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Assembly Line Integration as a Lever for Efficiency and Space Utilization in Automotive Parts Production

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Abstract

1. Introduction

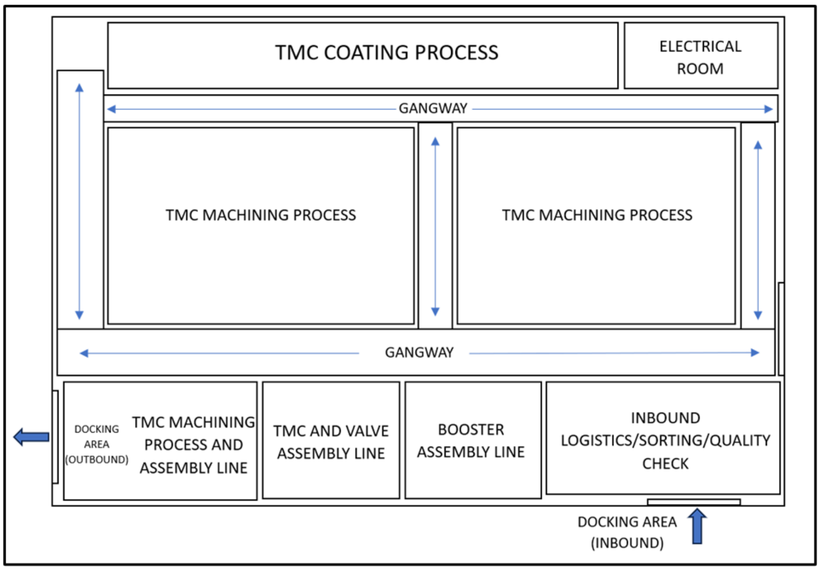
The drive towards optimized space utilization in manufacturing is underpinned by the recognition that space is a limited and costly resource. Effective space utilization not only impacts productivity and efficiency but also plays a critical role in the strategic planning of factory layouts. The goal of achieving optimal space utilization involves minimizing area occupancy while maximizing value-adding potential per unit of floor space. This concept is integral to lean manufacturing principles, where the focus is on value-adding activities and the minimization of waste, including the inefficient use of space. Various metrics, such as surface area productivity in retail, offer insights into the effectiveness of space utilization by measuring outputs, such as turnover per square foot, in relation to space occupied.

In manufacturing and assembly environments, optimizing space involves a detailed analysis of value-adding, value-supporting, and waste areas. This includes the designation of workspaces, handling areas, and storage as either contributing to or detracting from the efficiency of space use. The challenge lies in the multitude of factors that must be considered, including safety clearances, escape route widths, and the overlapping of functional areas, which complicate the measurement and achievement of optimum space utilization.

The approach to floor space planning typically involves comparing different facility arrangement variants, using area balances to measure space usage across various categories and their proportions of the total floor space. This process highlights the importance of detailed planning and the need for tools and methodologies that can simplify and enhance the layout planning process.

Manufacturing layout optimization, therefore, does not necessarily require significant investments but can lead to substantial improvements. Simple changes to the layout can yield 50 to 80 percent improvements in space efficiency. This optimization is crucial not only for enhancing production efficiency but also for adapting to changes and challenges, such as those posed by the COVID-19 pandemic, which forced manufacturers to reconsider factory layouts to ensure safety and continuity of operations. The pandemic underscored the importance of flexible and efficient use of space to meet evolving operational and safety requirements.

Keywords: Space utilization, Lean Manufacturing, Manufacturing Layout Optimization.



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2. Literature Review

Recent advancements in manufacturing processes emphasize the importance of integrating assembly lines to optimize space utilization, enhance efficiency, and reduce operational costs. A growing body of research has explored various aspects of this topic, focusing on technological innovations, methodologies, and practical applications in different industrial contexts.

Xue, Liu, Wu, and Tong (2020) highlighted the potential of In-space Assembly (ISA) technologies in adapting to the assembly of large space structures, improving spacecraft performance, and reducing operating costs. They pointed out that ISA technologies are crucial for future human space exploration, underscoring the importance of assembly structure design, robot technologies, and integrated management technologies (Xue, Liu, Wu, & Tong, 2020).

