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Optimizing Steaming Line Layout for Manufacturing Plant Using ProModel Simulation †

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Abstract

Plant layout significantly influences manufacturing performance by optimizing the placement of machines and resources to enhance output and minimize operational costs. We redesigned the layout for the steaming line of a food manufacturing facility to improve line efficiency and labor productivity without compromising product quality. We used the define-measure-analyze-design-verify six sigma methodology to identify problems and develop solutions. Layout modifications were validated using ProModel 2016. Results demonstrated reduced process bottlenecks and improved workflow. The results offered actionable insights into food manufacturing and similar industries, promoting the adoption of data-driven, technology-enabled approaches to enhance operational efficiency and productivity.

Keywords: DMADV six-sigma; process simulation; productivity; manufacturing

1. Introduction

Production planning is essential in manufacturing, with plant layout playing a key role in optimizing performance. According to Kiran, plant layout involves strategic space allocation and equipment arrangement to ensure smooth production flow [1]. A well-designed layout can reduce bottlenecks, minimize cycle time, optimize resource use, enhance supervision, lower material handling costs, and improve adaptability [2].

A snack-food manufacturing plant in San Pedro City, Laguna, Philippines had identified inefficiencies in its critical steaming line, which directly affects product quality and output. We improved the line's performance by optimizing its layout and refining processes. The define–measure–analyze–design–verify (DMADV) six sigma approach was employed in this study for process simulation to evaluate proposed changes. The anticipated outcome includes improved productivity, line efficiency, and overall operational gains for the company.

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2. Materials and Methods

2.1. Manufacturing Process Optimization

Garcia defined manufacturing plant optimization as a practice of utilizing data and information to produce better products at a faster pace with the objective of being more competitive [3]. There are several studies related to manufacturing optimization. Goyal and Verma designed a new plant layout of micro, small, and medium enterprises using the Spaghetti Diagram. However, the analysis can be created at any time, and the simulation data are theoretical [4]. Ejeh et al. presented an optimization-based approach to solve the multi-floor process plant layout problem and adopted cost and management/engineering drivers, including connectivity, operations, land area, safety, construction, retrofit, maintenance, and production organization had been considered [5].

On the other hand, simulation provides a mechanism for robust validation under realistic conditions and allows organizations to dynamically test the flow of processes, verify the model, and gather timing and resource information on proposed or legacy processes with a view to improving them [6]. Vanner stated the advantages of conducting business process simulation to be productive by saving time and providing an overview of the process. The advantages ensure consistency and standardization across the organization, making it easier for the end-users to communicate with each other and apply coordination among people, systems, and information across the organization for an effective implementation of the business strategy.

2.2. Methodology

We applied the Six Sigma DMADV framework to improve the steaming process. The Define stage addressed the current line layout and problem identification. In the Measure stage, key performance indicators from January to July 2021 were evaluated, including operating days, actual and target outputs (kg/month), line efficiency (actual/target output), and productivity (actual output/working man-hours). Root causes such as method errors and machine downtimes were identified using a fishbone diagram in the Analyze stage, categorized into manpower, methods, materials, and machines. In the Design stage, a modified steaming line layout was developed using ProModel 2016, based on insights from the previous stages. The Verify stage involved simulation and performance analysis via Output Viewer to assess the proposed layout's effectiveness. Conclusions and recommendations were drawn from the results. Figure 1 illustrates the study's conceptual framework.

