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# Production Layout Design for Modified Cassava Flour-Based Product

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ABSTRACT

Having an increasing trend in demand for healthy food and the government's support in meeting the cassava needs, this study aims to improve the scale of production of Modified Cassava Flour (MOCAF) by applying the systematic layout planning (SLP) method. This method is used to review the existing conditions of the production process and design a new layout for scaling up production. The result of the new layout is an ideal condition and a stable production target, but it is implemented gradually. By adopting systematic layout planning, it is expected to improve production efficiency and optimize resource utilization. This study provides useful information for the food industry in improving Mocaf production scale and can also contribute to research on production management and production layout.



## I. Introduction

The Indonesian government's focus in reducing dependence on imported food ingredients is to increase food self-sufficiency. One of the initiatives taken is to promote cassava as an alternative to imported food ingredients and as a substitute for wheat in making flour. According to Katadata [1], the Ministry of Agriculture aims to substitute 20% of imported wheat with cassava. This is in line with the increasing trend of demand for healthy food, including the demand for mocaf-based product. However, many Indonesians still considers cassava as a food for low social-economic status [2]. Although foods which made from raw cassava has less preferred, public perception towards mocaf-based product is relatively higher [3]. Meanwhile, Mocaf flour is claimed as a healthier alternative compared to wheat flour due to its higher composition and lower gluten [4]. With the increasing demand, it is necessary to develop and increase the scale of production to meet the customer's voice, whereas unfamiliarity aspect also considered as a challenge to increase mocaf-based product supply [5].

One of the challenges in increasing the scale of MOCAF-based production is benchmarking with similar industrial production scales. In this case, examples can be taken from the wheat or corn flour industries, which already have a large-scale production [6]. Having an increased urgency for production scale-up allows for the development of production technology and optimal facility layout design to improve efficiency and production capacity [7].

In addition, the design of production facility layout is also critical in increasing the scale of mocaf flour production. A good layout can improve production efficiency, optimize space and equipment usage, and minimize production costs [8]. Moreover, food industries such as MOCAF production contains abundant opportunities, including its industrial waste [9]. Study related to optimal facility layout design for mocaf flour, and its derivative products are needed to achieve an increased production scale. This study involves an analysis of the production process, production facility needs, and proposed layout design.

## II. Method

The research stages begin with reviewing the production process, procurement of materials, calculation of resource requirements, and the creation of a layout design. This planning process adopts the systematic layout planning stages proposed by Muther et al. [10], in which the characteristics of a product's production process will influence the type of layout planned. The detailed stages are as follows.

### A. *Review of The Existing Production Process*

By reviewing the current production process, the workstations involved become a reference for scaling up production needs to a larger capacity. This is based on demand projections with the target production per year of 300 tons overall. This target is implemented gradually from 2020 to 2026. At this stage, a process flow diagram is also created for all products, including their derivatives as a process mapping.

### B. *Machine Requirements Calculation*

The calculation of machine requirements is based on the predetermined production flow from the previous stage. We can obtain the machine requirement by evaluating both production capacity and its demand [11]. This calculation is done using equation (1), which defined as:

$$Machine\ Requirement = \frac{Demand\ per\ unit}{Capacity\ per\ time\ available} \quad (1)$$

After the machine requirements are calculated, the dimensions of the machines are also recorded for spatial requirements. An allowance of 150% of the main machinery is given to provide extra space for worker’s movement [11].

### C. *Material Handling Requirements Calculation*

The number of material handling equipment is determined based on the type of material, production flow, and its exposure to the environment. In addition, the output from the previous process will affect the amount to be transported to the next process, so the dimensions and categories of material handling will also differ [8].

### D. *Number of Worker Requirements*

The determination of operators already includes the main tasks in the production system, namely operation, transportation in the production line, inspection, and storage. Consideration of the number of operators assigned includes several factors, such as the number of machine requirements and operators, the amount of workload received by each operator, the number of products to be produced, and if there is a need for specialized skills/certification to operate certain equipment.

### E. *Layout Design Construction*

The layout design is created using Microsoft Visio 2016 software. This creation stages include adjusting the dimensions of the machines and placing them based on the production flow in the process flow diagram. The actual layout design starts from the material input process, proceeds to the first process, and ends at the storage of finished goods. Therefore, an evaluation of the percentage of the overall layout building area is conducted [12].

