.001

Martin, N., Depaire, B., Caris, A., Schepers, D. (2020). Retrieving the resource availability calendars of a process from an event log. *Information Systems, 88*, 101463. https://doi.org/10.1016/j.is.2019.101463

Mondal, A., Datta, A. (2008). Bread baking – a review. *Journal of Food Engineering, 86*(4), 465-474. https://doi.org/10.1016/j.jfoodeng.2007.11.014

Muscalu, G., Voicu, G., Istudor, A. (2017). Bread dough kneading process optimization in an industrial environment, using a device for dough consistency control. *UPB Scientific Bulletin, Series D: Mechanical Engineering, 79*(3), 225-236.

Naegele Inc. Bakery Systems. (2019). *Automating industrial bakery production lines: Benefits and tips*. https://www.naegele-inc.com/wp-content/uploads/2020/06/Naegele-automating-industrial-bakery-production-web.pdf

Oladejo, K., Abolarinwa, A., Salawu, S. O., Lukman, A. F. (2019). Optimization principle and its application in optimizing landmark university bakery production using linear programming. *International Journal of Civil Engineering and Technology (IJCIET), 10*(2), 183-190.

Patel, A., Devraja, H., Sharma, P., Singh, R. (2019). *Food technology II. Technology Division NDRI*, Karnal-132001. https://agrimoon.com/wp-content/uploads/FOOD-TECHNOLOGY-II.pdf

Peinado, J., Graeml, A. R., Vianna, F. (2018). Operations management body of knowledge and its relevance to manufacturing and service organizations. *Revista de Gestão, 4*, 373-389. https://doi.org/10.1108/REGE-03-2018-0049

Petzoldt, C., Niermann, D., Maack, E., Sontopski, M., Vur, B., Freitag, M. (2022). Implementation and evaluation of dynamic task allocation for human–robot collaboration in assembly. *Applied Sciences, 12*(24), 12645. https://doi.org/10.3390/app122412645

Pufahl, L., Ihde, S., Stiehle, F., Weske, M., Weber, I. (2021). Automatic resource allocation in business processes: A systematic literature survey. *arXiv preprint arXiv*:2107.07264, 1-28. https://doi.org/10.48550/arXiv.2107.07264

Purlis, E. (2012). Baking process design. In *Handbook of Food Process Design*. Blackwell Publishing Ltd.

Sheveleva, L., Jones, M., Harris, I. (2023). It does not matter how hard you work: The importance of task allocation for worker productivity. *Economics Letters, 227*, 111115. https://doi.org/10.1016/j.econlet.2023.111115

Slack, N., Brandon-Jones, A. (2019). *Operations management*. Pearson.

Stanojeska, M. (2022). An implementation of digital technologies to improve productivity and reduce non-value adding activities in the production process. *AICEI*, 198-207. https://doi.org/10.5281/zenodo.7643579

Stanojeska, M., Cepujnoska, V. (2014). A model of statistical process control of quality and cost optimization in milling industrial processes. *Journal of Hygienic Engineering and Design, 7*, 87-95.

Suchintita, D. R., Tiwari, B. K., Garcia-Vaquero, M. (2023). The fundamentals of bread making: The science of bread. In *Traditional European breads: An illustrative compendium of ancestral knowledge and cultural heritage* (pp. 1–40). Springer International Publishing. https://doi.org/10.1007/978-3-031-23352-4_1

Tausch, A., Kluge, A. (2022). The best task allocation process is to decide on one's own: Effects of the allocation agent in human-robot interaction on perceived work characteristics and satisfaction. *Cognitive Technology & Work, 24*, 39-55. https://doi.org/10.1007/s10111-020-00656-7

Trinh, L., Campbell, G. M., Martin, P. J. (2016). Scaling down bread production for quality assessment using a breadmaker: Are results from a breadmaker representative of other breadmaking methods? *Food and Bioproducts Processing, 100*, 54-60. https://doi.org/10.1016/j.fbp.2016.06.004

Van den Broeck, A., Parker, S. (2017). *Job and work design*. In Parker, Morgeson, & Johns.

Wang, J., Yu, D., Liu, C. (2024). *Task allocation for maximum cooperation in complex structured business processes*. Knowledge-Based Systems, 299, 111989. https://doi.org/10.1016/j.knosys.2024.111989

Williamson, M. E., Wilson, I. (2009). Development of an improved heating system for industrial tunnel baking ovens. *Journal of Food Engineering*, *91*(1), 64-71. https://doi.org/10.1016/j.jfoodeng.2008.08.004

Wolniak, R. (2020). Main functions of operation management. *Production Engineering Archives*, *26*(1), 11-14. https://doi.org/10.30657/pea.2020.26.03

Zandieh, M., Adibi, M. A. (2010). Dynamic job shop scheduling using variable neighborhood search. *International Journal of Production Research*, *48*(8), 2449–2458. https://doi.org/10.1080/00207540802662896

Zhao, W., Pu, S., Jiang, D. (2020). A human resource allocation method for business processes using team faultlines. *Applied Intelligence*, *50*, 2887-2900. https://doi.org/10.1007/s10489-020-01686-4