Investigation of Production Line Layout through Line Balancing Method: A Case of Fikir Food Processing Company

Elshaday Girma T/haimanot

A Thesis Submitted to the Department of Mechanical Engineering

College of Mechanical, Chemical, and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Manufacturing Engineering

School of Postgraduate Studies
Adama Science and Technology University

June, 2025
Adama, Ethiopia

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Main Advisor: Dr. Habtamu Beri

Co-Advisor: Mr. Hailu Beyecha

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I hereby declare that this Master Thesis entitled "**Investigation of Production Line Layout through Line Balancing Method. A Case of Fikir Food Processing Company**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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ABSTRACT

The production line effectiveness is an important driver of operation efficiency, particularly in food processing when demand is varied and the quality level is high. This study investigates the production and layout problems that Fikir Food Processing Company has, particularly about making their Unic soft biscuit products. The current layout of operation suffers from overall inefficiencies such as unbalanced workstations, excessive idle time, and gaps between batches. To solve such problems, the study employed a line-balancing method. Direct observation, interviews, and time studies were used in carrying out an intensive investigation of the current manufacturing system. The collected data were simulated with ARENA simulation to identify bottlenecks and quantify performance measures. Based on the findings, a new production line layout was proposed for soft biscuit production is balances the line of production smooth workflow, aligns process duration to takt time, eliminates idle machines, decreases total cycle time from 48:06 minutes to 29:42 minutes, reduces the number of worker from 60 to 54, increasing total production per day from 2401 to 3514. The enhanced layout is modeled to increase production capacity by a significant 46.3%. This research not only delivers viable solutions to Fikir Food Processing Company's production constraints but also delivers a scalable method that can be adopted by other food processing firms with similar problems.

Keywords: *Line balancing, Simulation, Production line layout, Bottleneck, Food processing*

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LIST OF ABBREVIATION

ALB	Assembly Line Balancing
FFP	Fikir Food Processing
GBT	Graph-Based Technique
NNVA	Necessary Non-Value-Added Activity
NVA	Non-Value-Added Activity
SLP	Systematic Layout Planning
VA	Value-Added Activity

CHAPTER 1

INTRODUCTION

1.1 Background of the study

This study was conducted in Fikir Food Processing Company. The company's main products include hard and soft wheat flour, wafer sandwich biscuits, and a range of soft and hard biscuits and flavor chips. The biscuit factory is the subject of the study. The products are extensively accessible in all markets across the country, and they have quickly been successfully marketed and accepted by the market. Fikir Food Processing Company produces both hard and soft biscuits. The factory's production lines are used to make both soft and hard biscuits. The machines and workstations are set up based on the sequence of biscuit production as this uses a product or line layout type. In the factory the production uses the Campaign Batch Production (Sequential Batch Production) means each type of biscuit is produced in a dedicated time slot or campaign, and after one batch is completed, the machine is cleaned and set up for the next biscuit type.

The company's product biscuits are becoming more acceptable to customers, and more customers want them, currently, the company is not able to keep up with the supply to equal the soft and hard biscuit demand with the current production. The company is unable to satisfy at least half of the customers' demands for soft biscuits since 16–18 working days are assigned to producing hard biscuits each month, with the remaining days being used to produce soft biscuits (Source, company data, 2024). The company decides to continue using the present line for hard biscuits while installing a new line for soft biscuits to satisfy a soft biscuit customer demand. In terms of producing a soft biscuit, the current line layout has an imbalanced workstation problem, which results in bottlenecks and machine idleness. The factory's current double-story manufacturing layout results in difficulties with supervision, higher labor expenses, and inefficient material handling. Productivity, process control, and quick decision-making are limited by vertical movement and poor communication across floors.

Bottlenecks are common problems in manufacturing plants. Elimination of bottlenecks in operations is crucial to improve productivity and throughput. That occurs when the capacity of an operation is inadequate to meet demand. Manufacturers usually encounter obstacles in their operations. Knowledge of bottlenecks and 'throughput' can improve efficiency and reduce negative impacts on operations. Bottlenecks occur when resources have limited capacity so that an organization is unable to satisfy product volume, mix, or variation in demand in the market(Pegels & Watrous, 2005).

Increasing productivity is not a simple task and takes continuous effort. Hence, firms need to be dedicated to continually enhancing productivity by process change. Line balancing is one of the methodologies to enhance productivity (Wening Ken Widodasih, 2023). Line balancing means distributing workloads across workstations on the manufacturing line to prevent bottlenecks and excess capacity (Neungmatcha & Boonmee, 2021). Line balancing in biscuit production focuses on its important contribution to improving production efficiency, reducing delays, and limiting waste. Unbalanced lines create bottlenecks, downtime, and excess work-in-progress, which negatively impact overall productivity. Research increasingly uses Lean Manufacturing and Six Sigma methodologies—such as Value Stream Mapping (VSM), DMAIC (Define, Measure, Analyze, Improve, Control), and 5S—to map inefficiencies throughout the production process. For instance, recent plant initiatives in Indonesia and Ethiopia demonstrated that line balancing, when combined with systematic problem-solving tools, greatly enhanced process flow, cycle times, and defect rates. Automation and intelligent technologies are also mentioned as auxiliary tools that assist in sustaining balance by synchronizing machine operation and aiding real-time monitoring. Line balancing is not a technical solution but a strategic imperative of today's biscuit factories for quality and competitiveness.

To reduce risk, inaccuracy, and uncertainty, the current system was analyzed using simulation, and an optimal alternative was proposed and studied before being implemented in the real system. It is simpler to develop a simulation model that can detect issues and bottlenecks in the actual system, enabling improved time, resource, and production efficiency (Neungmatcha & Boonmee, 2021). Simulations offer advantages such as reasonableness, provability, and output comparison. The re-configurable assembly line provides flexibility, increasing throughput and lowering labor requirements. These results can assist the firm to satisfy increasing customer demand. Improved work procedures can save time, increase efficiency, and ensure smooth output (Gopalakrishnan et al., 2004). Plant layout in a food production system is necessary to ensure maximum productivity and cost-effectiveness. Proper production layout can lower material handling costs by 10-30%. Layout directly affects operation performance, including manufacturing lead time, rate of output, and work-in-process. Productivity at work is increased based on a good layout. A layout is a space in which workstations are established and equilibrated to minimize downtime and maximize efficiency (Amit et al., 2012). Plant layouts usually respond to the original requirements of the business.

Increasing productivity is not a simple task and takes continuous effort. Hence, firms need to be dedicated to continually enhancing productivity by process change. Line balancing is one of the methodologies to enhance productivity (Wening Ken Widodasih, 2023). Line balancing means distributing workloads across workstations on the manufacturing line to prevent bottlenecks and excess capacity (Neungmatcha & Boonmee, 2021).

As a result, the most essential criteria for biscuit manufacture in this paper are whether or not the processing output matches the demands of the customer. To implement this strategy, line balancing, and simulation techniques are applied to the production line to raise the productivity and efficiency of the biscuit company.

Biscuit Machine Operation

Fikir food processing uses the "Sinobake" biscuit production line. The biscuit line processes both soft and hard biscuits. There are different machines in this line.

- **Horizontal mixer machine:** A horizontal dough mixer is used to make dough. The dough is kneaded and folded while being mixed to provide a flat surface with good elasticity, toughness, and extensibility. This mixer machine is used for both hard and soft biscuits. After the mixing process the mixer bowl tilts to discharge the mixed dough for feeding the next stages (Davidson, 2019).

Figure 1.1: Horizontal mixer machine

- **Laminating machine:** The dough sheets for different crackers and hard sweet biscuits are laminated, or layered, before being delivered to the gauge rolls and cutting machine. The layered structure of the dough sheet results in an open flaky structure. The laminating apparatus consists of a layering section, gauge roll units (usually two), and a three-roll sheeter (Manley, 1998a).

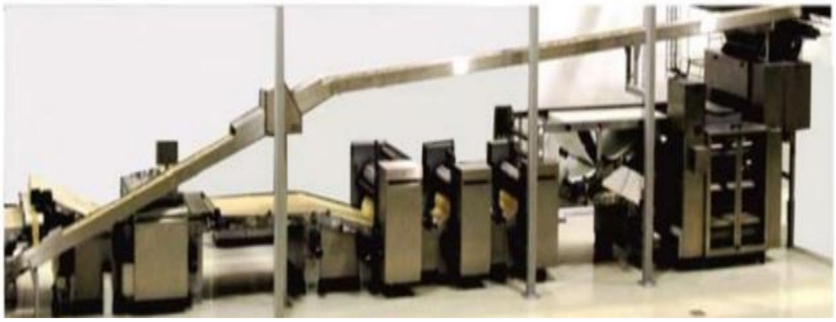

Figure 1.2: Laminating machine

- **Rotary molding:** Rotary molding is a versatile shaping technique for a short, soft dough. Rotational molding involves pressing the dough into molds on a roll, and then removing the molded pieces. The molds contain the full biscuit pattern (Davidson, 2019).

Figure 1.3: Rotary molding

- **Baking oven:** In biscuit baking ovens, also called tunnel ovens, long conveyors pass the dough pieces through a heated box section baking chamber. Oven lengths typically fall between 25 and 100 meters (Davidson, 2023).

Figure 1.4: Baking oven

- **Sandwiching machine:** The Biscuit Sandwich Filler with Cream Dispenser (stencil) can be used to create sandwich items with a wire-cut and extruded cream in the middle (Davidson, 2019).

Figure 1.5: Sandwiching machine

- **Packing machine:** The packaging machine of biscuits, which describes the techniques used to preserve and present biscuits for sale, includes sandwich goods with a wire cut and extruded cream. These are the final steps in the biscuit-making process and the last opportunity to make sure the product is in good condition and conforms with legal standards before it leaves the plant and is made available for sale to customers (Manley, 1998b). The Biscuit Sandwich Filler with Cream Dispenser (stencil) can be used to make this (Davidson, 2019).

Figure 1.6: Packing machine

- **Cream mixer machine:** This machine is used for making a cream for cream-filled biscuits. It mixes like fat, sugar flavors, and emulsifiers for getting smooth and consistent cream. This machine provides smooth texture and aeration, which give stable consistency color uniformity, and ease of use during sandwiching processes. Maintaining product quality with a defined shelf life and production efficiency is crucial (Manley, 1998a).

Figure 1.7: Cream mixer machine

1.2 Statement of the Problem

The soft biscuit production process at Fikir Food Processing Company suffers from a line balancing challenge that generates severe operational inefficiencies together with large production time and system bottlenecks. The production line workstations including dough mixing, baking, cooling, and packing have poor synchronization that produces processing time mismatches which disrupt material flow The absence of effective coordination creates unbalanced batch movements and extended waiting periods during baking because the oven operates without producing anything for 6 hours in every 16-hour workday. The packing speed and quantity of packing machine also not balanced with baking time so this results in the queue of baked biscuits before processing. Delayed biscuits are stored for longer periods of time, often overnight.

1.3 Research Objective

1.3.1 General objective

The general objective of this research is to investigate the existing production line layout and develop a new production line layout for Fikir Food Processing Company.

1.3.2 Specific objective

The specific objectives of the study are to:

- To determine and examine the production line layout's current inefficiencies
- To use the line balancing technique
- To develop a new, effective production line layout
- To compare the performance of the current and improved production layouts

1.4 Significance of the Study

The importance of the research is to improve the layout of the Fikir food processing biscuit factory production line to meet the increasing demand for Unic biscuits. By using the line balancing method and simulation software to design a new line layout, the study strives to enhance operations by eliminating the current production line issue, i.e., unbalanced workstation, batch gap, and manual feeding system time-consuming, as well as supervising problems. Besides, also helps to achieve improved product quality and reduced waste, thus making FFP more competitive in the market.

1.5 Expected Outputs of the Study

The following results should be anticipated once the study is finished:

- Identifying the real problems of the factory biscuit production line layout.
- Increase workstation balance to enhance better workflow by removing gaps between batches. This leads to improving the company's production efficiency.
- The new suggested layout should maintain better product quality less scrap and less labor intensity.
- By resolving production inefficiencies, the study is expected to increase productivity and efficiency by increasing the company's production capacity.

1.6 Scope of the Study

This study explores how Fikir Food Processing Company (FFP) currently produces soft biscuits. It covers the soft biscuit production system. The aim is to determine basic problems in the current layout, including unbalanced workstations and gaps between batches. These problems make it challenging for the company to satisfy growing customer demand. The research will further involve developing a new layout of a production line, for soft biscuits. This is done by using the line balancing method and Arena simulation software.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

An efficient production line is essential to productivity, quality, and competitiveness in manufacturing, particularly in food processing where timely processes and sanitation conditions are the issues. For biscuit production, where there are sequential activities of mixing, molding, baking, sandwiching, and packaging, even minor inefficiency or mismatch between workstations can generate significant production delays, queues, and wastage of resources. The method of line balancing—allocation of equal workload on each station of a production line—is a key approach for eliminating idle time, maximizing cycle time, and enhancing throughput.

This chapter presents a general overview of the existing literature related to the design of plant layouts, bottlenecks, line balancing methods, and the role of simulation tools for the betterment of production. It looks at how different strategies, including Lean Manufacturing, Six Sigma, and Systematic Layout Planning (SLP), have been adopted globally to tackle production inefficiencies. The review also incorporates specific research studies that were conducted within food and biscuit manufacturing environments, outlining how technological integration and task redistribution contribute to more streamlined workflow alignment.

2.2 Plant Layout

Facility layout involves planning and integrating the production flow to optimize the efficiency of personnel, equipment, and material transformation from reception to finishing areas. Factory layout is part of facility design, which includes factory allocation and building design. It is strongly tied to material handling. These efforts aim to optimize production facilities, reducing production time and producing high-quality products. Facility layout involves analyzing, planning, designing, and arranging facilities, equipment, and people to improve production efficiency and services (Gozali et al., 2020). The plant's productivity depends on its layout, which has adverse effects on many parts of the production process if it is not done properly. Layout affects operating time, labor intensiveness, and cost of equipment material handling (Wyk, 2016).

The overall objective of plant layout is to design a physical arrangement that most economically meets the required output – quantity and quality. Plant layout ideally involves the allocation of space and arrangement of equipment in such a manner that overall operating costs are minimized (Ummah, 2019). For manufacturing systems, plant layout is the basic concept. It affects the company's efficiency, worker productivity, and operational cost. An organized layout provides a smooth flow of material, minimizes bottlenecks and gaps between batches, and eliminates of unbalanced workload (Tompkins, 2010).

Plant layout is an important decision as it represents a long-term commitment. An ideal plant layout should provide the optimum relationship between output, floor area, and manufacturing process. It facilitates the production process, minimizes material handling, time, and cost, and allows flexibility of operations, easy production flow, makes economic use of the building, promotes the effective utilization of manpower, and provides for employee convenience, safety, and comfort at work. It is also important because it affects the flow of materials and processes, labor efficiency, supervision and control, use of space and expansion possibilities, etc (Ummah, 2019).

An efficient plant layout can be instrumental in achieving proper and efficient utilization of available floor space, ensuring that work proceeds from one point to another point without any delay, providing enough production capacity, reducing material handling costs, reduce hazards to personnel, utilize labor efficiently, increase employee morale, provide for volume and product flexibility, provide ease of supervision and control, provide for employee safety and health, allow ease of maintenance and allow high machine or equipment utilization, improve productivity (Ummah, 2019).

Plant layout problems can arise in various numbers of ways and can have a significant effect on the overall effectiveness of the production system. Therefore the optimum plant layout should be designed. Unfortunately, the magnitude of plant layout problems in any factory is so great that true system optimization is beyond our current capabilities. The approach normally taken by many researchers to solve plant layout problems is to try to find a satisfactory solution. A layout problem might arise because of bottlenecks in the production process, replacement of one or more pieces of equipment, unexplainable delays and idle time, addition or deletion of a product from a company's product line, significant increase or decrease in the demand of a product, organizational changes within the company or decision to build a new plant, crowded conditions, backtracking, poor housekeeping, excessive temporary storage space, obstacles to materials flow, failure to meet schedules, high ratio of material handling time to production time (Drira et al., 2007).