## III. Results and Discussion

This section describes the treatment of each MOCAF product in its production process until it becomes a finished good. In this process, calculations are provided for the resource requirements based on each stage in the methodology.

### A. *Production Process Observation*

The production system flow for MOCAF flour and its derivative products was illustrated using a process flow diagram. All processes for each product were carried out in a single line, and no parallel processes were implemented. Information on the production process was obtained from data provided by PT. Rumah Mocaf and adjusted with the latest technology adopted.

1. Production Flow for MOCAF Flour

There are nine involved processes for managing MOCAF flour. The process map is depicted in Figure 1, whereas the detailed process is described as follows:

a. Receiving/inspection: Cassava raw materials are placed in a room for preparation for washing and peeling. All cassava received in a day must be processed entirely into MOCAF flour to maintain its quality.

b. Peeling and washing: Cassava is transported using a container to the peeling and washing machine. Both processes are carried out simultaneously in the same machine with flowing water. During the process, inspection is also carried out to ensure that the cassava is peeled perfectly. The processed cassava is then transported back with the container.

c. Cutting: Cassava is transported to a cutting machine to change its shape into chips. The cut cassava is then transported using a hand pallet to the fermentation process.

d. Fermentation: This process is carried out in a 300 m3 container that can accommodate a maximum of 30 tons of cassava per day. Fermentation is done by putting cassava into the container and mixing it with fermentation trigger enzymes. The process is left for approximately 24 hours.

e. Second washing: This process is carried out to rinse the fermented cassava. The cassava is moved from the fermentation container to the washing container. After washing, the cassava is transported to the drying stage.

f. Drying: The fermented cassava chips are dried continuously on a line belt dryer. The drying process is carried out by utilizing the dehydration process of the water content in cassava.

g. Milling: The dried cassava chips are then transported to a milling machine to be crushed into flour powder. The input process is carried out manually from the top of the machine, while the output result of the milling process will be sifted to meet certain granule sizes.

h. Sifting: The sifting process is directly carried out after the cassava is crushed by the milling machine. In this process, metal scanning is also carried out using a metal trap to ensure that the flour does not contain metal.

i. Packaging: The sifted flour is then transported for packaging according to the demand. There are two types of MOCAF flour packaging, namely pouch and B2B packaging. These two packaging types are carried out on different machines because of different demand segments.

The summary of the nine processes is depicted in the process flow diagram in Figure 1. This process flow will be used as a reference for calculating the facility requirements for MOCAF flour production. The assumptions used in the calculation are as follows:

a. The monthly production target used as the basis for the calculation is 300 tons of MOCAF flour production. This amount is also used as raw materials for derivative products, namely: (1) noodles; (2) premix flour; and (3) cookies.

b. The ratio of cassava raw material volume to the resulting MOCAF flour is 3:1.

c. To maintain flour quality, cassava must be processed within 24 hours after harvest.

d. The daily working hours are 7 hours/day with 26 working days per month.