Liu et al. (2020) developed an integrated optimization control method for the remanufacturing assembly system, demonstrating how optimized control can improve the quality of remanufactured products and reduce the cost of reassembly systems. Their findings illustrate the significance of dynamic programming in assembly process optimization (Liu, Zhu, Wei, Rao, Liu, Hu, & Cai, 2020).

Yi et al. (2020) proposed a digital twin-based smart assembly process design for complex products, emphasizing the deep integration between information and physical worlds to bridge the gap between product assembly design and manufacturing. The study showcases the application of digital twin technology in improving assembly process planning, simulation, prediction, and control management (Yi, Yan, Liu, Ni, Feng, & Liu, 2020).

Vilda et al. (2018) presented a geometrical model for optimizing U-shaped assembly line (U-SAL) surface productivity. Their industry-validated model connects the drivers for market, product, and process with geometrical design, offering a novel approach to layout design for enhanced space productivity (Vilda, Yagüe-Fabra, Torrents, Jauregui-Becker, & Wits, 2018).

These studies collectively illustrate the nature of assembly line integration and space optimization in manufacturing. By leveraging advanced technologies, innovative methodologies, and holistic approaches, significant improvements in manufacturing efficiency and productivity can be achieved.

3. Methodology

3.1. Objectives

1. To optimize space utilization within the automotive parts production facility
2. To reduce cost in the integrated assembly lines with labor optimization.
3. To maximize the efficiency and effectiveness of the integrated assembly line machinery.

3.2. Research Design

This study employs a sequential explanatory mixed-method design, characterized by two distinct phases: an initial quantitative phase followed by a qualitative phase. This design is particularly suited for research aiming to not only quantify changes or outcomes (e.g., in operational efficiency, space utilization) but also to understand the underlying reasons, stakeholder perceptions, and contextual factors behind those numbers.

3.3. Quantitative Phase:

The first phase involves collecting and analyzing numerical data. This phase is critical for establishing baseline measurements (pre-integration) and assessing outcomes (post-integration), allowing for a clear comparison of key performance indicators (KPIs) such as space utilization, manpower efficiency, operational costs, Overall Equipment Efficiency (OEE), and First Pass Yield (FPY). Data will be collected through:

Direct Measurement: Utilizing floor plans, operational records, and production data to assess changes in space utilization and efficiency metrics.

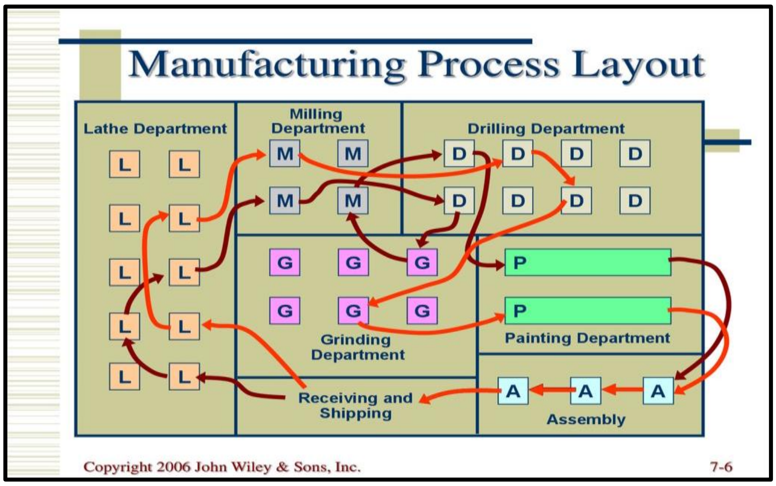
Surveys: Deploying structured questionnaires to relevant personnel to quantify perceptions of changes in workflow, productivity, and safety.

3.4. Qualitative Phase:

Following the quantitative analysis, the second phase aims to explore the "how" and "why" behind the quantitative results. This phase enriches the study's findings by providing depth and context to the numerical data. Methods include:

Semi-structured Interviews: Conducting interviews with key stakeholders, including project managers, engineers, and floor staff, to gather detailed insights into their experiences, perceptions, and the impact of the integration on their work.

Observations: Observing the manufacturing environment post-integration to note changes in workflow, employee interactions, studying different types of layouts (fig. given below) and the use of space.