There are 5 types of layouts in manufacturing and production systems (Pérez-Gosende, 2021);-

1. Product Layout

Another name for it is line layout. Product layout organizes equipment and workstations sequentially according to specific product operation requirements. The design proves most effective for high-volume manufacturing operations that feature standardized work procedures like those found in car assembly lines. The key benefits include increased production speed and decreased material movement as well as lower WIP stock. The major disadvantage of this approach stems from its insufficient adaptability. Failure to maintain continuous operation results in complete line halts and product modifications require the entire system to be reorganized. Maintaining proper line balance to prevent bottlenecks and idle operations remains an ongoing operational difficulty.

2. Process Layout

Functional Layout is another name for it. Similar functions or machines in process layouts get grouped in one area (e.g., all drills in one area). Job shops and hospitals commonly use this layout because it provides the needed customization and flexibility. Process layout enables efficient handling of diverse products by supporting various types of processes. The combination of high material handling expenses together with extended lead times and intricate scheduling processes create operational inefficiencies. The main operational bottleneck occurs due to routing complexity together with the growing probability of material flow congestion.

3. Cellular Layout

The organizational structure of cellular layouts organizes machines into cells that handle similar parts. Group technology layout is another name for it. This approach balances the adaptability found in process layouts against the productivity benefits of product layouts. The enhanced material movement as well as the shortened preparation periods together with increased production speed. Even though these systems provide numerous benefits they face challenges from unequal workload distribution between cells and the need for employees who can perform multiple tasks. The effectiveness of this method primarily stems from the precise identification of part families and accurate cell formation.

4. Fixed-Position Layout

The fixed-position layout functions by transporting tools and workers to the product site when dealing with large heavy or immovable products such as ships or aircraft. The method proves effective for minimizing product transportation requirements when handling large or delicate items. This layout demonstrates substantial operational inefficiencies by creating poor coordination among resources and leading to congestion because of limited space. The timetable for moving people and tools serves as a fundamental obstacle that directly hampers workplace efficiency.

5. Hybrid Layouts

The combination of two fundamental layout designs in hybrid layouts maximizes their respective benefits so it also called combination layouts. A factory can implement process layouts for machining operations while adopting product layouts for assembly work. Hybrid layouts as systems that provide operational flexibility along with enhanced workflow capabilities. The main operational challenge stems from managing complexity while the dominant bottleneck occurs at the points where different layout patterns connect. Properly coordinated activities throughout layout zones become essential to avoid operational delays and achieve efficient workflows.

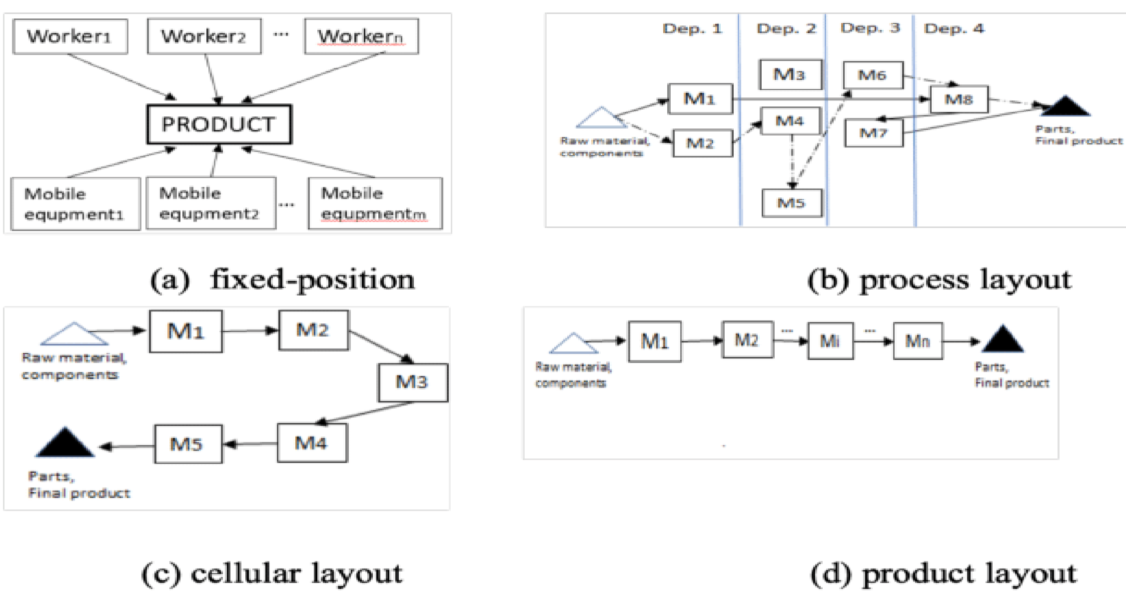

Figure 2.1: The fundamental types of plant layout (Di Gregorio et al., 2020)

2.3 Layout in Food Processing Facilities

Biscuit manufacturing operates most effectively through the implementation of a line layout as its fundamental system. When machinery and workstations follow a straight or logical sequence according to production stages in a line layout, the process maintains an uninterrupted flow from ingredient mixing through baking to cooling and packaging. The line layout configuration eliminates the need for materials to travel back and forth and this results in decreased costs for both labor and material transportation. There is a linear biscuit line layout which allows automated or semi-automated operations between machines while preventing bottlenecks and reducing cross-contamination risks thus enhancing safety and hygiene. The linear layout enhances operational management because operators can easily oversee and repair each process stage (Yulia, 2023).

Product layout, referred to as line layout, organizes machinery and workstations along a straight line that follows the production sequence of a specific product. Mass production environments with stable product designs and high-volume production achieve their maximum efficiency through this layout. According to the authors, this type of layout minimizes material handling time and ensures a smooth production flow with reduced work-in-progress inventory. Yet the layout suffers from extreme rigidity because any change in product design or volume demands extensive reconfiguration. The method requires a large upfront financial commitment and has strict requirements for maintaining balanced production lines (Naik & Kallurkar, 2016).

A line layout represents a biscuit potential solution for increasing manufacturing facility efficiency. A line layout establishes equipment and workstations according to production process sequences which proves most effective in high-volume continuous production settings such as biscuit manufacturing. The factory's initial layout design showed poorly positioned equipment which led to worker movement that disrupted material flow throughout the facility. The existing production process failed to match the necessary repetitive sequence that biscuit manufacturing required (Wyk, 2016). The factory can implement a line-oriented design that organizes machines and work areas according to the sequence of biscuit production phases starting with mixing and ending with packaging. The goal of using line layout is to minimize unnecessary movements while decreasing process waiting times and optimizing workflow efficiency (Moktadir et al., 2017).

Food processing requires that the layout provide a smooth flow of material, people, and finished goods, and eliminate zero the possibility of contamination while high standards of hygiene are maintained. Properly planned redesign of the factory layout is capable of eliminating unnecessary distances, making procedures more logical, and maximizing the use of space—considerations that become very essential when dealing with perishable goods and product processing over time. Additionally, the layout planning strategy promotes systematic arrangement of the equipment and workplaces in a systematic order that supports production processes, thus minimizing disturbances and maximizing labor productivity. In addition, layout optimization works to meet safety and hygiene concerns by providing effective segregation of the raw materials, processing, packaging, and store facilities, thus eliminating possible contamination and enhancing sanitation operations. Generally, this redesign is facilitating a more efficient, responsive, and secure food processing factory to help the factory achieve levels of production with quality control in food processing (Yulia, 2023).

Food processing layout design has a direct impact on product flow, material flow, and labor flow and aids substantially in waste elimination, saving production time, and complying with food safety requirements. The systematic Layout Planning process is one of the tools of equipment layout and workstation layout design such that unnecessary motion and wait time are avoided and as many as possible production operations utilizing existing resources are maximized. Thus, food processing plants can design their processing lines, storage, and packaging stations for optimal design in such a manner that the risk of contamination is less and sanitation levels are increased (Badharinath et al., 2024). Food equipment design, working surfaces, and material flow patterns in food processing, particularly bakery items such as cakes, are most sensitive to product quality and the requirement of production. By applying the Systematic Layout Planning method, the study reveals inefficiency in layout that now manifests itself as unnecessary movement, cross-traffic, and wasted space. A higher quality design that yields improved logical and hygienic ingredients, semi-products, and finished product flow. Improved material handling reduces the risk of contamination while allowing ingredients to be moved throughout the processing steps in an efficient and safe process (Herriyzka Meiliati, 2023). Material flow analysis to design a production line in such a way that travel distance, handling time, and operations sequence are reduced.

With the material flow brought to a bare minimum, the reconfigured layout allows each operation of production—raw material introduction to final packaging to be efficiently performed economically. This not only maximizes productivity and operating expenditure but also ensures easy enforcement of essential food processing conditions such as cleanliness, segregation of zones, and temperature. Integration of material flow concepts within layout design leads to clean production lines, hygiene, and more consistent products—needs demanded by any food processing facility (Michal Buck, 2024). In food processing, e.g., biscuit making that entailed high-volume production, Equipment physical layout, workstation, and path materials flow affect cycle time, labor productivity, and product consistency.

By studying and redesigning the layout according to production flow, process sequence, and use of space. Not only does a good layout reduce bottlenecks, but it also facilitates better practice of hygiene and safety standards, which are critical in food processing factories. Thus layout optimization, as a reaction to facilities processing requirements, can go far toward quicker throughput, waste reduction, and better product quality for biscuit manufacturing (Ahmad Mukti Almansur, Sukardi, 2024).

2.4 Line Balancing

The equitable distribution of workload among tasks within a cell or value stream is called line balancing, and it is a key aspect of assembly line efficiency. Line balancing is necessary to realize optimal assembly line efficiency (Teshome et al., 2024). To establish a balanced production process, line balancing involves the distribution of work tasks within a production line into several workstations while sustaining the load and time balance between each workstation (Iwan, 2018). Line balancing describes the process of allocating workload and working activities to workstations in all activities of the production line in a way that eliminates bottlenecks and maximizes efficiency (Zupan & Herakovic, 2015). To reduce waiting time and to have each operator perform with the same intensity level, line balancing assembly is performed by allocating jobs and activities to operators in a balanced manner. It tries to establish a balance between the time needed to finish each activity in the line (Wening Ken Widodasih, 2023).

Line balancing refers to the balancing of a production or manufacturing process. The primary objective of line balancing is to balance tasks evenly across workstations to prevent idle time for machines and humans. Line balancing is the positioning of workers or facilities in an effective sequence to achieve an optimum balance of capacities and flows in manufacturing or assembly processes. Line Balancing is a term used universally to describe the decision-making process in the allocation of tasks to workstations in a serial production system. The task is basic activities that transform raw materials into finished goods (Manaye, 2019). Line balancing assembly improves the efficiency of production. The process synchronizes and organizes assembly line tasks and provides cost-effective and efficient output. Line balancing assembly is the equal distribution of tasks and activities among operators to minimize waiting time and provide constant intensity (Wening Ken Widodasih, 2023)

Mass production requires producing similar or interchangeable parts at several workstations, which is termed Line Balancing. As understanding is improved, there is a need to improve line balancing methods. Line balance was used to allocate tasks to workers, and it led to efficiency and productivity improvement. Shop floor managers seek the allocation of equal amounts of work to workstations to realize line balance. The uneven workload in a sewing line accumulates work in progress (WIP) and waiting time, resulting in longer production cycles and higher costs (Manaye, 2019).

A crucial aspect of production processes in the majority of industries, including manufacturing, is line balancing. It entails the allocation of tasks and resources in the most effective manner possible for a productive and defect-free production process. Line balancing techniques are being widely used to control problems occurring in assembly line processes and minimize imbalances between workers and workloads to achieve the desired production rate (Teshome et al., 2024).

2.4.1 Line Balancing and Layout

Line balancing is the process of distribution of work among workstations in such a manner that each workstation receives approximately the same amount of work, minimizing idleness and maximizing output. Material flow analysis is used to create a layout that not only minimizes the total distance traveled by the materials but also closely approximates balanced workstations. This balance ensures that all stages within the process of production operate at the same time, helping to reduce bottlenecks and delays. During food processing or manufacturing procedures, as in the case of an assembly line for baked goods or packaged foods, this balanced setup is instrumental in maintaining consistent production levels and quality compliance. By optimizing the task assignment as well as layout, superior material flow can straightaway cause better line balancing to result in more productivity, lead times in decreased quantity, and better labor as well as space utilization (Michal Buck, 2024).

Streamlining the layout (the physical arrangement of workstations) and line balancing (equitably distributing work among stations), the system runs more smoothly—reducing delays, idle time, and resources used. The process accomplishes this with the added benefits of lowering carbon output and improving profitability, so the production or disassembly process is now economically as well as environmentally sustainable (Yang et al., 2024).

A bottleneck is a stage or resource in a production system that restricts the process's overall throughput and efficiency (Dogru, M., & Keskinocak, 2008). The facility system resource or workstation, which most tightly limits the entire system's output during a certain point in time, is designated as the bottleneck. It identifies that the bottlenecks are not stable but instead transform under operating situations, e.g., equipment capacity, buffer usage, or shifts in schedules, rather than normal fixed definitions. The equipment whose capacity constrains the overall output of the system is the bottleneck, and not always the most heavily used. It must be determined because it directly affects the production rate, and adjustment can result in substantial increases in system efficiency (Sprock, T., 2020).

In the production process, where capacity constraints limit the overall throughput there is a bottleneck. The effect of bottleneck can be controlled with an optimal plant layout since it ensures a smoother flow, ensures that resources are employed efficiently, and reduces unnecessary motion at every point of production processes. Plant layout should be developed with a consciousness bottleneck that will shift in response to changes in demand or production conditions (Spearman, 2000). Ineffective plant layout planning can lead to unnecessary movement, unbalanced process flow, and congestion, all of which worsen the bottleneck's effects. Proper layout planning is essential to improving flow and reducing bottlenecks. Workstations and equipment should be positioned carefully to enhance productivity and avoid delays (Meyers, 2013). Poor plant layout contributes to bottleneck issues, but effective plant layout planning and design can remove these issues (Tompkins, 2010).

The new layout eliminated or repositioned bottlenecks and improved cycle times, flow, and utilization of space. Layout changes always become unavoidable to accomplish the best possible lean initiatives, yet well-delineated procedures can fail if the layout is causing drag or deceleration (Hanane Rifqi, 2021). Inadequate process planning, usually the product of ill-conceived layouts, can cause material accumulation, long wait times, and unbalanced workload distribution, all contributing to the development of bottlenecks (Roser, C., Nakano, M., Tanaka, 2002).

Unbalance flow refers to the irregular or uneven movement of components, materials, and goods across different departments within a factory. It is when some areas are overloaded and another department is overloaded, typically due to poorly planned layout or incompatible processing time. Poorly designed layout generates unbalanced flow through congesting, elevating the travel distance, or requiring excessive manual handling Material flow intensity and departmental relationships are used to suggest a layout that minimizes unnecessary movement and unbalanced workload allocation. Proper layout planning aims to ensure processes are streamlined, minimize bottlenecks, and maximize the overall plant efficiency (Suhardini et al., 2017). By increasing the efficiency of the facility layout, the optimum plan can effectively reduce costs. The plant layout also has an impact on the manufacturing flow. A properly organized layout will improve the stability and smoothness of the manufacturing flow. Flexibility and space utilization are significant factors when designing the structure of the facility so that the workers can work efficiently and the equipment is installed appropriately (Suriansah et al., 2022). The design of a facility significantly affects how efficiently its production activities are carried out.

Efficient movement and utilization of workspace, and the performance and throughput of the facility, are dependent on an effectively designed facility layout and process flow. Facility layout must be appropriate for the product type being produced as it is a significant factor in the success of production (Wyk, 2016). An unbalanced flow in a plant design is an irregular allocation of material flow or workload across the sections of the production system. It will result in bottlenecks, unused capacity, and reduced efficiency. Designs that create an unbalanced flow will have lower ratings for flow efficiency and can get in the way of continuity in production. Hence, reducing unbalanced flow is the key to achieving an efficiently balanced, high-performance design that facilitates strategic and operational objectives (Chantrasa, 2020).

Unbalanced flow in plant design means unequal distribution of material flow and workload across different processing stations. Imbalance accounts for fluctuations in capacities, longer cycle times, and idle equipment. Layout improvement therefore has a close relationship with the pursuit of balanced flow; it involves the re-arrangement of workstations and equipment for the sake of balancing process capacities to allow the free flow of materials. The improvements ultimately improve overall production efficiency, as well as responsiveness (Waewdao Samanphan, 2013).