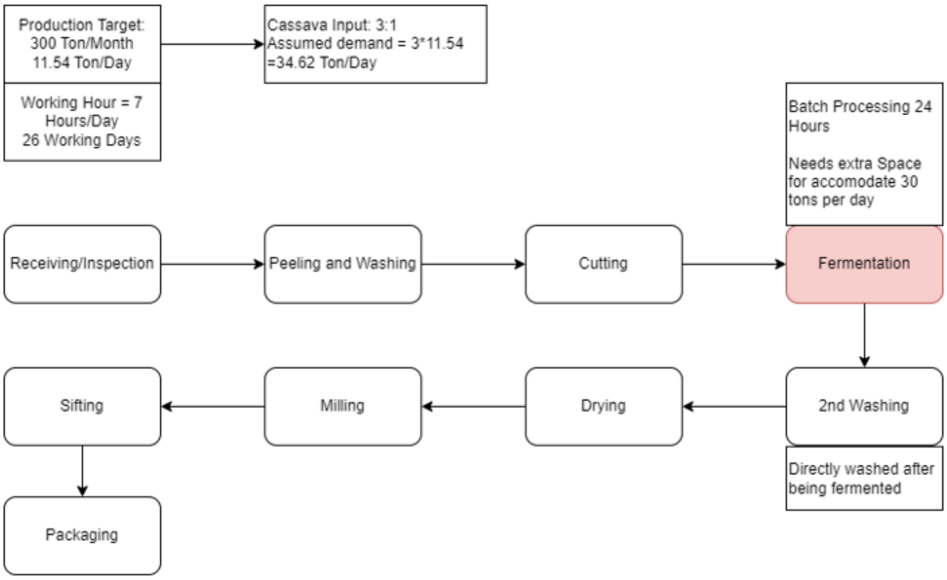


Fig. 1. Process Flow Diagram for MOCAF Flour

2. Production Flow for MOCAF Noodles

Mocaf noodles are one of the three derivative products that will be produced from mocaf flour as the main ingredient. Therefore, a portion of the finished goods produced in mocaf flour production will be allocated to the mocaf noodle production line.

The production process of mocaf noodles is summarized in the process flow diagram in Figure 2. There are three main processes in the production flow, starting from the raw materials input, then processed through the noodle production machinery, and ending with the packaged noodles being placed in cardboard boxes for packing. The noodle-making process is an integrated machinery process that starts from the input of raw materials and ends with packaging. The processes involved in the production line are as follows:

a. Mixing: The initial mixing process of all raw materials for the noodles, including the previously made mocaf flour.
b. Aging: The noodle dough is left to rest for a certain period.
c. Rolling: The noodle dough is rolled into thin layers using a multi-stage rolling machine.
d. Slitting: The dough is sliced to separate the rolled noodles.
e. Steaming: The noodles are steamed at a certain temperature until cooked.
f. Cutting: The steamed noodles are cut to a specific size to fit the packaging.
g. Frying: The noodles are fried to create a hard texture like dried noodles.
h. Cooling: The noodles are cooled before entering the packaging machine.
i. Packaging: The dried noodles are packaged in noodle wrappers.

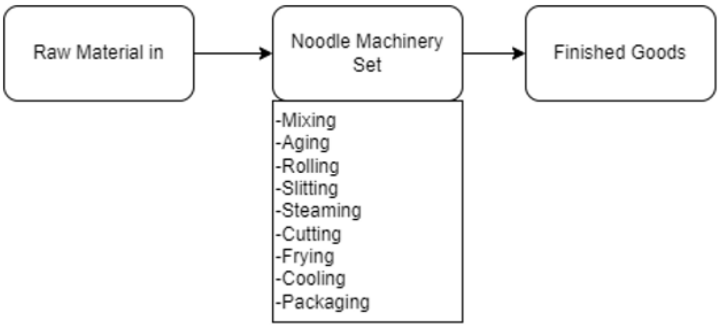


Fig. 2. Process Flow Diagram for MOCAF Noodles

There are two types of noodle production lines that will be created, namely low-gluten noodles and gluten-free noodles. Both products cannot be made in the same line simultaneously due to the risk of contamination of wheat flour, which is one of the ingredients in low-gluten noodles, either from airborne flour dust or from flour residue on the equipment. Therefore, the production of both types of noodles is separated and a boundary is set between the two lines, particularly during the mixing to steaming process, to avoid wheat flour contamination. The capacity of the noodle production lines for the two products also differs due to different demand levels.

3. Production Flow for Premix Flour

Premix flour is one of the three derivative products that will be produced from mocaf flour. Therefore, a portion of the finished goods from mocaf flour production will be allocated to the premix production line. The premix powder is made by combining mocaf flour with other ingredients to make it ready-to-use. The flowchart of the premix powder manufacturing process is shown in Figure 3. The main processes involved in its formation are mixing and roasting. After that, the premix powder is ready to be packaged in pouches using a packaging machine.

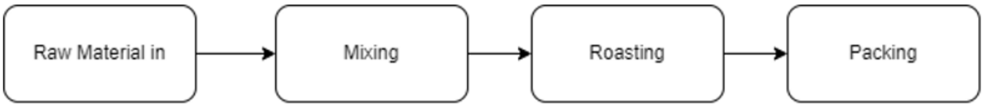


Fig. 3. Process Flow Diagram for Premix Flour

4. Production Flow for MOCAF Cookies

Cookies are one of the three derivative products that will be produced from mocaf flour. Therefore, a portion of the finished goods from mocaf flour production will be allocated to the Cookies production line. The overall cookie-making process is shown in Figure 4. Some processes involved in making cookies are as follows:

a. Mixing: Adding all the raw materials gradually using a mixer.

b. Molding: The mixed dough is put into a cookie molding machine for shaping and resting.

c. Cooling: The molded dough is cooled in the freezer.

d. Baking: The cooled dough is baked in the oven.

e. Sealing: The baked cookies are packed in a pouch and sealed.