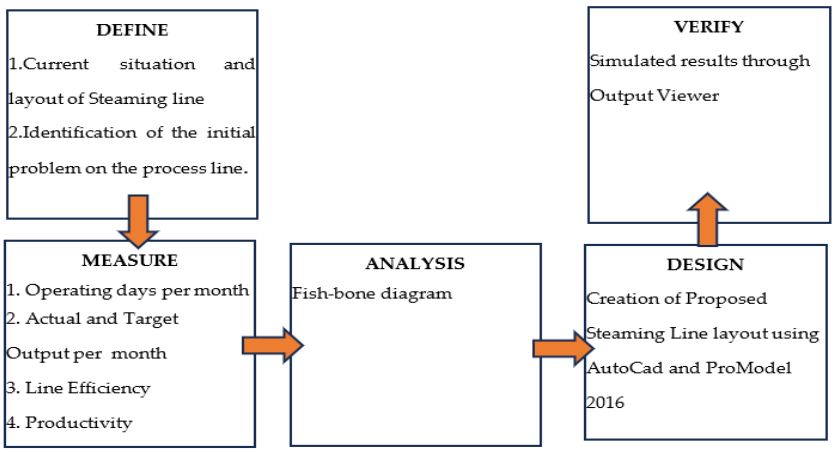


Figure 1. DMADV six-sigma framework.

3. Results and Discussion

3.1. Define Stage

Company XYZ's production operations play a pivotal role in determining overall product quality and output volume. It starts with a corn powder mixture stored in a 3500 kg silo. The dough-mixing operator manually dispenses 74.2 kg of powder and adds 24 kg of water into an industrial mixer. The mixing process takes 18 min, with an additional 12 min for manual bowl transfer between equipment. The dough is then cut into strips using a cutter machine. Cut pieces are placed on trays, loaded onto trolleys (each holding up to 667 kg), and manually moved to steam cookers. Each cooker processes three trolleys per 90-min cycle (45 min come-up and 45 min steam circulation) at 100 °C. After cooking, products are depanned to cooling screens and cooled to 25 °C. A minimum of three workers is required for de-panning. Finally, the cooling loader transfers the screens to trolleys and moves them into a cooling room for 9 h of blower cooling.

This process layout currently faces bottlenecks and flow restrictions, which will be examined further in the analysis stage. Figure 2 presents the value-stream mapping of the steaming line where rectangle represents the operation process while triangle represents waiting or transfer process.

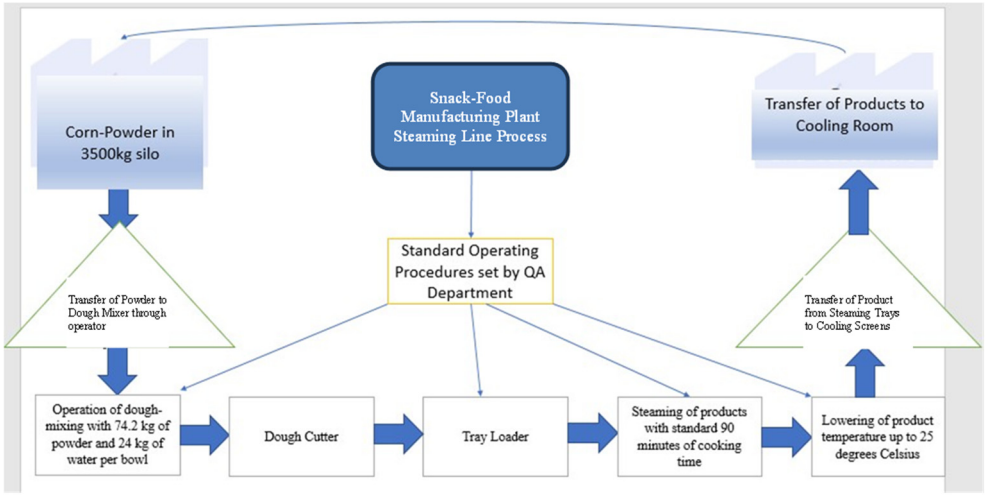


Figure 2. Value stream mapping.

3.2. Measurement Stage

Table 1 shows the availability percentage of steamer cookers without a supervisory control and data acquisition (SCADA) system. Planned operation hours are total number of hours a line is scheduled to run, while actual operation hours are real number of hours the line actually operated. Availability percentage is calculated as actual operation hours divided by planned operation hours. Hence, overall equipment efficiency (OEE) gauges equipment performance based on product quantity and quality.