2.4.2 Line Balancing in Food Processing

Using time study techniques, the research sets task durations and inefficiencies in labor along the line of production typical in food processing due to handling manually and uncertain processing durations. Through line balancing, jobs are re-balanced in a way that each workstation will receive equal amounts of work to eliminate idle time, reduce bottlenecks, and ensure maximum line efficiency overall. In food processing, where product speed and freshness are of utmost priority, these technologies are reflected in terms of increased throughput, enhanced resource utilization, and reduced operating expenses without compromising product quality and hygiene (Nurul Nazeerah Mishan, 2023).

Line balancing along with material flow optimization is of utmost significance in increasing efficiency in food processing operations. In food production, where there should be timely processing and sanitation, equipment and workstation layout must support free-flowing, unobstructed movement of materials. Observing material movement and rebasing the layout on this, there can be an enhanced balancing of activities at workstations to prevent congestion and waiting time. This synergy between layout design and line balancing leads to reduced processing time, less manual handling, and improved continuity of workflow, keystone considerations in ensuring quality and raising productivity levels in food processing environments (Michal Buck, 2024)

In food processing, task times can be extremely variable due to factors like ingredient consistency, operator productivity, or machine dependability, and defect opportunities—such as packaging errors or contamination—can disrupt the flow. Through the inclusion of stochastic task times and defect frequencies into line balancing approaches, the research presents more realistic and reliable solutions that maintain consistent production under uncertainty. This technique allows food processors to maximize the utilization of equipment and labor, reduce waste, and deliver uniform-quality products, resulting in increased efficiency and reliability in food processing plants (Nur et al., 2025).

2.4.3 Line Balancing for Batch Process

Line balancing can boost productivity even within batch manufacturing operations, prevalent in industries like appliance manufacturing and even food processing companies. Though typical that assembly lines be connected with continuous flow, the research reveals that balancing work tasks across workstations even in batch configurations is also of similar importance as a means to avoid idle time between batches, bottlenecks, and constant throughput. In batch production, where work is accumulated and processed in planned lots, line balancing application helps reduce the order of operations and synchronize labor and equipment capacity with production demand. This provides improved scheduling, reduced lead times, and improved synchronization of batch flows in the production line (Thanakarn Prapasajjawet, n.d.)

Line-balancing principles can be applied equally to batch processing configurations, where the activities are carried out in isolated phases based on time. The study indicates that by balancing the load across these phases, downtime between batches can be minimized, machine utilization increased, and the process as a whole leveled. It is of direct applicability to other batch businesses, e.g., food processing, where the same issues of synchronization, energy usage, and quality exist. Synchronizing task assignment to batch cycles and line balancing can create more balanced levels of production along with operating effectiveness for batch production systems (Wai Man Kong et al., 2024).

2.5 Takt Time Analysis for Balance Workflow

Takt time is a design parameter used in machine-paced manufacturing lines to ensure that customer demand will be satisfied. Production-system success depends on striking a balance between creating a Takt that equals the capabilities of every workstation in a line (system) and, conversely, modifying workstation capabilities to match Takt. When Takt time and workstation capabilities are significantly out of sync, either a workstation will starve (wait for work) when it completes its tasks far more quickly than its predecessor or a product will accumulate between workstations when the subsequent workstation is not yet prepared to perform its operation on the product. Changes in production rates make this delicate balancing act more difficult (Frandson et al., 2013).

$$\text{Takt time} = \frac{\text{Available production time}}{\text{Customer demand}}$$

A manufacturing concept known as "takt time" refers to the amount of time required to produce a single item based on the pace of consumer demand. It can be computed by dividing the daily client demand by the amount of useful working time in a single day (Adnan Alkindi et al., 2021).

2.6 Time Study as a Tool for Measuring a Work

A time study is a method of measuring work that involves timing the completion of a particular task or its components under predetermined circumstances and then analyzing the data to determine how long it would take an operator to complete it at a given rate of performance (Ummah, 2019). Any company, especially small and medium-sized ones, needs to measure working hours. When it comes to their manufacturing activities, companies at this level frequently disregard working hour standards. Without working time rules, industrial activities become inefficient, resulting in labor and time waste. Measuring working time involves keeping an eye on the company's operations and production processes, including how long it takes to produce a good or provide a service and how long it takes to complete specific tasks under typical circumstances (Budiman et al., 2019).

One method for determining a time standard for completing a certain assembly task is time study. Its foundation is the measurement of the chosen sewing assembly line's job content, taking into account any personal allowances and inevitable delays. It is the first step necessary to identify the chances to enhance assembly processes and establish production standards (Yemane et al., 2020).

Time study contains measuring time taken by task or process, identifying inefficiency, where the delay or unnecessary effort occurs. Time study information will provide point out specific problems, for instance, unnecessary motion, waiting or delay, and poor ordering of tasks. Upon identification of inefficiencies, redesign of layout as a strategic technique can be adopted to remove inefficiencies. Through rearrangement of workstations, machines, or workflows based on time study data, a more efficient layout may be designed that eliminates unnecessary travel, reduces waiting times, and improves the overall flow of material and tasks. The time study is a diagnostic instrument that offers input into the design of a more efficient layout, thus allowing for improvement in operational productivity and efficiency (Adnan Alkindi et al., 2021).

A Stopwatch Time Study will be used for the measurements, which will be conducted regularly to determine the workers' productivity level, ability, and sustainability in doing their work. Cycle time, assuming constant for all meetings is the interval between the conclusions of two consecutive sessions. The cycle time, as indicated by the stopwatch, might be considered the outcome of direct observation (Masniar et al., 2023).

2.7 Graphical Representation of Task Allocation Yamazumi Chart

Yamazumi chart is a bar chart to indicate the balance between cycle time and takt time at each station (Kal et al., 2012). This Yamazumi chart, as a useful means for kaizen activities in the line, can be applied to graphically depict work time on whole stations on an assembly line (Nithish Kumar et al., 2021). A Yamazumi chart is a plot of each of the dimensions of the time it takes to complete an activity. In this case, a bar chart is typically employed to show the data in terms of color difference. A Yamazumi chart is similarly a type of bar chart that plots the amount of time it would take for each workstation or operator to complete its activity (Kays* & Prodhan, 2019).

To continue with line balancing through Kaizen, the Yamazumi chart is used. A man-machine bar chart called a Yamazumi chart displays the total cycle time per operation that is carried out in the process of production flow. It is a visual representation of each station's workload that indicates how the time of production is divided in the line. To prepare the Yamazumi Chart, begin by using the actual basic cycle time from the time measurement sheet. Second, use the total cycle time per operator and create a bar chart. The talk time is graphed on the horizontal axis and the cycle time is on the vertical axis. The Yamazumi chart is used to balance the total cycle time at every one of the workstations (Talapatra et al., 2018).

2.8 Plant Layout and Productivity

Productivity is defined as the ratio of value produced to resources required for production. A productivity index is commonly estimated as a component of productivity measurement that compares output quantities to input resources (Yemane et al., 2020).

Productivity measures the amount of output items produced from a certain amount of input materials Productivity measurement is becoming increasingly important in sectors. Profit enhancement for a corporation depends on improving productivity based on input variables. Reducing non-value-added procedures and bottlenecks in production leads to increased productivity and customer satisfaction. A correlation between productivity, production, material usage, output prices, inventory management, and distribution times. Improved productivity leads to increased profits (Neungmatcha & Boonmee, 2021).

An increase in productivity makes it easier to satisfy customers and cuts down on the time and money needed to create, produce, and deliver items. Elimination, process repair, method simplification, system optimization, variation reduction, output quality or responsiveness maximization, and setup time reduction are some methods for achieving this improvement. Additionally, productivity can be increased by lowering production costs or enhancing product value (Moktadir et al., 2017).

All company strive for increased productivity levels since increased production automatically means increased revenues. There are numerous ways to optimize productivity. Having an effective plant layout is one among them. Every Infrastructural plan needs a layout. A layout is the plan of the structure either being made or remade. It highlights the designs and correct placements of the basic components of the strategy. A layout is a blueprint for the owners and builders of the buildings to see how the infrastructure will look. The plant's production space and equipment needs are also included in the layout. It is a crucial component of the manufacturing process. The plant design must be good if you want to achieve maximum production. Plant designs, nevertheless, have a dynamic idea because they tend to change concerning the requirements for the development of industry (Neungmatcha & Boonmee, 2021). Economic growth affects our standard of living as well as global prosperity. This is because the ability of the nation to consume eventually has a straight relation to its ability to produce. Similarly, success in a company usually depends on its ability to generate more real value using more labor, capital, or other inputs without increasing them, for consumers. Greater output means greater opportunities for success. It also has many positive effects like low cost of production, having a chain reaction, and lowering the price of the good thereby it available and accessible to the masses (Akhil & Deepthi, 2019).

One of the basic things that can affect an industry's productivity is plant layout. A well-designed plant will end up producing more while smarter working. Good planning and attention are thus just a few recommendations that should be observed. If plant layout is going to fulfill a series of purposes that an industry requires, particularly in terms of productivity, it is said to be efficient. Good plant layout has a significant impact on production efficiency (A. Mulugeta, 2009).

2.9 Simulation for Optimizing Manufacturing Processes

Simulation models aim to facilitate experimentation, predict system behavior, and answer questions such as "What would happen if …?", and enhance understanding of the system. These models allow for experimentation and observation of decisions in systems where real-world testing may be costly, time-consuming, or risky. Models are typically created to analyze system behavior over time and evaluate performance under various scenarios (Orta et al., 2014).

Simulation is used to imitate the actual operations of a real system. It is used to assist decision-makers in understanding the behavior of the system and making necessary modifications. Several studies have been undertaken in various sectors using simulation approaches to solve problems in manufacturing and food processing (L. Mulugeta, 2020). Simulation is often used to evaluate the impact of decisions in several sectors. Simulation tools, combined with operations research and artificial intelligence, aid decision-makers in identifying system problems and evaluating potential changes before making decisions (Nallusamy, 2016).

Simulation is a scientific approach to studying systems without disrupting them. It can also be used to evaluate concepts that have not been tested in the real world. Simulation predicts assembly line performance and helps identify the optimal machine layout and scheduling guidelines. Simulation modeling is primarily utilized for decision-making in commercial jobs. Model simulations provide insights into process outputs, performance, and behavior across various process structures. The factory simulation technique aims to optimize performance while balancing profit criteria with company objectives (Orta et al., 2014).

Arena is a flowchart application that one uses in conjunction with Visio. In Arena modeling, entities are the masters of resource capacity as they travel through a process flow chart. For process engineers and designers who need to be capable of fully detailing a process so that it can be modeled and analyzed correctly, the flowchart method of model building is the most logical. Hence, the process models being researched become highly detailed documents (Amit et al., 2012).

Cycle time, idle time, resource usage, throughput, defect, and work in progress (WIP) were some of the output parameters from the Arena model. WIP was used to identify the optimal line balancing condition at the global level (Ivatury & Bonsa, 2022). Arena simulation modeling is used to enhance system performance, i.e., manufacturing lines and supply chain management. Arena simulation models and lean tools, for example, were used for greater output (Tau et al., 2023).

ARENA simulation is used to model and analyze the idle, queue, and process flow in various manufacturing systems to fix issues. It also helps in maximizing throughput, locating bottlenecks in the process, and assessing possible future improvements. To find the production line bottleneck and boost productivity, it is necessary to measure and identify the cycle time of all operations, which is the total amount of time the product spends in the manufacturing or assembly system from start to finish (Ali & Zulkifli, 2017).

Arena simulation software demands specific types of input information to perform precise system modeling and analysis. The first essential data category involves information regarding entity arrivals which consists of both arrival frequency and the temporal pattern of their entry. The system requires detailed process time data for all workstations together with any relevant statistical pattern information. The system needs a clear definition of its resources which includes both machines and workers as well as their available numbers and working capabilities. The system must operate according to specific queue characteristics that establish both the longest possible waiting line as well as the predetermined order for processing. The system needs specific rules about entity movement which depend on either probability distributions or condition-based decisions. The system requires additional information about both cost variables and initial state conditions which include resource availability and starting inventory levels. The combination of all these input parameters enables Arena to create accurate simulations of system performance and flow (Tau et al., 2023).

2.10 Related Works

Some research studies have examined line efficiency and line layout optimization employing line balancing techniques in various industries. Line balancing techniques have also been applied widely in manufacturing environments to mitigate the issues of workload imbalance and inefficiency employing techniques such as antecedent time analysis, genetic algorithms, and lean manufacturing techniques.

In the food industry as well, layout and line balancing improvements have been extremely advantageous. Buchari et al. (2018) demonstrated the improvement in space utilization and reduction in energy losses in small-scale food businesses through the implementation of Systematic Layout Planning (SLP) and line balancing techniques. Similarly, Mishan & Tap (2015) and Kal et al. (2012) demonstrated phenomenal efficiency enhancement in food production lines through time studies and line balancing, characterized by the reduction in imbalance losses and throughput enhancement.

Table 2.1: Related articles and journals

Title of articles	Tools	Problem	Finding
Increasing Line Efficiency by Using Line Balancing in a Steel Manufacturing Company (Pham, 2023)	Takt time method Lean manufacturing	Production problems due to mismatched workload in a steel manufacturing field	Line balancing implementation raised the line balance percentage from 77% to 99% and efficiency from 93% to 99%, with a decrease in the number of operators by nine.
Assembly Line Balancing Considering Stochastic Task Times and Production Defects (Nur et al., 2025)	Adjusted processing time approach Statistical analysis	Traditional assembly line balancing models would simply assume equal task times and zero defects, which is unrealistic.	The model suggested herein accounts for variability in task durations and defects, thereby enhancing operational efficiency by realizing optimum resource allocation.
Production layout improvement by using line balancing and Systematic Layout Planning (SLP) at PT. XYZ (Buchari et al., 2018)	Line balancing techniques Systematic layout planning (SLP)	Solving low utilization of equipment and inefficiency in a parallel production line with mixed flow	Line balancing and utilization of SLP led to reduced idle energy consumption and improved logistics.
Integration of Lean Concepts and Line balancing Focusing on Value-Adding Activities (Adnan Alkindi et al., 2021)	Line balancing techniques Arena simulation	The firm was plagued by inefficiencies such as imbalanced lines, long cycle times, and overstocking.	Lean tools increased productivity by 16.66%, cycle time reduced by 32.73%, and lead time reduced by 11.8%.

Increasing Line Efficiency by Using Time Study and Line Balancing in a Food Manufacturing Company (Mishan & Tap, 2015)	Time study Method study Line balancing techniques.	The company's bun production line was inefficient with unbalanced workloads that caused line balance loss to be high and productivity to be low.	Implementation of time study and line balancing reduced line balance loss from 69% to 23% and increased line efficiency from 30% to 76% with a high increase in productivity.
Increasing Line Efficiency by using Time Study and Line Balancing (Kal et al., 2012)	Time study Line balancing techniques	Inefficiencies in a production line at a food business, where uneven workloads caused inefficient work and high idle times.	Through the application of time study and line balancing methods, the business achieved a tremendous improvement in line efficiency and idle times reduction, leading to overall increased productivity.
An Optimal Layout Design in an Apparel Industry by Appropriate Line Balancing: A Case Study (Sakib, 2014)	Time study Assembly line balancing Layout design techniques	The clothing factory's sewing floor was suffering from low productivity due to back-imbalanced line and poor layout, with a loss of cycle times and under-productive labor.	Redesign of layout and line balancing reduced the number of workers from 23 to 22. Line efficiency was increased from 46.2% to 50.9%, thus improving productivity as a whole.

2.11 Research Gap

Many manufacturing sectors have received extensive research on production line balancing and layout optimization but the food processing industry remains unexplored because it presents distinct challenges regarding cleanliness standards and short product lifespans alongside input quality variations. This means that food processing plants have special difficulties that other industries might not face. They must keep everything very clean to ensure food safety, work quickly because food can spoil fast, and handle raw materials that can vary a lot in quality. These factors make it harder to design and improve their production processes efficiently. The majority of studies in this field treat line balancing separately from layout planning while only a few provide integrated solutions for food production settings. The absence of real-world case studies related to practical food processing company implementations demonstrates the necessity for research that combines these specific elements. The current study fills an essential research gap by implementing an integrated line balancing system with layout design features in food processing facilities which generates practical insights for this specific industry.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Research Design

The study design uses the case study method to conduct a depth analysis of Fikir Food Processing (FFP) Company and its existing operational problems. Through analysis of existing inefficiencies and production bottlenecks, in particular plant layout, the study aims to develop a comprehensive understanding of the same by keeping FFP under focus. Ultimately, the outcome is providing practical suggestions that can improve productivity and efficiencies of the biscuit manufacturing process at FFP.