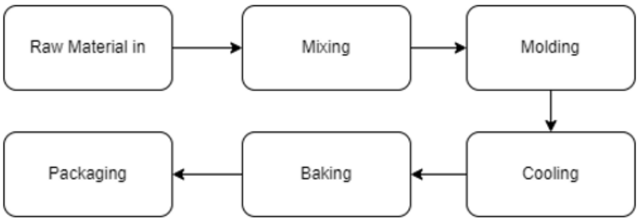


Fig. 4. Process Flow Diagram for MOCAF Cookies

### B. *Machine Requirements*

The machine allocation is obtained from the machine's working capacity per unit time. Meanwhile, the projected demand is obtained from sales projection based on forecasting. The unit of demand at each workstation must be adjusted to the desired unit so that the calculation can be done proportionally. All machine capacities have been adjusted to demand predictions based on the reference in Table 1. Furthermore, every machine dimensions are also recapitulated for space requirement purposes in Table 2.

1. MOCAF Flour Machine Requirements

The required number of machines, considering the machine capacity and product demand, is shown in Tables 1. In the fermentation process, a stirring mechanism is required to distribute enzymes evenly in the cassava tank, maximizing the fermentation process. Meanwhile, the capacity of the drying machine is based on the machine's evaporation ability in 1 hour. Given that:

a. The cassava evaporation capacity of the machine is 1.2 tons/hour

b. The percentage of water content in cassava is 65%

c. The dehydration process reduces the water content to at least 5% [13]

Therefore, the total mass of cassava that can be processed in 1 hour in the drying machine is:

$$= 1200\,\frac{kg}{hr}\,x\,\frac{100\%}{(65-5)\%}$$
$$= 2000\,\frac{kg}{hr}$$
$$= 2\ ton/jam$$

Table 1. Machine Requirements Recapitulation

| **Work Center** | **Capacity** | **Demand** | **Machine amount** | **Work Center** | **Capacity** | **Demand** | **Machine amount** |
|---|---|---|---|---|---|---|---|
| Peeling and washing | 2 ton/hr | 3.75 tons/hr | 2 | Noodle Machinery (low gluten) | 5000 pcs/hr | 4200 pcs/hr | 1 |
| Cutting | 0.8-1.5 tons/hr | 3.75 tons/hr | 3 | Noodle Machinery (gluten free) | 2000 pcs/hr | 1400 pcs//hr | 1 |
| Fermentation (include mixing) | | | 3 | Mixer (Premix) | 25kg/5 min | 23kg/5min | 1 |
| Drying | 2 tons/hr | 3.75 tons/hr | 2 | Roasting (Premix) | 25kg/5 min | 23kg/5min | 1 |
| Milling | 0.5 tons/hr | 1.25 tons/hr | 3 | Packaging (Premix) | 12-15 pcs/min | 3 pcs/min | 1 |
| Sifting | 0.3-2 tons/hr | 1.25 tons/hr | 1 | Mixer (Cookies) | 8 kg/5 min | 4kg/5min | 1 |
| Packaging (pouch) | 12-15 pcs/min | 10 pcs/min (pouch) | 1 | Molding (Cookies) | 90kg/hr | 48kg/hr | 1 |
| Packaging (B2B) | 4-10 pcs/min | 1 pcs/min (sak) | 1 | Cooler (Cookies) | 8000 cookies/ 2 hr | 15.400 cookies/2 hr | 2 |
| | | | | Oven (Cookies) | 800/15 min | 1925/15 min | 3 |
| | | | | Sealing (Cookies) | 15 *pack* / min | 6 *pack* / min | 1 |

2. MOCAF Noodle Machine Requirements

   The machining facilities provided cover the entire process of noodle production, from material mixing to packaging. Therefore, the machinery needs in Table 1 are calculated in an aggregate manner, not separately. Considering the separate production lines for gluten-free and low-gluten noodles, each noodle product requires one set of machining facilities.

3. Premix Flour Machine Requirements

   The required number of machines for premix flour production is based on the machining capacity per batch processing. Based on the calculation in Table 1, the machinery requirement for premix flour production is one machine for each process.