Table 1. Monthly line performance (January–July 2021).

Date	Planned Operation Hours	Actual Operation Hours	Availability (%)	OEE (%)
January 2021	600	500	83.33%	64.31%
February 2021	552	425	76.99%	60.33%
March 2021	648	526	81.17%	62.07%

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Table 1. *Cont.*

Date	Planned Operation Hours	Actual Operation Hours	Availability (%)	OEE (%)
April 2021	600	523	87.17%	68.50%
May 2021	624	615	98.56%	76.44%
June 2021	624	600	96.15%	73.09%
July 2021	600	587	97.83%	77.00%

Figure 3 shows the initial condition of the steaming line illustrated through Pro-Model 2016.

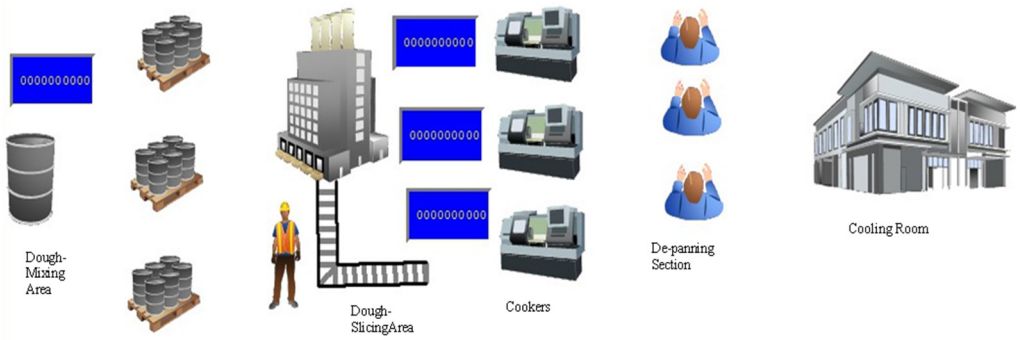


Figure 3. Steaming line initial layout illustrated through Promodel 2016.

3.3. Analysis Stage

Figure 4 presents a fishbone diagram identifying root causes of bottlenecks in the steaming line, based on data from production meetings, incident and maintenance reports, and worker surveys. Key manpower issues include high attrition, absenteeism, and limited worker skills. Process inefficiencies stem from deviations in cooking time and reduced operator cycle time. Major technical causes include pressure drops below 12 psi, steam leaks, boiler malfunctions, and delays in reaching 100 °C. Material-related issues involve substandard raw materials, high moisture content, and poorly mixed ingredients.