3.2 Data Collection Methods

Data collection can be divided into two categories: primary and secondary data. Primary data is new and obtained for the first time. Secondary data is data that has previously been acquired and examined. This paper's data collection strategy includes both primary and secondary data from the real production system.

Primary data collection: The primary approach for gathering data regarding the current production system will be direct data collection from the shop floor. Direct observation and recording is a fundamental strategy for gathering primary data. Observe the production line to document how materials flow through it and to record time spent at each workstation, cycle time, idle times or delays, machine utilization and downtimes, worker movement and bottlenecks, and other relevant data that will aid in line balancing using an observation sheet or template. An unstructured or informal interview is also used to collect relevant information. These interviews attempted to collect data on a variety of aspects, including working hours, the number of machines, workers allocation per operation, and work-related factors such as shift duration, machine utilization, and daily production output.

Secondary data collection: Previous data collected by other researchers and studies done on different manufacturing industries are used as secondary data sources. Useful information from these studies has been used. A literature review is another secondary data source. Different books found on different sites (electronic information sources) and the internet, to obtain articles and journals; have been assessed to obtain information on line balancing and simulation. Company document and report review is also a secondary data source.

The data collected is obtained from unstructured interviews with the factory manager, production manager, shift leaders, operators, quality department, and sales department, as well as from the observation of the production line and company documents and reports.

3.3 Data Analysis Methods

The collected data were analyzed using the concept of line balancing method. Further, Arena simulation was used to model and simulate both the current and improved production process of the company.

Line balancing: After collecting all data from the company, analyze the present line balancing. This includes analyzing cycle time, and workload at each workstation, and finding any imbalances or bottlenecks. Use these steps to analyze the data:

1. Task Distribution: Calculate the total time required for all tasks in the production process. This is the sum of cycle times for all workstations. Determine the number of workstations available on the line. Calculate the ideal task time: This is the time available to produce one unit of product, which can be determined based on production goals (e.g., units per hour).

$$\text{Takt time} = \frac{\text{Available production time}}{\text{required output}}$$

2. Assign Tasks to Workstations: Based on the cycle time data, distribute tasks across workstations so that the total task time at each workstation does not exceed the ideal takt time. Balance the load: Ensure that each workstation’s cycle time is as close as possible to the ideal cycle time while maintaining the required flow of production.
3. Identify Bottlenecks: Bottleneck stations are those where tasks exceed the ideal takt time or where delays lead to a backlog of work. These need to be addressed to improve line efficiency. Use the data from your observation to locate these bottlenecks and recommend possible adjustments in task distribution, equipment placement, or staffing.

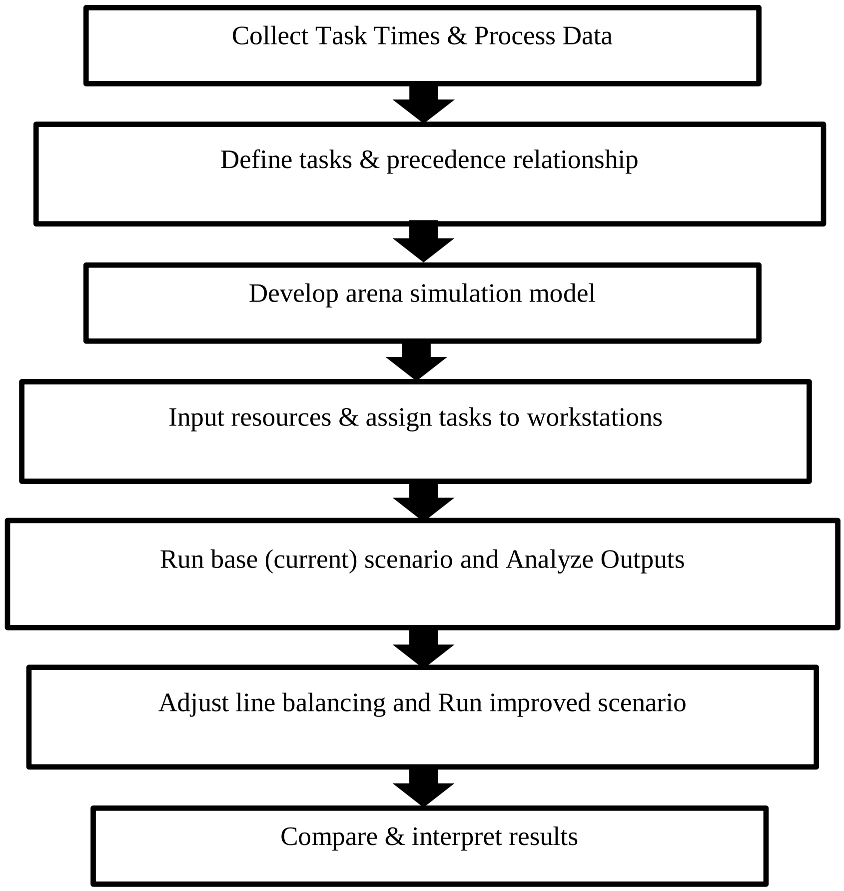

Figure 3.2: Flow chart of line balancing using arena simulation

Analyze production line data using Arena simulation software for line balancing first input critical data such as task times, resource availability (e.g., number of machines and workers), task dependencies, and customer demand into the simulation model. The model is then constructed using Arena's modules (Create, Process, Queue, Decide, and Dispose) to represent the flow of entities (products) through workstations, with processing times and resource constraints applied. By running the simulation, evaluate performance metrics such as cycle time, throughput, workstation utilization, queue lengths, and idle times, allowing you to identify bottlenecks and areas of inefficiency in the current production line.

3.4 Flow Chart for Research Methodology

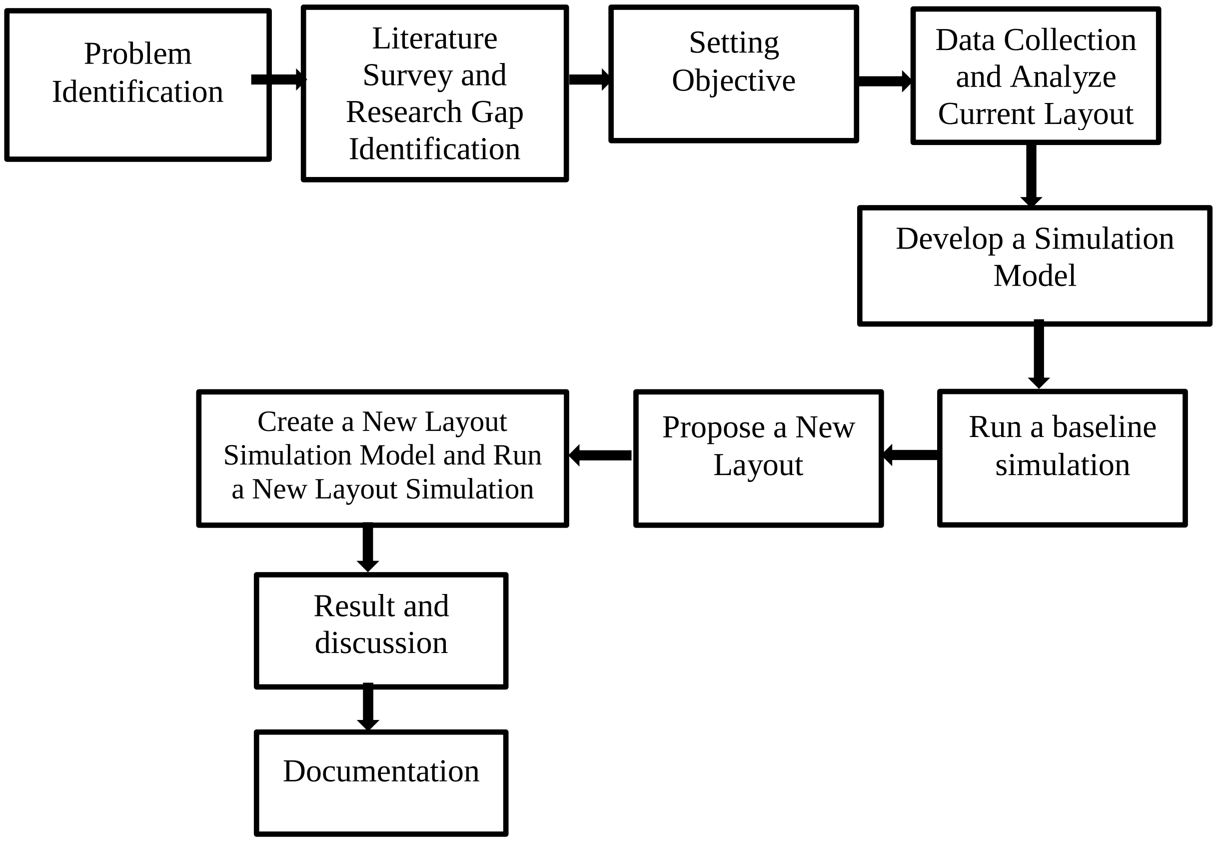

Figure 3.3: Flow Chart for Research Methodology

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Analysis of the Production Process

Fikir Food Processing Company produces both hard and soft biscuits; the hard biscuits are made 16–18 working days a month, while the soft biscuits are made the remaining working days. There are as many as 150 employees in the biscuit factory. Production continues for 16 hours per day, divided into two 8-hour shifts.

Because the study addresses soft biscuits, data collection is primarily focused on soft biscuit procedures. The company produces 6 types of soft biscuits: An abounded cream sandwich, and a flavored cream sandwich (Cappuccino, Vanilla, Apple vanilla, Mango, Banana). The flavor is the only difference between flavored cream sandwich biscuits, which are the same in terms of weight and production process. The production process and processing time for flavored cream sandwich biscuits and abounded sandwich biscuits are nearly the same, but the number of packets produced in each carton varies. For example, a carton of flavored cream sandwich biscuits contains 60 packets, while a carton of abounded cream sandwich biscuits contains 48 packets, each of which contains three pieces of packets. As a result, different quantities of cartons are produced from a single batch of shells.

A soft biscuit production line's performance throughout several production days from September 2024 to March 2025 is thoroughly examined in the data presented. In contrast to other soft biscuit varieties, abounded cream sandwich biscuits are usually produced due to strong demand. Abounded sandwich biscuits make up almost 70% of all soft biscuits produced, according to statistics gathered over the previous months. So abounded sandwich biscuit provides the focused point.

Based on observations and the daily company report, the following table data relates to the production of abounded sandwich biscuits for almost seven months.

Table 3.1: Data of production of Abounded soft biscuit

Production days	Shift	No of batch		Total product (Carton)	Total scrap (kg)	Downtime (hour)
		Shell	Cream			
24/09/24	Shift A	22	9	833	115	0:30
24/09/24	Shift B	21	6	958	89	3:35
05/10/24	Shift A	13	6	554	84	2:25

07/10/24	Shift A	28	9	1105	86	0:17
07/10/24	Shift B	25	8	1032	97	1:25
08/10/24	Shift A	16	6	904	74	4:00
08/10/24	Shift B	23	8	1064	69	1:15
14/10/24	Shift B	4	4	103	25	6:30
14/10/24	Shift A	24	7	998	85	1:36
15/10/24	Shift B	18	7	784	72	2:36
15/10/24	Shift A	16	5	836	99	2:30
01/11/24	Shift A	19	7	721	47	3:20
02/11/24	Shift B	25	9	1100	59	1:08
02/11/24	Shift A	28	9	1232	67	1:10
03/11/24	Shift B	26	9	1038	77	0:30
03/11/24	Shift A	24	8	1168	96	1:55
04/11/24	Shift B	26	9	1258	73	0:23
04/11/24	Shift A	26	8	1193	79	1:46
06/11/24	Shift A	14	6	454	58	4:43
06/11/24	Shift B	18	6	885	48	2:40
19/11/24	Shift A	24	9	978	70	0:30
19/11/24	Shift B	22	7	1022	71	2:00
20/11/24	Shift A	27	9	1181	57	0:31
20/11/24	Shift B	26	10	1137	85	1:30
21/11/24	Shift A	4	3	215	19	7:08
21/11/24	Shift B	13	3	529	53	4:32
22/11/24	Shift A	30	9	1179	65	0:28
22/11/24	Shift B	25	10	1212	72	1:12
23/11/24	Shift A	27	9	1287	61	0:30
23/11/24	Shift B	23	8	1162	86	1:10
11/12/24	Shift A	7	4	236	26	5:15
11/12/24	Shift B	23	8	1014	102	2:00
12/12/24	Shift A	7	1	363	35	4:43
01/01/25	Shift A	17	6	499	65	2:38
01/01/25	Shift B	22	8	1095	75	1:30
02/01/25	Shift A	23	8	1043	55	1:38
02/01/25	Shift B	26	8	1305	68	0:40
03/01/25	Shift A	19	6	850	32	3:10
03/01/25	Shift B	18	5	708	51	3:32
04/01/25	Shift A	26	8	1086	75	1:38
04/01/25	Shift B	10	4	558	40	4:40
23/01/25	Shift A	14	6	524	70	4;33
24/01/25	Shift B	26	9	1069	74	0:45
24/01/25	Shift A	27	8	1214	76	1:40
25/01/25	Shift B	25	8	1074	82	1:08
25/01/25	Shift A	17	7	879	58	3:45
13/02/25	Shift B (12)	35	11	1652	138	0:25
13/02/25	Shift A (12)	40	15	1624	156	0:50

18/02/25	Shift A (12)	33	8	1525	167	2:07
18/02/25	Shift B (12)	31	13	1263	112	1:00
26/02/25	Shift A	20	7	658	128	2:20
26/02/25	Shift B	22	8	1050	80	1:58
27/02/25	Shift A	27	9	1129	68	0:28
27/02/25	Shift B	25	9	1203	103	0:40
28/02/25	Shift A	19	6	724	62	2:40
28/02/25	Shift B	20	9	1058	81	2:05
10/03/25	Shift A	22	9	851	72	1:55
10/03/25	Shift B	25	7	1231	82	1:05
21/03/25	Shift B	24	10	946	91	2:02
21/03/25	Shift A	16	4	790	84	0:25
25/03/25	Shift A	15	8	566	170	4:10
25/03/25	Shift B	26	8	1212	237	2:02
26/03/25	Shift A	18	6	786	67	3:15
26/03/25	Shift B	26	9	1127	102	2:38
27/03/25	Shift A	31	10	1387	89	0:25
27/03/25	Shift B	22	6.5	1038	104	2:30

Typically, abounded sandwich biscuits are produced four to six days per month in the factory. The 16-hour production day is separated into two 8-hour shifts, called shift A and shift B. Due to an excess of orders, the production occasionally operates around the clock, which is overtime. During those production days, several batches of dough and cream were consumed. Cartons are used for recording the total output product. Biscuit scrap is present in the factory for several reasons, including the fact that it is not raised during the lamination (stamping) stage, that it may break when it moves from one belt to the next, that it is transported manually from the stacker belt to the crate and from the crate to the shutter, that it may break during the sandwiching and packaging stage, and other factors. Every evening shift entails a 40-minute break to cool down the oven and for cleaning. There are several reasons behind the downtime which include power interruptions and other electrical issues as well as mechanical breakdowns raw material shortages and product surplus before packaging and biscuit variety changes and other variables.

The evaluation of the seven-month production is shown in the following table. A campaign biscuit's total product quantity, total biscuit scrap and available time, total downtime recorded throughout those days, total effective time, batch present time, and gap are all explained in detail in each row. Eight hours times the number of shifts that were in the campaign is the available time. To calculate the total number of cartons produced from a batch, the total output and total biscuit scrap are determined by the carton. The real amount of time spent on production, excluding downtime, is an effective time. The presence time of a single batch on the line defines the term batch presence time. The time needed for one batch to pass through the process takes between 11:00 and 12:30 minutes since the master speed of the line determines the reference speed for all synchronized equipment, especially the oven speed. The gap between total effective time and batch presence time serves as a measure of time lost during production.

Production time available was anywhere from 16-hour to 80-hour campaigns. Even the quantity of batches put together in those lengths of time was fairly inconsistent, from a 37-batch span within 24 hours to as many as 221 batches within an 80-hour campaign. Consistent productivity was evident through relatively constant carton production per batch; an abounded sandwich biscuit produced in a batch shell for such tests gives a production of nearly 44.48 cartons. Almost 2.83 batches of shell could be made from one batch of cream.