4. MOCAF Cookies Machine Requirements

   The machinery requirement for cookies production uses the same approach as premix flour. Based on Table 1, it is shown that the number of machines required for making cookies is higher than for premix flour production. This can be seen in the cooling and baking processes, where each batch of cookie dough requires a significant amount of space to be placed in the freezer or oven.

### C. *Material Handling*

Material handling equipment is used to assist the process of transferring, storing, and handling materials for raw materials, work-in-process (WIP), and finished goods. Although most of the material processing is done automatically, the transfer process is still done manually. There are six types of material handling needed in this production system as shown in Table 3. The roles of each material handling are as follows.

1. Pallets: Maintain material integrity to facilitate storage processes. Pallets will assist in stacking materials for raw materials for derivative products and finished goods of mocaf flour. The determination of pallet requirements considers 50% of the predicted demand to be stored first, especially for bulk mocaf flour. If it is known that:

   Demand for bulk MOCAF flour = 150 tons per month, 70 tons/2 weeks

   Assumed storage = 50% x 70 tons = 35 tons/2 weeks

   Stacking load capacity = 1.5 tons

   The number of pallets = 35 tons/1.5 tons = 24 pallets

Table 2. List of Machines Needed and Its Dimension

| Product | Machining Type | Amount | Machine Code | Dimension (w x l x h) | | $m^3$ |
|---|---|---|---|---|---|---|
| MOCAF Flour | Peeling and washing | 2 | TM11 | 1.5 | 0.9 | 1.22 |
| | | | TM12 | 1.5 | 0.9 | 1.22 |
| | Cutting | 3 | TM21 | 1.2 | 0.8 | 1.6 |
| | | | TM22 | 1.2 | 0.8 | 1.6 |
| | | | TM23 | 1.2 | 0.8 | 1.6 |
| | Fermentation | | - | 17.3 | 17.3 | 1 |
| | Drying | 2 | TM31 | 6 | 2.2 | 2.2 |
| | | | TM32 | 6 | 2.2 | 2.2 |
| | Milling | 3 | TM41 | 1.4 | 0.7 | 1.2 |
| | | | TM42 | 1.4 | 0.7 | 1.2 |
| | | | TM43 | 1.4 | 0.7 | 1.2 |
| | Sifting | 1 | TM51 | 0.8 | 0.8 | 1.1 |
| | Packaging (pouch) | 1 | TM611 | 0.43 | 0.51 | 1.4 |
| | Packaging (B2B) | 1 | TM612 | 2 | 0.87 | 1.5 |
| Premix Flour | Mixer | 1 | TP11 | 0.7 | 0.4 | 0.9 |
| | Roasting | 1 | TP21 | 1.1 | 5.8 | 1.1 |
| | Packaging | 1 | TP31 | 0.43 | 0.51 | 1.4 |
| Noodles | Low-gluten noodle machinery | 1 | MMA1 | 80 | 5 | 4 |
| | Gluten-free noodle machinery | 1 | MMB1 | 65 | 5 | 5 |
| Cookies | Mixing Dough | 1 | CM11 | 0.52 | 0.42 | 0.78 |
| | Molding Machine | 1 | CM21 | 2.04 | 1.12 | 1.54 |
| | Cooler | 2 | CM31 | 1.85 | 0.98 | 2.46 |
| | | | CM32 | 1.85 | 0.98 | 2.46 |
| | Oven | 3 | CM41 | 1.33 | 0.84 | 1.5 |
| | | | CM42 | 1.33 | 0.84 | 1.5 |
| | | | CM43 | 1.33 | 0.84 | 1.5 |
| | Sealing | 1 | CM51 | 0.85 | 0.4 | 0.66 |

Meanwhile, the number of pallets for raw materials for premix and cookies are each 1 pallet, and noodles, each 2 pallets for gluten-free and low-gluten. This number is determined by considering the daily product demand not exceeding 1.5-3 tons per day.