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Document Review: Analyzing project reports, meeting minutes, and internal communications to understand the planning, challenges, and decision-making processes behind the integration.

3.5. Data Collected

Pre-integration:

Space Utilized (Area): The total area utilized by the assembly lines was 450 m^2.

Manpower (Quantity/Units): A total of 13 employees were required to operate the assembly lines.

Cost (Salary): The operational cost in terms of salary was ₹2,600,000.

Overall Equipment Efficiency (OEE): The OEE was recorded at 72%.

First Pass Yield (FPY): The FPY was between 82-85%.

Post-integration:

Space Utilized (Area): The area utilization was reduced to 168.75 m^2, indicating a significant improvement in space efficiency.

Manpower (Quantity/Units): The required manpower decreased to 10 employees.

Cost (Salary): Operational costs in terms of salaries were reduced to ₹2,000,000.

Overall Equipment Efficiency (OEE): OEE increased to a range of 78-80%.

First Pass Yield (FPY): FPY improved to 90%.

3.6. Hypotheses and Justifications

1. Hypothesis 1 (H1): Assembly line integration significantly improves space optimization in a manufacturing environment.
   Justification: The reduction in space utilization from 450 m^2 to 168.75 m^2 post-integration provides a tangible measure of improved space efficiency, suggesting that integration can lead to significant space savings.
2. Hypothesis 2 (H2): Assembly line integration significantly reduces operational costs in a manufacturing environment.
   Justification: The decrease in operational costs, specifically salaries, from ₹2,600,000 to ₹2,000,000 post-integration indicates a direct financial benefit of integrating assembly lines, supporting the hypothesis that integration can reduce costs.
3. Hypothesis 3 (H3): Assembly line integration significantly enhances production efficiency in a manufacturing environment.
   Justification: The improvement in OEE from 72% to 78-80% and FPY from 82-85% to 90% post-integration suggests enhanced production efficiency and product quality, affirming the hypothesis that integration can positively impact production outcomes.

3.7. Questionnaire

1. How would you describe the workflow and space utilization on the assembly line before the integration process began?
2. What were some of the biggest challenges or inefficiencies you encountered with the assembly line setup before integration?
3. Prior to the integration, what improvements or changes were you most anticipating?
4. How has the integration affected the utilization of space within your work area?
5. In what ways has the workflow and overall efficiency changed on the assembly line after the integration?
6. How did you and your team adapt to the new processes and layouts introduced by the integration? Were there any challenges or successes during this transition?

7. Please specify your views on the new safety systems which were put in place.
8. Based on your experience, do you have any feedback or suggestions that could help improve future integration projects or operational enhancements?

3.8. Analytical Framework

The analysis employs a combination of statistical methods to quantify the impact of assembly line integration on key performance metrics and thematic analysis for qualitative data to extract insights on process improvements, safety enhancements, and workforce adaptation. This dual approach allows for a comprehensive understanding of the integration's effectiveness and its contribution to space optimization and manufacturing efficiency.

3.9. Review of Existing Literature and Best Practices

In addition to primary data collected from the case study, this research incorporates a systematic review of related literature, including academic journals, industry reports, and case studies on manufacturing efficiency, space optimization, and assembly line integration. This review helps to contextualize the findings within the broader field of manufacturing engineering and identify emerging trends and methodologies that could further enhance space utilization and production efficiency.