Table 4.1: Analysis of production data for seven months

Production days	**Available time (hr)**	**No of batches**		**Total product (carton)**	**Total biscuit scrap (kg) (carton)**	**Cartons per batch**	**Total downtime (hr.)**	**Total effective time (hr.)**	**Batch presence time**	**Gap**	
		Shell	**Cream**							**(hr.)**	**%**
24/09/24	16:00	43	15	1791	204 (34)	42.4	4:05	11:55	8:06	3:49	32.0
05-08/10/24	40:00	105	37	4659	410 (68)	45.0	9:22	30:38	20:08	10:30	34.3
14-15/10/24	32:00	62	23	2721	281 (47)	44.6	13:12	18:48	12:24	6:24	34.0
01-06/11/24	72:00	206	71	9094	604 (100)	44.4	17:35	54:25	39:29	14:56	27.4
19-23/11/24	80:00	221	87	9902	639 (105)	45.3	19:31	60:29	44:12	16:17	27.0
11-12/12/24	24:00	37	13	1613	163 (27)	44.3	11:58	12:02	7:43	4:19	35.9
01-04/01/25	64:00	161	53	7144	461 (76)	44.8	19:29	44:31	32:12	12:19	27.7
23-25/01/25	40:00	109	38	4760	360 (60)	44.2	11:51	28:09	20:31	7:38	27.1
13/02/25	24:00	75	26	3276	294(48)	44.3	01:15	22:45	14:41	8:04	35.5
18/02/25	24:00	64	21	2788	279 (46)	44.3	03:07	20:53	13:52	7:01	33.6
26-28/02/25	48:00	133	48	5822	522 (87)	44.4	10:06	37:54	25:07	12:47	33.7
10/03/25	16:00	47	16	2082	154 (26)	44.8	3:00	13:00	08:52	4:08	31.8
21/03/25	16:00	40	14	1736	175 (29)	44.3	05:22	10:38	7:32	3:06	29.1
25-27/03/25	48:00	138	47.5	6116	769 (128)	45.2	13:00	35:00	25:18	9:42	27.7

Nearly the total production of 1.37% is scrapped for some reason in the stacker area and for packing operations. Gap (hr) and Gap (%) columns in the table reflect the time lost during the total effective time when there was no running batch production. It is the idle time between batches when the line was idle but no product was in process, i.e., reflecting idle or unproductive time between batches. The gap reflects very much how effectively production time is being used in various production periods.

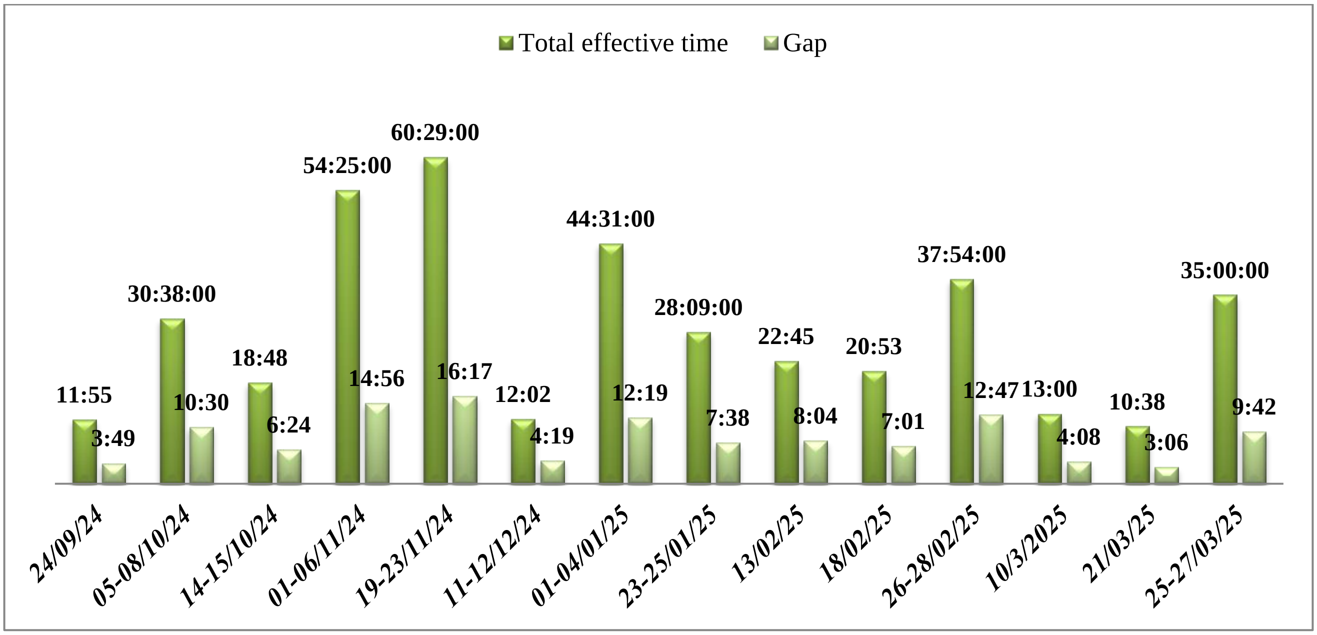

Figure 4.1 Flow chart comparing total effective time with a time of gap

As can be observed from the chart, gap values range between approximately 27% to 36% for abounded sandwich biscuits, indicating that on average a third of productive production time is lost without any effective batch processing occurring. The operational data revealed that the week of 19-23 November 24 registered 60 hours and 29 minutes of effective operation which contained 16 hours and 17 minutes of downtime equivalent to 27% of total operations. The week between 1-6 November recorded 54 hours and 25 minutes of operations with 14 hours and 56 minutes of downtime which reached almost 27.4%. The shorter hours of operational time on 21 March 25 (10 hours and 37 minutes) included 29.1% of gap time which suggests recurring production deficiencies. The data pattern reveals that many production hours are lost because of irregular work rates within the processing phases of mixing and packing operations. The prevalence of downtime is persistent over long and short production a period which suggests underlying process-related concerns instead of certain one-time incidents.

4.2 Production Line Description

Fikir Food Processing's biscuit production process follows in a sequential order to ensure precise efficiency and product quality from raw material to packed output. To ensure uniform product quality, all ingredients required that is, chemicals and additives radical and gluten are precisely measured and produced as per a predetermined formulation. The first creaming step is where the ingredients are mixed in a mixer tank with these ingredients and water. The mixer tank is cleaned after creaming is finished to remove the color spout on the tank. The second mixing of the dough is done to create its texture and shape after wheat flour has been added to the creamed mixture. The ready dough is discharged to a vessel, which is then transferred to a tilting machine. This type of machine effectively transfers the dough over to the feeding conveyor.

The dough is subjected to a metal detector to remove any possible metallic contaminants before being fit for human consumption. The dough is then subjected to a recycled belt and an incline belt in a bid to maximize its thickness and fluidity. Then the dough is stamped with the required weight and shape with its design pattern by the rotary moulder. Each of the dough stamps is checked visually to ascertain that it has the quality requirement before going into the oven system. The dough is baked on an oven wire belt to gain the right flavor and texture when entering through an enter oven belt.

The biscuits after baking pass on the oven wire belt, out-oven belt, u-turning belt, and oiling belt. After that, it goes via Cooling A and Cooling B, two distinct cooling conveyors that lower their temperature to room temperature, prevent accumulation of moisture, and stabilize the shelf. The biscuits undergo cooling before they enter the stacker belt system where skilled workers extract them from the stacks to place them in pre-staged crates which they transfer to a loading mechanism.

Applying cream on one side of a biscuit and then placing another biscuit on top results in a sandwich packed with cream. After that, the sandwich biscuits are delivered to the packing division and placed in airtight containers. When handling packets in bulk, they are stacked and kept in small cartons that are then sealed and placed within larger carton boxes. After that, the boxed product is safely wrapped and put on pallets for shipping or storage.

4.3 Current Layout of the Biscuit Factory

The double-story biscuit factory with a total size of 1922.23 square meters (80.85*23.8) is seen in the below figure. There are two biscuit production lines in this factory: the wafer biscuit line and the hard and soft biscuit line. The second floor consists of the wafer biscuit production line. Hard biscuits and soft biscuits are produced on lines on each of the two floors that are attempted to be illustrated in Figure 4.3 accompanying it.

Stamping is where hard and soft biscuit production differs most. For hard biscuits, the dough is elastic and stiff and is processed on gauge rollers (sheeting), lamination, and cutting machine, while a soft biscuits, the dough is pliable and sticky and is molded simply with a wire cutter or a rotary molder. Following this, follow the same steps, but do not use the sandwiching step for hard biscuits.

The current factory two-story designs have several problems with productivity and efficiency. One of the well-known problems is the delivery of heavy materials like sugar and flour handled by human labor. The manual movement needs another manpower means increased labor costs with no adding value and improving productivity. Up and down moving heavy materials across floors puts extra pressure on laborers, resulting in fatigue and also risk. Supervisors struggled to control many activities happening at once on two floors. This leads to delays in making decisions for an extended period and not responding quickly enough to problems. In addition, the two-story design of the factory makes communication and process control challenging for workers. Important information cannot easily move between departments across various floors, quality control, and resource utilization. Due to this, the doubled story building is limiting the company's performance.

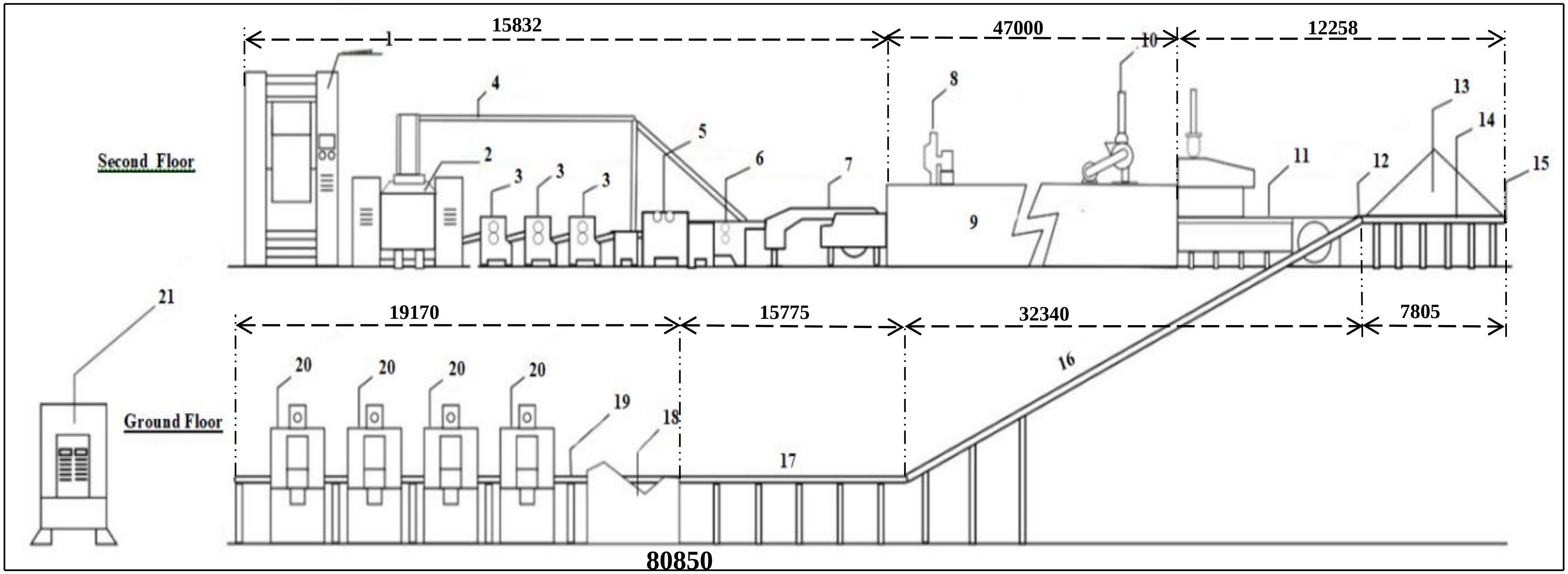

Figure 4.2: Front view of the current layout of the biscuit factory

1, Horizontal mixer machine	8, Exhausting fan motor	15, U-turning belt
2, Tilting machine	9, Baking oven	16, Cooling A belt
3, Gauge roll 1,2,3	10, Exhausting fan	17, Cooling B belt
4, Recycle belt	11, Oven wire belt	18, Stacker
5, Cutting machine	12, Out oven belt	19, Stacker belt
6, Rotary moulding	13, Oil spray machine	20, Packing machine 1-4
7, Enter oven belt	14, Oil belt	21, Cream mixer machine

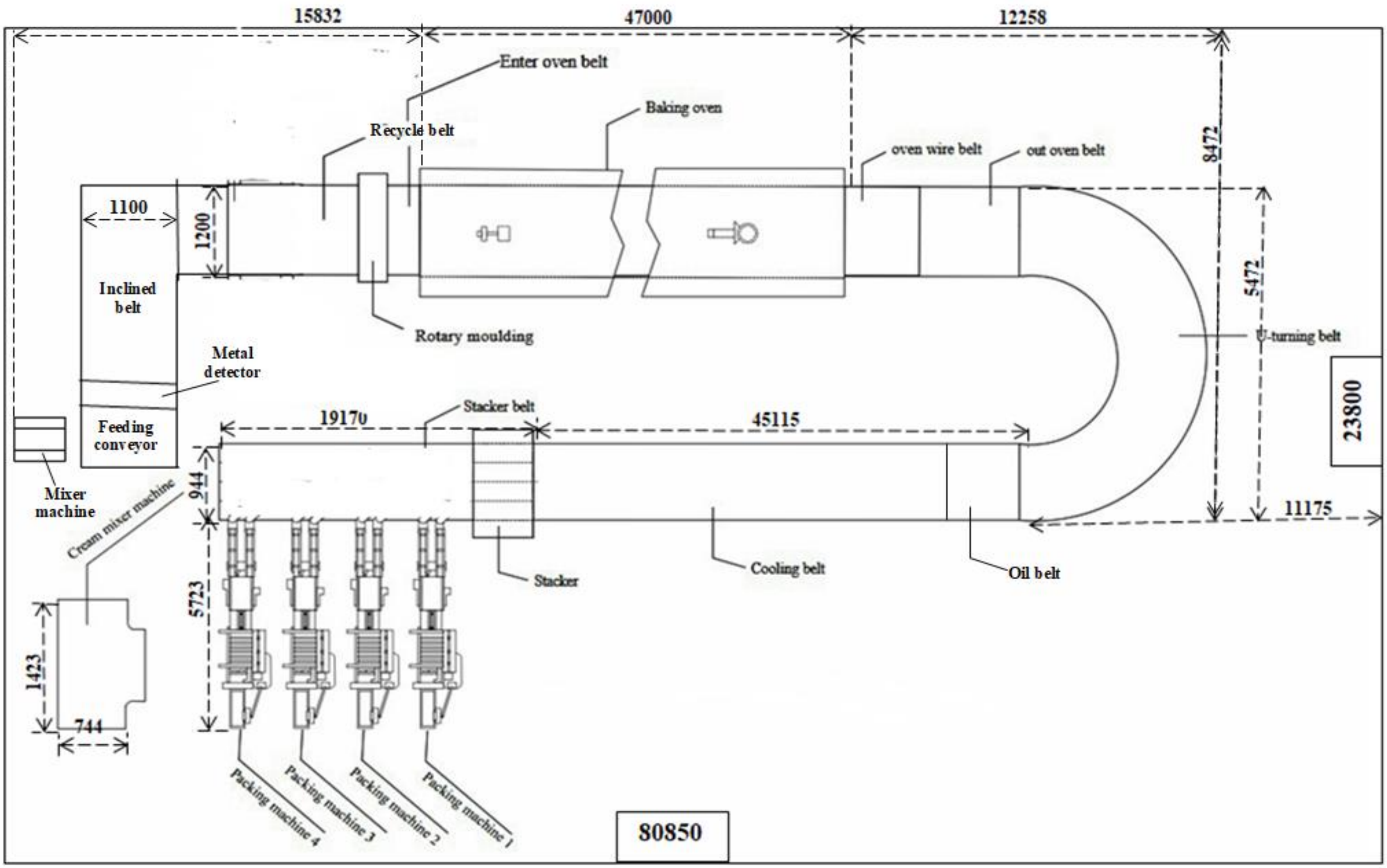

Figure 4.3: Top view of the current layout of the biscuit factory

4.4 Production Process Analysis

A detailed process chart was developed to further analyze and study the flow of the production of soft biscuits. All the stages, beginning with the first mixing of ingredients up to the finishing of packaging and loading onto pallets, are mapped in the process chart. Every process is classified into Value-added Activity (VA), a Necessary Non-Value-Added Activity (NNVA), or Non-Value-Added Activity (NVA). VA (Value-Added) work truly changes the product in a way the customer will pay for. NNVA (Necessary Non-Value-Added) work doesn't add value from the customer's perspective, but cannot be avoided based on the situation. NVA (Non-Value-Added) work contributes no value and must be reduced or minimized as much as possible, i.e., waiting time, unnecessary transport, or manual handling created by inefficiencies. The reason for classified activities is to enhance overall production performance. This classification helps in process bottleneck identification by reflecting where time and resources are being heavily consumed without adding to the product value directly. It also helps in minimizing waste by aiming to remove or streamline unnecessary or ineffective steps. Also, classifying such activity types supports more effective line balancing by keeping work more equitably distributed over processes, hence enhancing workflow and optimal operational performance.