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2. Blockstacking: This effort is used to stack finished goods without the help of any positioning units. In other words, the stacking of goods is only based on the finished goods box. This strategy is used for noodles and premix flour products.
3. Handpallet: Used for reducing the workload of transporters in moving materials, especially in large quantities or over long distances. Each process from peeling to fermentation requires 2 units, while the process from drying to packaging requires 1 unit each.
4. Tote Container: Used for transporting cassava in the raw material, peeling, washing, cutting, and fermentation areas. Totes are used for wet cassava, with the number determined based on the container dimensions of (65 x 50 x 40) m3, and then adjusted to the capacity of the machine. Therefore, peeling, washing, and cutting each require 4 units, while 16 units are used in the fermentation process due to the large batch size.
5. Jumbo Bag: Used for transporting dry cassava in the drying, grinding, sieving, and packaging areas. Jumbo bag has similar dimension with tote container, but with higher height. Hence, the amount is also similar but in different usage.
6. Rack: Used to store materials that are prone to damage if stacked directly without support. There are 3 racks used at the noodle station to store supporting raw materials and seasoning. Meanwhile, 4 other racks are used to store supporting raw materials for premix and cookie flour, as well as storage for finished goods cookies.
7. Forklift: There is one forklift to assist in transporting finished goods to be distributed through trucks.

Table 3. Material Handling Recapitulation

| Material Handling Equipment | Amount |
|---|---|
| Pallet | 30 |
| Hand pallet | 10 |
| Tote Container | 24 |
| Jumbo Bag | 15 |
| Container | 7 |
| Forklift | 1 |

*D. Operator*

Table 4 shows the number of operators required for each workstation. This number also considers the scenario of demand according to the forecast, so that the number of operators is not too high. The reference number of operators is based on the condition of 300 tons. If the demand is lower, the focus will be on reducing the number of material handling workers. This is due to the nature of the investment, which is only made at the beginning of the project, so the number of facilities is not added or reduced.

Table 4. Manpower Requirement Recapitulation

| | Workstation | 300 tons | 240 tons | 180 tons | 120 tons | 75 tons |
|---|---|---|---|---|---|---|
| **Subtotal** | mocaf | 23 | 23 | 22 | 21 | 20 |
| | mie | 14 | 14 | 14 | 14 | 14 |
| | premix | 4 | 4 | 4 | 4 | 4 |
| | cookies | 9 | 8 | 7 | 7 | 7 |
| | penyimpanan | 15 | 13 | 11 | 9 | 7 |
| | total | 65 | 62 | 58 | 55 | 52 |

*E. Layout Finalization*

There are 4 main production departments (1 for mocaf flour and 3 for derivative products), 1 warehouse, and 1 office. All planned facilities require a building area of 2465.18 m2 and a land area of 4783.27 m2, with the area of each department indicated in Table 5. Mocaf flour provides the largest building area contribution, followed by noodles as the largest derivative product in terms of area.

The overall layout visualization is shown in Figure 5. The front of the factory faces east, with the office in the front position. The production process starts from the loading and unloading of raw materials in the west position on the layout. The material then flows along the indicated colored arrows. Four colors are used to represent each production flow. Purple for mocaf flour, green for premix flour, red for cookies, and blue for noodles. Finished goods that have been completed are taken to the warehouse before being distributed via truck. The transport process to the truck is carried out with the assistance of a forklift according to the path depicted by the dashed line.

Table 5. Building Area for All Department

| Department | Area ($m^2$) | Percentage of overall area (%) |
|---|---|---|
| MOCAF flour | 1141.58 | 46.31 |
| Noodles | 789.05 | 32.01 |
| Warehouse | 177.58 | 7.20 |
| Premix Flour | 39.07 | 1.58 |
| Cookies | 70.97 | 2.88 |
| Office | 158.75 | 6.44 |

There are several important highlights regarding the relationship between workstations in the factory. These workstations are important to be given special treatment (isolation) so as not to contaminate the surrounding area. The first area is the milling and sifting process, where this process must be done in a closed manner to prevent flour contamination from affecting other areas. In addition, workstations for mixing the gluten-free noodles with low gluten noodles should also be separated. This is done so that the gluten-free noodle content is not contaminated by the low gluten noodles. This isolation only applies until the rolling process, because once the steaming process begins, there is no opportunity for gluten content contamination.