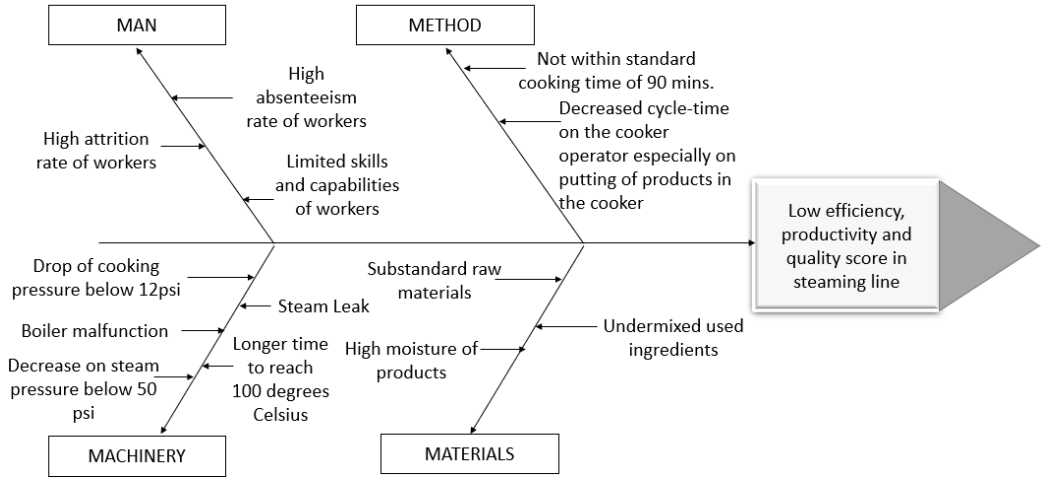


Figure 4. Fishbone diagram.

3.4. Design Stage

This stage discusses the proposed steaming line layout modification with Figure 5 that presents its ProModel 2016 CAD.

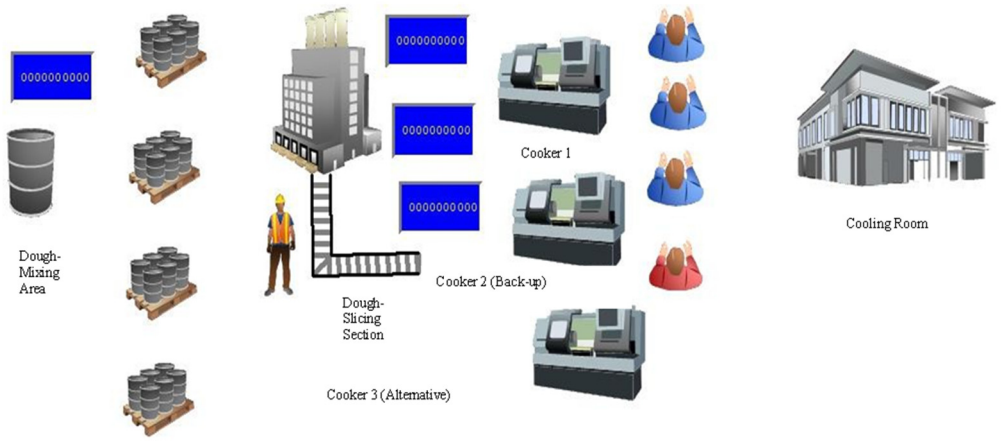
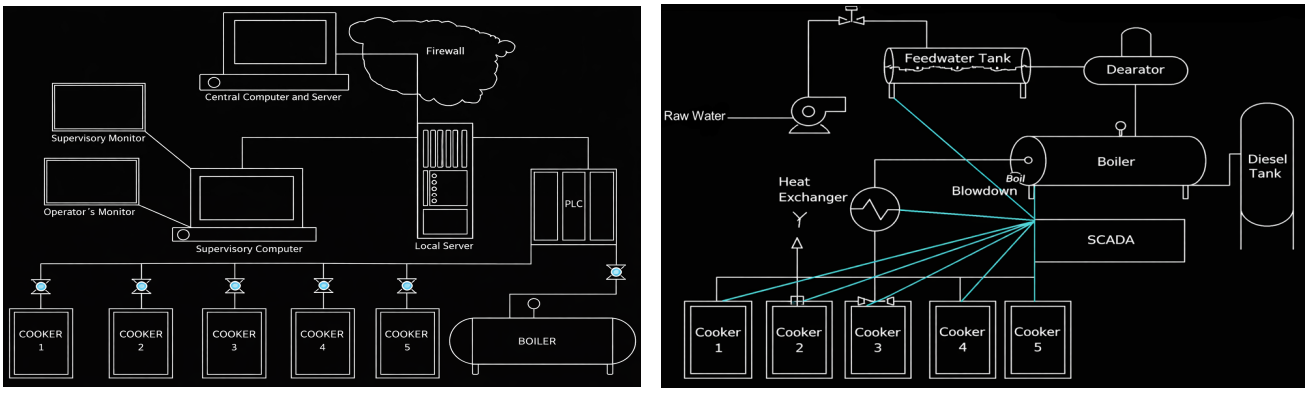


Figure 5. Steaming line-modified layout.