The cycle time of every process is determined by using direct observation and the stopwatch timing method. Further, details about the classification of each step in the process, the number of workers, and machine involvement were also recorded. The processes chart illustrates the task order, duration of each process, and idleness or inefficiency. The processes chart serves basement for further analysis, including line balancing, bottleneck analysis, and enhancement suggestions to eliminate non-value-added tasks and achieve maximum production efficiency.

Symbols depicted various operations throughout the manufacturing process in the process chart devised for the soft biscuit production line. An operation is the main step of a process, method, or procedure and is shown by a filled circle (○). In mixing parts, baking, or sandwiching, for example, the part, substance, or product undergoing the operation is normally altered or transformed in the process. The movement of goods or material from one place to another, such as moving biscuits from one belt to another or dough along conveyors, is referred to as a transport activity and is represented by an arrow pointing to the right (⇨). An inspection activity, or the measurement or checking of the quality of a product, such as metal detection or checking of dough after stamping, is represented by a square (□). A delay, usually represented by a (D) is used to indicate periods where the material or product is briefly stopped because of lines or waiting periods, such as where biscuits must wait to go through the shutter. A triangle (▽) lastly depicts a storage activity, which is the intentional holding back of finished goods or resources, such as keeping packaged biscuits in cartons. Additional line balance and process optimization analysis are facilitated by placing these symbols in the process chart, which enables one to more easily see how much time is being spent on value-adding versus non-value-adding activities.

4.4.1 Process chart of Abounded soft biscuit production process

The factory uses a batch production approach: 150 kg of wheat flour, water, and other ingredients form one batch. Each process's cycle time was determined by measuring the amount of time the dough or biscuits required to complete that process. Every batch conforms to mixing, forming, baking, cooling, sandwiching, and packaging.

The following processes chart is the Material Type Process Chart. This type of chart represents a visual tool that visually documents all material changes in a production sequence. Through this chart, the system documents all specific points in the production process where materials receive treatments and inspections or undergo storage and delays. According to your biscuit production description, this chart examines the sequence of dough and biscuits from mixing through baking to conveyor-belt transportation, quality inspection, stacking, and packaging. The chart creates a visual representation of material handling steps which enables process flow enhancements by pointing out material handling inefficiencies, unneeded activities, and time spent waiting. The chart provides essential value to manufacturing facilities by disclosing material paths that when optimized produce both operational efficiency and waste reduction.

Table 4.2: Process chart of Abounded soft biscuit production process

Flow process chart: Material type

Chart No.1 sheet No.1	Summary			
Subject charted: Abounded soft biscuit production process	Activity	Present	Proposed	Saving
	Operation ○	13		
	Transport ⇨	17		
Activity method - Present	Inspection □	2		
	Delay D	1		
	Storage ▽	2		
Location- Biscuit factory	Time(work-min)	48:06	29:42	18:24
Charted by: Elshaday Girma	Labour	60	54	6
Approved by:	Material			
Date:	Total			

Process Description	Time (min)	Symbols					No. of workers	No. of machine	VA /NNVA/NVA
		○	⇨	□	D	▽			
Apply ingredients and water into to mixer tank	01:25	○					3		VA
Mixing ingredients and water (Creaming)	08:32	○						1	VA
Clean the mixer tank	03:40	○					1		VA
Apply wheat flour to creamed dough	0:40	○					2		VA
Mixing creamed dough with wheat flour (Mixing)	01:45	○						1	VA
Discharging the dough into a vessel	0:30	○					2		NVA
Transport the vessel to the tilting machine	0:20		⇨				1		NVA
Tilting the dough into the feeding conveyor	01:00		⇨				1	1	NVA
Transport the dough by the feeding conveyor	0:10		⇨					1	VA
Determining a metal by metal detector machine	0:10			□				1	VA
Transport the dough by the inclined belt	0:30		⇨					1	NNVA
Transport the dough by the recycle belt	0:45		⇨					1	NVA
Forming the dough (Lamination)	0:30	○					2	1	VA
Inspecting the stamped dough’s quality	0:15			□			2		VA
Transport the dough by the enter oven belt	0:17		⇨					1	VA
Transport the dough by the oven wire belt	0:06		⇨					1	VA
Baking	04:37	○					1	1	VA
Transport the biscuit by the oven wire belt	0:28		⇨					1	VA
Transport biscuit by the out oven belt	0:10		⇨					1	VA
Transport biscuit by the u-turning belt	0:30		⇨					1	VA
Transport biscuits by the oil belt	0:19		⇨					1	NVA
Transport biscuit by the cooling A	02:00		⇨					1	NNVA
Transport biscuit by the cooling B	01:25		⇨					1	VA
Stacking biscuit	0:45	○					3	1	VA
Transport the stacked biscuit by stacker belt	11:52		⇨						NVA
Picking the biscuit manually and placing it in crate	0:30		⇨				15		NVA
Waiting biscuit to be put into the shutter	???				D				NVA
Inserting the biscuit into shutter	0:30		⇨				6	6	VA
Applying a cream to the biscuit (Sandwiching)	1:45	○						3	VA
Packaging	0:30	○					6	3	VA
Storing the packet into a small carton	0:20					▽	6		NNVA
Covering the small carton	0:20	○					6		NNVA
Storing the small carton into to carton box	0:20					▽	6		VA
Encase the carton box.	0:50	○						3	VA
Loading the carton on the pallet	0:20		⇨				3		VA

Mixing involves applying ingredients into a mixer and then tilting towards the conveyor. The Sinobake horizontal mixer machine with a capacity to process 150 kg of wheat flour and other materials is used in the factory. All the processes at this point are a value-added activity. The mixing procedure takes the longest, which is the primary reason for the lag; it takes about 17:52 minutes in total. To apply flour and other ingredients to the mixer tank, clean it, and move the vessel to the tilting to line conveyor, four personnel are needed: an operator and an assistant.

One of the shaping techniques used in the creation of soft biscuits is stamping or forming. Used to manage the weight and thickness of the biscuits, imprint designs, and shape the dough to the desired size. This step uses a rotary molder or soft stamping roller for forming and mostly consists of belt conveyors (feeding, inclined, recycle, and entry oven). The time taken is 02:37 minutes. Assistant and operator are needed at this stage. Since it transforms the dough into the finished biscuit, baking is the primary operation in the production line. The dough is conveyed by an oven wire to bake it sequentially in the nearly 47-meter-long tunnel oven. To get the proper texture, biscuits must bake gradually through moisture evaporation (drying), expansion (rising), and color and flavor development. It takes 05:11 minutes as well. Following baking, the technique of cooling is utilized to progressively lower the temperature to room temperature before packaging. The quality of the biscuits depends on that. It avoids moisture issues, maintains the structure, which means it maintains its desired form and attractive surface, and also helps to preserve flavor and shelf life. Therefore, an excellent biscuit requires good cooling. Nearly 04:24 minutes pass. Transportation conveyors, including oil belts, u-turning belts, cooling A belts, and cooling B belts, process the entire cooling step.

Sandwiching is placing a measured cream on one biscuit and pressing another biscuit on the top to create a sandwich. The biscuits go to the packaging department after being sandwiched, where they are stacked, collated, and wrapped using flow wrap machines that operate automatically. By shielding the biscuits from air, moisture, and mechanical harm, packaging helps to preserve their freshness and lengthen their shelf life. Maintaining quality and meeting food safety regulations requires proper sealing, orderly packaging, and precise labeling (such as batch codes and expiration dates). There are four packaging machines in the facility, however, due to a manpower shortage; only three sandwiching and packaging machines are used for soft biscuits. It takes about 18:02 minutes to package one batch of biscuits. Additionally, it also generates a gap between the processes. At this point, the majority of labor is needed. Three encasing carton box machines are also present.

At least 60 personnel are required for the entire production process. These include those who operate mixers, laminating machines, ovens, stackers, and packing machines, as well as their assistant operators, packers, and carton, encase men.

4.4.2 Process chart of soft biscuit cream production process

The task order and cycle time involved in preparing the cream and transferring it to the sandwiching machine are illustrated in Table 4.3 process chart, which also shows the batch preparation of cream and transfer of cream filling in the biscuit production line.

Table 4.3: Process chart of soft biscuit cream production process

Flow process chart: Material type				
Chart No.2 sheet No.2	Summary			
Subject charted: Soft biscuit cream production process	Activity	Present	Proposed	Saving
Activity method - Present	Operation ○ Transport ⇨ Inspection □ Delay D Storage ▽	7 1 1		
Location- Biscuit factory	Time(work-min)			
Charted by: Elshaday Girma Approved by: Date:	Labour	2		
	Material			
	Total			

Process Description	Time (min)	○	⇨	□	D	▽	No. of workers	No. of machine	VA/ NNVA/ NVA
Apply vegetable oil and other ingredients into a mixer bucket	1:30	○					2		VA
Melting the vegetable oil and mix with ingredients with a cream mixer machine	2:40	○						1	VA
Clean the stirring paddle of the machine	2:00	○					1		NNVA
Apply sugar into the mixer bucket	1:10	○					2		VA
Mixing sugar with mixed oil mixer machine	3:15	○						1	VA
Checking a quality	0:10			□			1		VA
Clean the stirring paddle of the machine	2:00	○					1		NNVA
Discharging a cream into the vessel	1:00	○					2		VA
Transport a vessel into to s machine	2:50		⇨				1		VA

The first step is to add the ingredients and vegetable oil to a mixer bucket, melt them, and then mix them in a cream mixer. Then add the sugar and stir with the melted vegetable oil. After that, it is released into a vessel to be transported to a packing machine and deposited into a sandwiching machine. The total time required to prepare a single batch of cream is approximately 13 minutes and 45 seconds. After the cream is prepared, it takes around 2 minutes and 50 seconds to transport it to the packing machine and place it in the sandwiching machine. At least two employees were required, including an operator and an assistant.

4.5 Takt Time Analysis

Takt time describes how quickly a good or service should be manufactured to satisfy consumer demand. It can be calculated by dividing the useful working time in one day by the daily customer demand.

$$\text{Takt time} = \frac{\text{Available production time}}{\text{Customer demand}}$$

Available production time means the total working hours per day after removing time that is not for production. During the evening shift, there is a 40-minute break in the factory for cleaning and oven cooling. There are two shifts of 16 hours or 960 minutes of production time per day.

$$\text{Available production time} = \text{Production time} - \text{Non production time}$$

$$\text{Available production time} = (960 - 40)\text{ minutes} = 920 \text{ minutes} = 55{,}200 \text{ second}$$

The amount of units needed each day is determined by customer demand. Nearly 3500 cartons are needed daily in the factory.

$$\text{Takt time} = \frac{55{,}200 \text{ sec}}{3500 \text{ carton}} = 15.8 \text{ second per cartons}$$

One carton must be finished in 15.8 seconds to meet daily demand. The factory produces in batches of 44.48 cartons. So

$$44.48 \text{ cartons} * 15.8 \text{ seconds} = 701.5 \text{ second} = 11{:}41 \text{ minutes}$$

Takt time is 11:41 minutes; the production line should be balanced so that one full batch must be completed every 11:41 minutes.

4.6 The Current Yamazumi Chart

Yamazumi chart is a bar chart that reflects where time is and how cycle time is allocated to the various processes. To demonstrate the actual time of work as well as identify the bottleneck process, the value of cycle time is plotted on the Yamazumi chart.

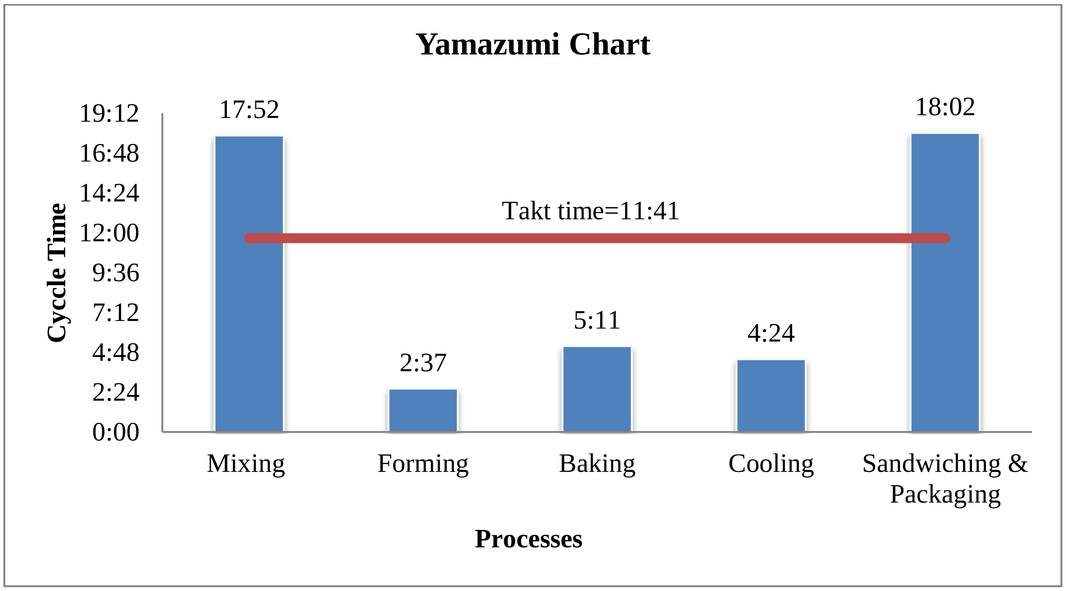

Figure 4.4: Yamazumi chart of current production system

According to the chart, the workload is not balanced; the bottleneck occurs when the cycle time exceeds the takt time, which is at 17:52, and 18:02. Targeted time, or takt time, is used to balance the workload by decreasing cycle time and increasing production.

4.7 Simulation of Current Production

A simulation model was created from the preview observation and the data collected were incorporated into ARENA software to simulate the existing production process. This approach utilizes create, process, decide, and dispose of since it employs various shapes based on their function. The simulation model began with the create shape called batch arrival, as seen in the figure below. The chosen shape was used for quality control on three stations for metal detection reviewing, dough shape quality inspecting, and, finally, inspecting the packed biscuit quality check on various true percent values. The majority of the modules are processes, which determine the production process. The pallet was delivered with the disposal at the end of the module.

From the figure, it is evident that the company manufactures 54 batches in a day with this cycle time and bottleneck. This implies the company produced 2401 cartons within a day. The simulation is conducted for a fifteen-hour working day with one hour of morning setup and evening cleanup since the downtime is excluded at that point.