## IV. Conclusion

Based on the review of the existing production process, a layout design has been proposed to increase production scale. In the future implementation, there will be adaptations from the old production system to the new production system. Therefore, the implementation of this proposed layout will be done gradually, with annual production targets projected at 10 tons, 20 tons, 40 tons, 120 tons, and up to 300 tons. Additionally, this gradual implementation will also affect the resources allocated to operate the proposed layout. The layout with a building area of 2465.18 m2 and a land area of 4783.27 m2 represents the steady production target. However, this proposal does not yet consider optimal material flow in quantitative aspects. In future research, it is highly possible to optimize with a quadratic assignment problem (QAP) for continuous production system model.

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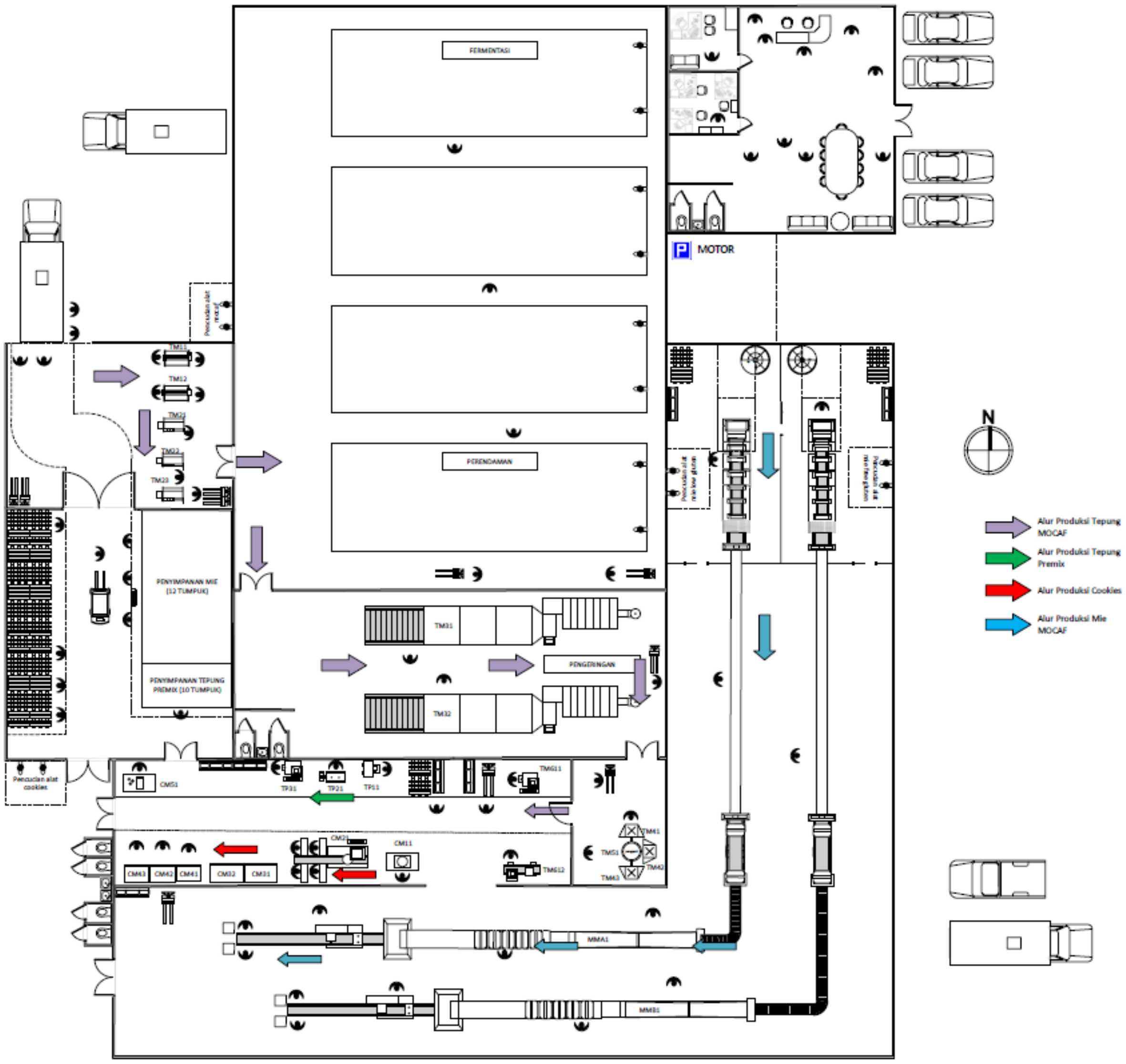


Fig. 5. Final Proposed Layout Design

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