Downtime types—entry, usage, and clock—were considered. To reduce machine downtime, an additional dough mixer is recommended to address material-related issues, and one steamer to serve as a backup, and another as an alternative.

Figure 6a shows the SCADA network setup for real-time monitoring of steam parameters from cookers and boilers via sensors, actuators, and programmable logic controllers. Data are transmitted through RS 485 and transmission control protocol/internet protocol to a local server, visualized through human-machine interface screens located in both the control room and steaming area. Figure 6b illustrates the SCADA terminal layout for the boiler, feedwater tank, and deaerator. The system monitors temperature, volume, and steam pressure to ensure boiler efficiency and steam quality. Alerts are triggered when parameters deviate from set standards, prompting corrective actions from production, quality, and maintenance teams.



(**a**) (**b**)

Figure 6. (**a**) SCADA and network architecture of the steaming line; (**b**) SCADA terminal connections in the steaming line equipment.

3.5. Verify Stage

Simulation results show that total production in an 8-h shift increased from 1750 to 2139 kg. Dough mixer utilization improved from an average of 43.79 to 64.07% with the addition of a fourth mixer. Individual utilizations rose as follows: mixer 1 (25.73 to 53.21%), mixer 2 (53.83 to 63.57%), mixer 3 (51.81 to 67.43%), and mixer 4 (64.07%). Dough slicing utilization remained constant at 93.75%. Table 2 shows that the range of availability percentage after SCADA installation and layout modification is within 86.80 to 97.83% while OEE is within 73.18 to 82.80%.

Table 2. Monthly planned operation hours, actual operation hours, and availability (%) (August 2021–February 2022).

Date	Planned Operation Hours	Actual Operation Hours	Availability (%)	OEE (%)
August 2021	600	565	94.17%	80.75%
September 2021	600	587	97.83%	82.8%
October 2021	624	600	96.15%	80.5%
November 2021	624	600	96.15%	80.44%
December 2021	624	598	95.83%	79.9%
January 2022	624	602	96.47%	81.34%
February 2022	576	500	86.80%	73.18%

Table 3 presents the comparative changes in average availability and OEE percentages resulting from the layout modification.

Table 3. Comparison of average availability (%) and OEE (%).

Average Availability (%)			Average OEE (%)		
Before Modification (January–July 2021)	After Modification (August 2021–February 2022)	Change (%)	Before Modification (January–July 2021)	After Modification (August 2021–February 2022)	Change (%)
87.89%	94.77%	7.26%	68.82%	79.84%	13.80%

4. Conclusions

The proposed layout modification resulted in a substantial improvement in production performance, yielding an 18.19% increase in output. This enhancement can be primarily attributed to the significant improvement in the utilization of dough-mixer equipment, along with marked increases in availability percentage and OEE. A key contributing factor to this outcome was the strategic shift in operational practice, transitioning from simultaneous usage to an alternating and backup system approach for the cookers. This adjustment not only optimized equipment deployment but also minimized idle time and reduced unnecessary overlaps in resource use. Furthermore, the integration of the SCADA system proved highly effective in facilitating real-time monitoring of equipment and process parameters. This enabled more accurate tracking of operational activities and faster response times to equipment downtimes or performance deviations, contributing to enhanced process stability and decision-making.

The findings of this study underscore the importance of leveraging simulation tools, advanced monitoring technologies, and proactive operational strategies in driving measurable improvements in manufacturing system efficiency. Quantitative analyses, such as those involving key performance indicators such as OEE, are critical in validating the success of such interventions. For future work, it is recommended that simulation-based improvements be validated through actual on-site implementation. Such validation should encompass not only productivity metrics but also a comprehensive evaluation of their effects on operational costs, energy consumption, and overall sustainability of the production system.

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