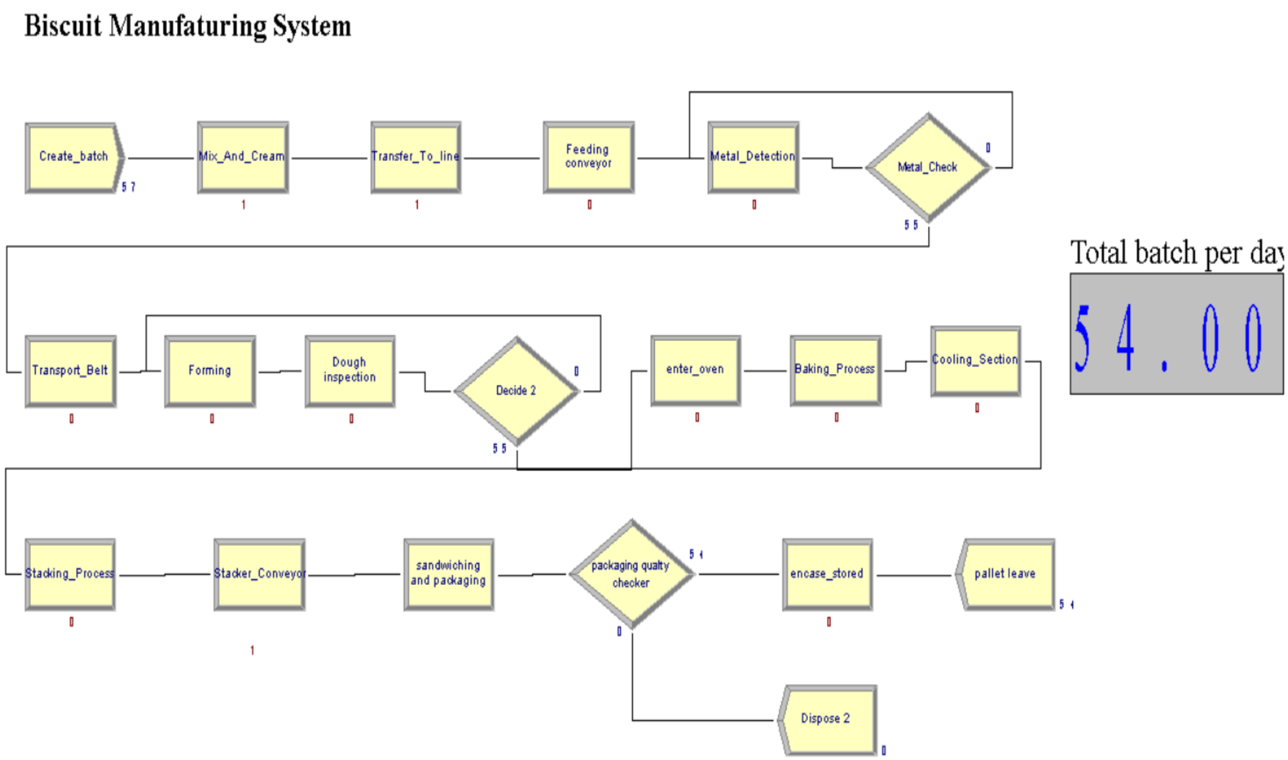

Figure 4.5: Arena simulation of the current production system

4.8 The Proposed Improvement of the Production System

To balance the manufacturing line, the study provided several particular improvements. Assigning a parallel mixer machine, removing non-value-added activities, automating the feeding system, and improving the packaging system are the most essential improvements.

Table 4.4: Process description of the improvement production system

No.	Processes description	Improvement	The old cycle time of one batch process	The new cycle time of one batch process	No. of workers
1	Applying ingredients, creaming, cleaning the tank, applying wheat flour, and mixing.	Use a second mixer to run batches in parallel.	16:02	8:01	6
2	Discharging the dough into a feeding conveyor then transporting the dough and detecting metal	Remove the tilting and vessel transport processes, and move the mixers parallel to the line.	02:10	0:35	1
3	Transport the dough by inclined belt, forming, inspecting its quality, and entering to oven.	Eliminate using a recycle belt process to move the dough.	2:17	1:32	3
4	Baking by oven wire		5:11	5:11	1
5	Transport the biscuit by out-oven, u-turning, and cooling belt and quality check.	Remove transporting by oil belt and merge cooling A and cooling B belts.	4:24	4:05	2
6	Stacking the biscuit and then transporting it on the stacker belt	Use automated feeding the biscuit process	13:37	7:14	5
7	Sandwiching and packaging	Use four sandwiches and a packaging machine	2:15	2:00	8
8	Store the packet in a small carton and cover it	Increase the workers for packing machine 4	0:40	0:35	16
9	Store small cartons in a carton box and encase that carton box then load on pallet.		1:30	1:18	11

Assigning a parallel mixer machine

In the improved, assigning or placing a second mixer machine parallel to another, allows two dough batches to be prepared at the same time. This reduced the mixing time per batch by 50% means it reduced from 16:02 to 8:01; this effectively eliminated the bottleneck caused by relying on a single mixer. Through loading the work by eliminating space between workstations, support for continuous flow, aid the mixing production to maintain an equal speed and capacity as that of downstream machines, reducing delay and enhancing the overall line efficiency and balancing. Three workers are operating a mixer since there are two mixers, so six workers are assigned.

Removing of non-value-added activities

When two mixers are placed parallel to the production line, the mixer can discharge the dough directly to the feeding conveyor. This is caused by eliminating the discharge of the dough into the vessel, transporting it to the line, and tilting it to the line processes; this reduces almost 01:20 minutes for every batch.so it improves the dough's condition when reaching the forming machines.

The dough was being transported by a recycled belt from an inclined belt to a rotary moulder, however, this is not required for the production of soft biscuits. In the process of making hard biscuits, it is used to recycle dough. The formation time was reduced by 0:45 minutes by eliminating this phase. By doing this, handling and transfer times were decreased, a non-value-added activity was successfully eliminated, and the production flow was improved to be more efficient and smooth.

In the cooling area, the biscuits were moved by an oil belt; an oil sprayer was present, but the company has never used it, to provide additional movement. It reduces the cooling time from 4:24 to 4:05 minutes. After the oil belt is removed, the cooling belts A and B are merged. As a result, the transfer flow is shorter and more direct.

Automating the feeding system

The old manual feeding system was time-consuming and labor-intensive. By substituting an automated feeding system, it reduces the number of workers which leads to lower labor costs. In the old method, it required fifteen workers to pick biscuits from the belt and place them in the crate, and it needed only five workers. With this automated system, however, no personnel are required for these tasks. It ensures a consistent feeding rate which improves the overall speed and reliability of the production process. The system also reduces handling time by allowing continuous and quick transfer of biscuit to shutter, which decreases delays and improves the flow of operation. It reduces the time from 13:37 to 7:14.

This system also improved biscuit safety, the automated process involved less human contact with the biscuit. It enhances food safety and helps to meet sanitary standards. Furthermore, the automation to achieve line balancing by matching the feeding rate with the sandwiching and packaging process. This reduces idle time and results in a smoother and more efficient production flow. Overall the improved automation feeding system provides faster, cleaner, and more cost-effective production processes.

In an old system, fifteen workers were needed to pick biscuits from the belt to the crate, and five workers were needed to insert biscuits into the shutter, but on this automated system, no workers were needed for these processes.

Improving the packaging system

The upgrading packaging process leads to several improvements in efficiency, consistency, and line balance. One of the major improvements was the introduction of four automated sandwiching and packaging machines. The automation of the feeding system reduced manual work, minimized human error, and ensured more consistent product handling. This results in the packaging process becoming quicker and more reliable, allowing the production line to handle higher production without interruption. In this section, the time is reduced from 4:25 to 3:53 minutes.

In addition, more work was invested in the final packing segment to help with the rush from the automatic machinery. This helped to speed up the boxing and packaging of finished items for shipping. All these altogether made the packaging segment more coordinated with the remainder of the manufacturing line, eliminating bottlenecks and downtime. Overall, the upgrades saw a more balanced and efficient running with improvements in quality and also efficiency at the latter stages of biscuit manufacture.

Cream production for proposed production

The current time to make cream is about 13 minutes and 45 seconds. Loading and transferring it into the sandwiching machine takes an extra 2 minutes and 50 seconds. As a result, it takes roughly 16:35 minutes to make and transport one batch of cream. Nearly 2.83 batches of shell can be produced from one batch of cream. This ratio shows that the cream-making device can process multiple batches of shells in a single cycle. This ratio is crucial in determining if the current cream output can satisfy the demands of the new production system. Divide the number of minutes needed to make one batch of cream by the number of shell batches it feeds to get how many minutes each shell batch needs to produce cream. It takes roughly 5.86 (5:51) minutes for each batch of shells to create a cream. Therefore, the current cream production process will continue smoothly without any bottlenecks or delays if the proposed production system produces batches of shells at an average time of 5:51 minutes or more per batch. In general, this ratio and time coordination allow the current cream production to supply the proposed shell production system without any delays or bottlenecks.

After the improvement, the new total cycle time for the batch has been reduced from 48 minutes and 6 seconds to 29 minutes and 42 seconds. Additionally, the number of processes that are not adding value to the production has been reduced by seven, and the number of workers has been reduced from sixty (60) to fifty-three (53). This reduction was achieved by adding workers to the new additional recommended machine, decreasing the number of workers from the non-value added place, and replacing manual operation with an automated system.

4.9 Improved layout for the factory

The new suggested layout is located on the ground floor so it addresses the double-story problems that are mentioned in the below section. In this layout, there is no tilting machine, or recycle belt cause these are non-value added also the mixer is two. Gauge rolls and cutting machines are removed because those are for hard biscuits. The oil spray and oil belt were removed cause the company has never used them. Cooling belts A & B are joined to one belt. This layout suggests an automated feeding system. And then there are 4 sandwiching and packaging machines and one cream mixer machine like an existing layout. So the company can implement this layout by simply placing an area of the existing layout.

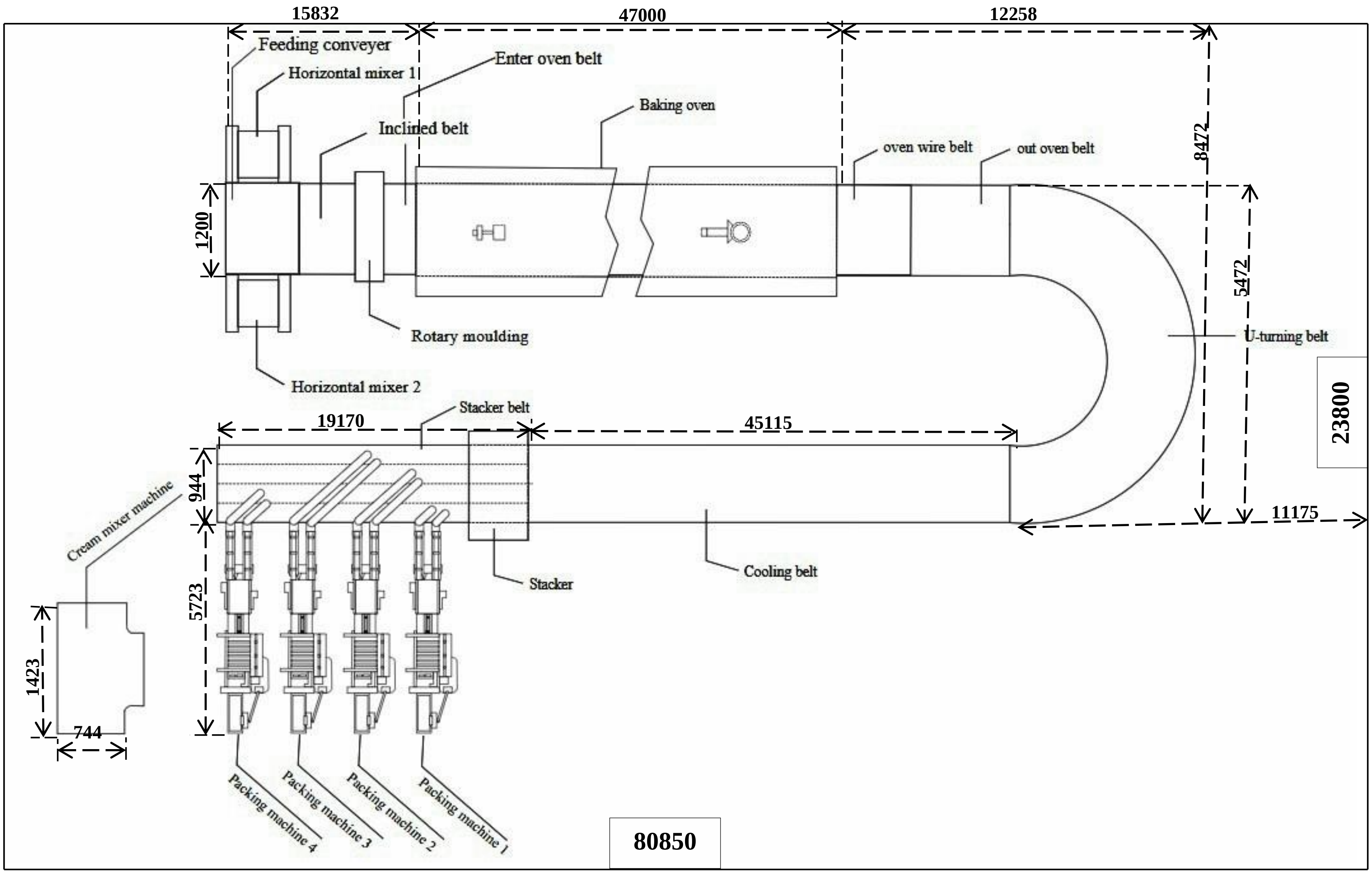

Figure 4.6: Top view of improved layout

4.10 The Improved Yamazumi Chart

This new yamazumi chart demonstrates critical improvements in process efficiency and production balance. An old chart showed high cycle time variation, processes like mixing (17:52 minutes) and sandwiching and packaging (18:02 minutes) consuming excessive time and creating major bottlenecks. So these processing times were greater than the takt time. That is why this station was caused by gaps or bottlenecks. The reliance on manual operations led to inconsistencies, longer durations, and greater physical strain on workers.

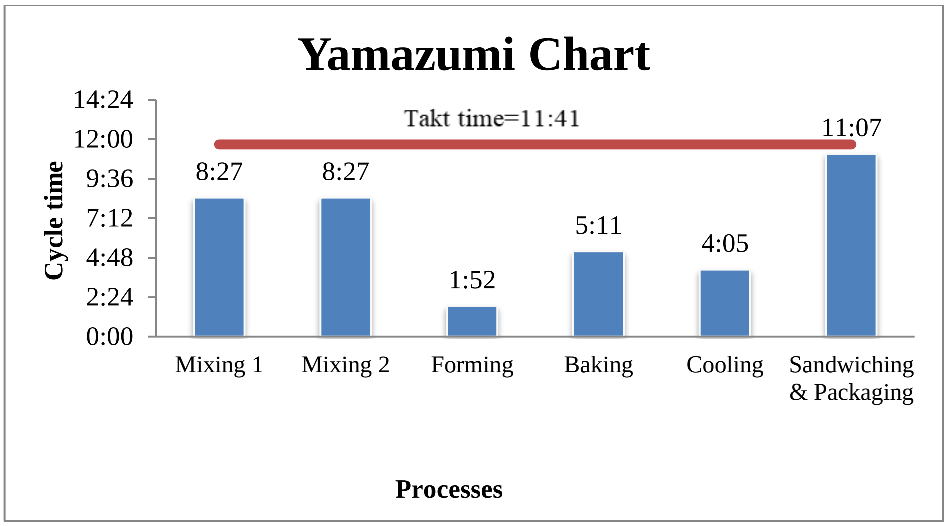

Figure 4.7: Yamazumi chart of improved production system

The presence of non-value-added activities such as tilting, vessel transport, and the use of recycling and oil belts introduced unnecessary time and complexity to the workflow. After improvement, the yamazumi chart showed better-balanced work. Incorporating the second mixer reduces the mixing time to 8:01 minutes, the automation feeding system and streamlining packaging operations cut the time to 11:07 minutes.

The visual difference between the yamazumi charts is clear: the "before" chart shows imbalance and inefficiency with tall, uneven bars and two processes that take longer than the takt time, while the "after" chart shows a balanced and optimized production flow with shorter, more even bars and entire processes that take less time than the takt time.

4.11 Simulation of improved production

Since the number of mixer machines has increased to two, the mixing time has already been cut in half. Removing the need to manually transport the dough from the mixer machine to the line also reduced processing time. To optimize the soft manufacturing layout, an unnecessary transport belt that is not value-adding was also removed. The automated feeding system used in the proposed system reduces processing time by stacking and feeding biscuits to the sandwiching machine. Additionally, it is advisable that the factory use four sandwiching and packing machines to minimize packaging time. A fifteen-and-a-half-hour workday is used for this simulation, with a half-hour downtime for morning setup and evening cleaning.

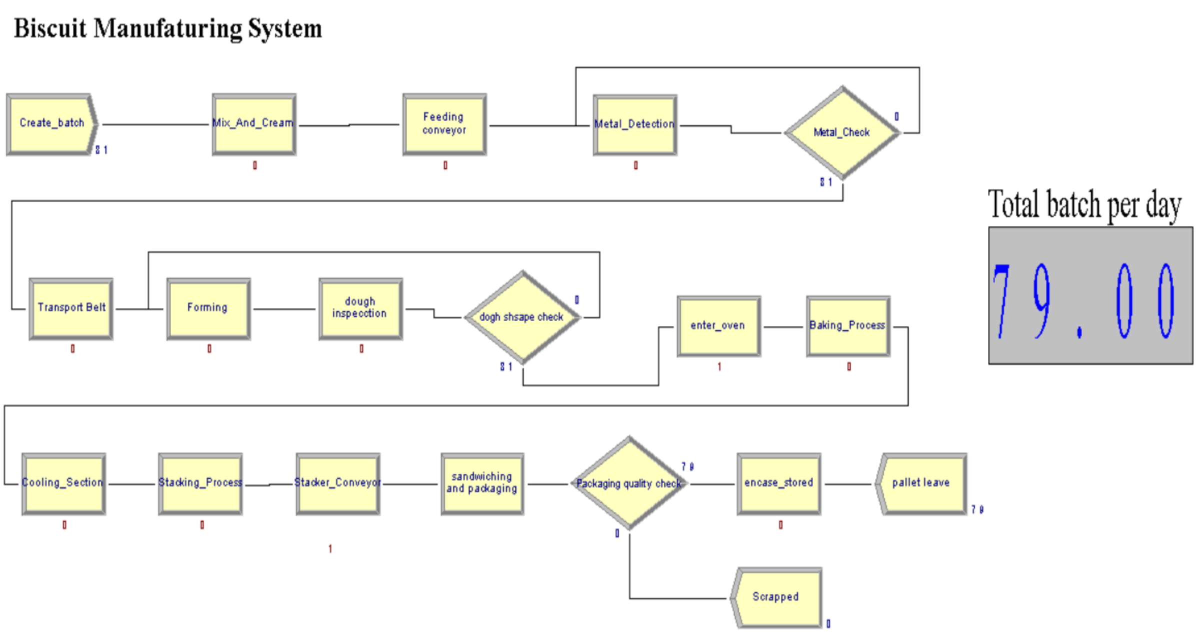

Figure 4.8: Arena simulation of an improved production system

Following improvement, the output simulation shows that the total number of batches per day increased from 54 to 79, resulting in a daily production increase from 2402 to 3514 cartons. Thus, there is a 46.3% growth in the company's production capacity.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research case study focused on the investigation of the unic biscuit production line layout at Fikir Food Processing Company. The study aimed to identify and show the inefficiency of the current layout, those contributing to an unbalanced workload or gap, bottleneck, the company prevents from satisfying increased customer demand for soft biscuits. To reach the research aim, the study used the combination of the line balancing method and arena software for simulation to design and assess an enhanced production line layout for improved productivity decreased waste, and better operational efficiency.

Based on the findings, the following key conclusions have been drawn:

1. Currently, the manufacturing process suffers from the underutilization of machines and labor throughout its production line. Some workstations operate under capacity, while others are overloaded and imbalanced impeding efficiency in the system. These manual packaging operations bring in processing delays, which slow down the operations, preventing the equipment from working to full capacity. Due to the imbalance of work distribution among employees, productivity levels are brought down, while delays are created in the production process.
2. The existing facility layout features numerous constraints which reduce operational efficiency. Operations in the two-story layout face challenges when moving materials and supervising activities. Employees and supervisors struggle with workflow coordination between different levels which results in high fatigue levels and poor communication and process control.
3. The newly introduced layout, as evidenced through simulation analysis, was found to possess significant performance gains in major performance metrics. In particular, the restructuring coordinates dough mixing, baking, and packaging operations, thereby ensuring greater coordination and eliminating delays between stages. The ground floor location of the newly proposed layout solves the problems associated with the double story.

4. By substituting an automatic feeding system for a human one, the new layout seeks to improve quality and decrease waste that results from manual feeding. Biscuits now run the risk of sustaining physical damages and contamination through manual handling; so, any lessening in inputs will go some way toward improving the product quality. Before, packing delays would result in biscuits being left about for a long time, exposed, and such exposure did not do well to maintain their freshness. The new flow ensures that such delays do not exist and therefore grants protection to product quality and reduced wastage.
5. A more efficient workflow with higher throughput and reduced production is the result of the enhanced production system. The production will grow from 2401 to 3514 cartons if the overall cycle time is shortened from 48:06 to 29:42 minutes, the number of workers is reduced from 60 to 54, non-value-added activities are decreased, and the number of batches produced per day is increased from 54 to 79 batches. Thus, the company's production capacity has increased by 46.3%.
6. The increased improvements in productivity will further enable the FFP to be competitive in the market. Hence, the new layout is most capable of taking advantage of the increased demand for Unic biscuits. Decreased wastage and increased production will help keep costs in check, thereby allowing the company to price competitively and start realizing better profits.

For FFP, the adoption of the suggested layout is not only a technical solution but an investment in productivity, quality, and sustainable growth over the long term.

5.2 Recommendation

Following the findings in this study, the below are suggested recommendations to enhance the production efficiency of Fikir Food Processing Company:

- Apply the proposed layout: the new production layout identified by the simulation should be adopted at once. Synchronizing process schedules, reorganizing the workstation, and automating critical steps like packaging workstations are ways to reduce loss and delays.
- Invest in packaging automation: by shifting the packaging system to an automated mechanism, minimizing biscuit wastage, sanitation can be improved, and

throughput can be increased. Additionally, automation will allow the company to meet growing demand without adding labor expenses as well.

- Educate employees on new flows: the staff should receive training on how to utilize the new equipment, upgrade safety procedures, and modify processes. This will reduce implementation delays and provide a smooth transition.
- Utilize the same methods for other soft biscuit lines: the same method of line balancing and simulation will be applied to the other soft biscuits.

Fikir Food Processing Company will be in a strong position to increase its operational effectiveness, fulfill growing customer demand, a keep a competitive edge in the biscuit sector through the adoption of these suggestions.

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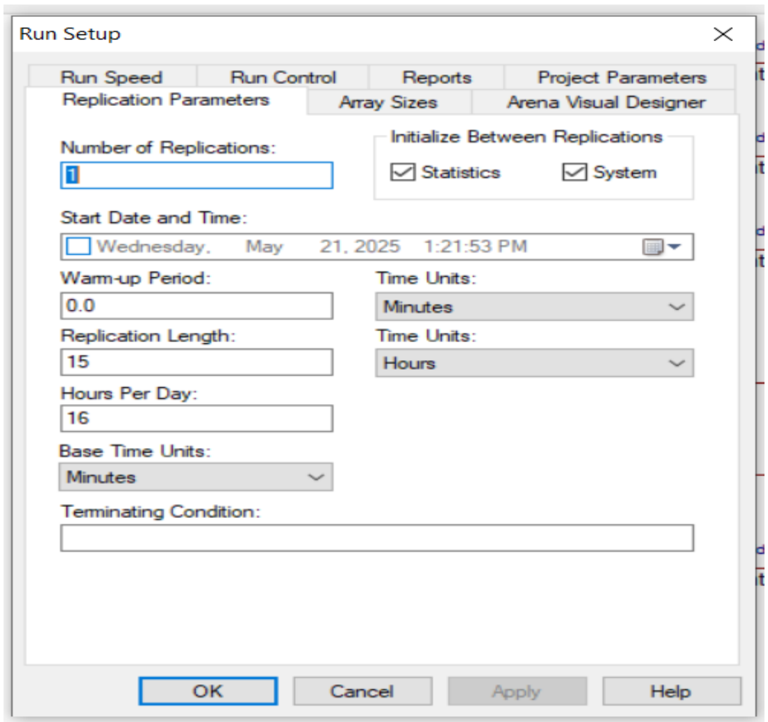
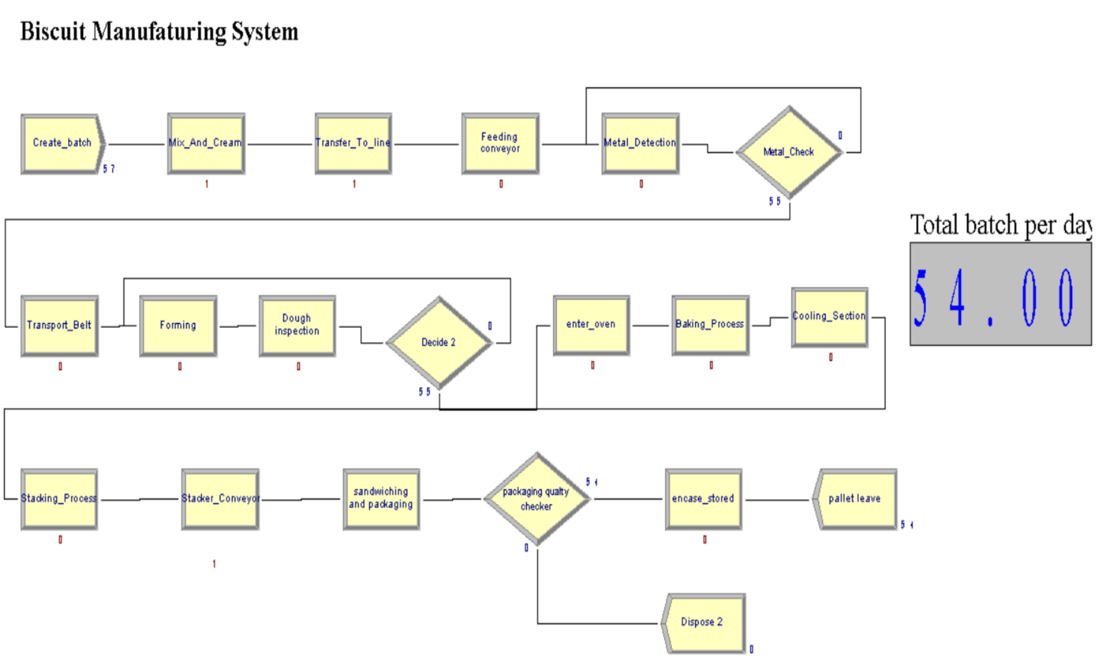
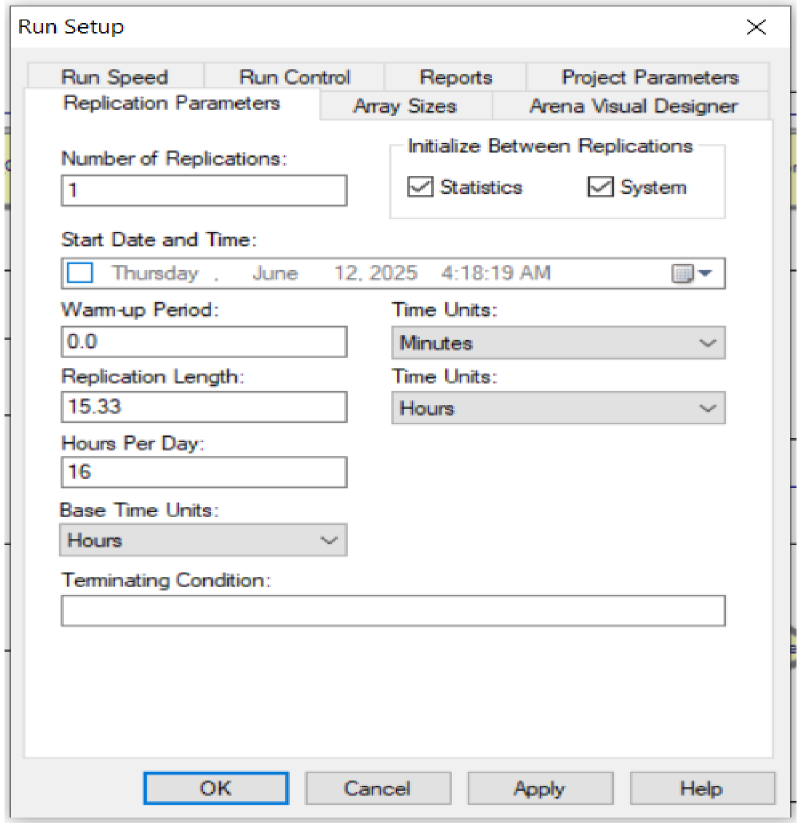
APPENDIX

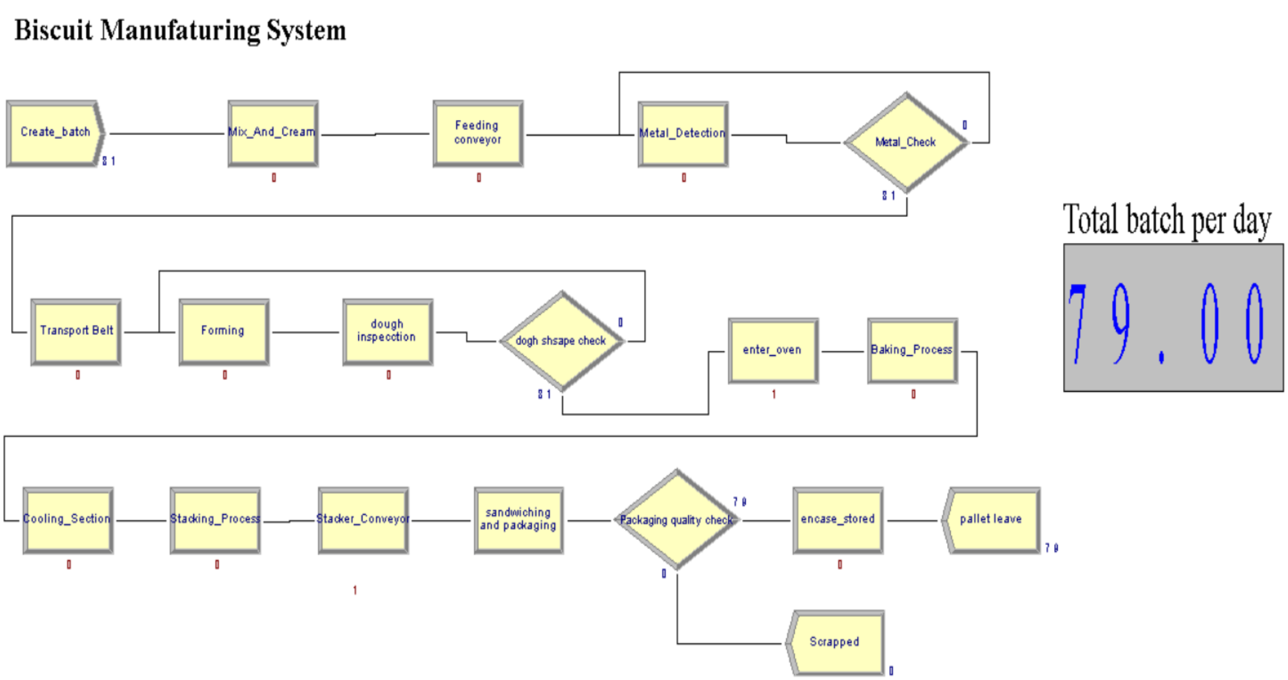
Appendix A: Running setting and simulation result of current production system





Appendix B: Running setting, simulation result of proposed production system and result of waiting time





Biscuit line

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Baking_Process.Queue	0.00	(Insufficient)	0.00	0.00
Cooling_Section.Queue	0.00	(Insufficient)	0.00	0.00
dough inspecction.Queue	0.00	(Insufficient)	0.00	0.00
encase_stored.Queue	0.00	(Insufficient)	0.00	0.00
enter_oven.Queue	0.00	(Insufficient)	0.00	0.00
Feeding conveyor.Queue	0.00	(Insufficient)	0.00	0.00
Forming.Queue	0.00	(Insufficient)	0.00	0.00
Metal_Detection.Queue	0.00	(Insufficient)	0.00	0.00
Mix_And_Cream.Queue	0.00	(Insufficient)	0.00	0.00
sandwiching and packaging.Queue	0.00	(Insufficient)	0.00	0.00
Stacker_Conveyor.Queue	0.00	(Insufficient)	0.00	0.00
Stacking_Process.Queue	0.00	(Insufficient)	0.00	0.00
Transport Belt.Queue	0.00	(Insufficient)	0.00	0.00