4. Results

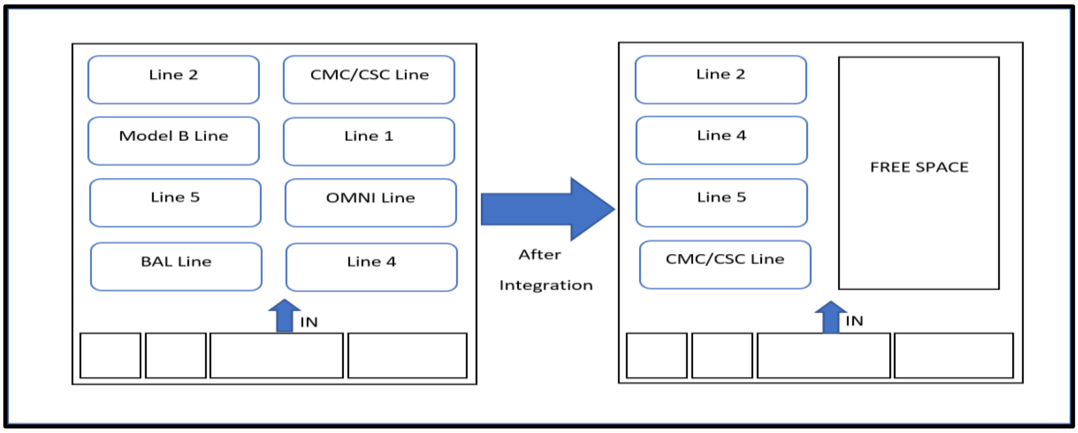
The strategic integration of conventional TMC assembly lines at Bosch Chassis Systems India Pvt. Ltd. achieved remarkable outcomes in space utilization, operational efficiency, cost savings, and safety improvements. By consolidating assembly lines, the project realized a substantial reduction in required floor space, from 450 m^2 to 168.75 m^2, marking a 62.5% decrease. This freed up valuable space within the facility, enabling the accommodation of new production lines or the expansion of existing ones without the need for physical expansion of the premises.

A. Space Utilization and Efficiency:

Pre-integration: The TMC assembly lines initially occupied a total area of 450 m^2.

Post-integration: The consolidated assembly line system now requires only 168.75 m^2, freeing up 281.25 m^2 of floor space.

This optimization was achieved through a detailed analysis and restructuring of the production floor, utilizing principles of lean manufacturing and efficient layout design. The integration process included the reevaluation of machinery placement, workflow paths, and the implementation of more compact, multifunctional equipment.



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B. Operational Cost Reduction:

Manpower: The number of operators required was reduced from 13 to 10, directly impacting labor costs.

Cost Savings: A significant reduction in operational costs was noted, with savings of approximately ₹6,00,000.

These savings are attributed to the decreased need for manpower.

The project utilized automation and Human-Machine Interface (HMI) programs to further reduce manual interventions, streamlining the production process.

C. Improvement in Production Metrics:

Overall Equipment Efficiency (OEE) saw an increase of 6-8%, rising from 72% pre-integration to 78-80% post-integration.

First Pass Yield (FPY) improved by 5-8%, from an initial rate of 82-85% to 90% post-integration.

These improvements reflect the project's success in enhancing operational reliability and product quality. The integration allowed for more consistent production processes, reduced downtime, and minimized defects and rework.

Sr. No.	Factors	Before Integration (Numerical Representation)	Before Integration (Change)	After Integration (Numerical Representation)	After Integration (Change)
1	Space utilized (Area)	450 m2	N/A	168.75 m2	281.25 m2 space freed with respect to original area
2	Manpower (Quantity/ Units)	13	N/A	10	Using 10 operators instead of 13
3	Cost (Salary)	₹26,00,000	N/A	₹20,00,000	We save ₹6,00,000
4	OEE (%)	72%	N/A	78-80%	Increase of 6-8% in overall equipment efficiency
5	FPY	82-85%	N/A	90%	Increase of 5-8% in first past yield

D. Safety Enhancements:

The project also prioritized safety improvements, implementing safety measures such as enhanced ergonomics, safety curtains, and automated emergency stops. These interventions have contributed to a safer working environment, reducing the likelihood of workplace accidents, and ensuring compliance with safety regulations.

5. Discussion and findings

The integration of assembly lines into a singular, more efficient system marked a significant turning point in the manufacturing process, particularly in the optimization of space and resource utilization. This section delves deeper into the observed changes and their implications for manufacturing efficiency, drawing upon the comprehensive data analysis presented earlier.

The reduction in space utilized, from 450 m2 to 168.75 m2, signifies a 62.5% decrease in the footprint of the assembly lines. This substantial reduction highlights the effectiveness of strategic layout planning and the integration of similar production processes. The liberated space offers potential for future expansion, diversification of product lines, or the introduction of new technologies without the need for additional physical expansion, underscoring the strategic value of space optimization in manufacturing settings.

The operational changes post-integration reveals a notable increase in Overall Equipment Efficiency (OEE) by approximately 6-8%, and a First Pass Yield (FPY) improvement of 5-8%. These improvements are indicative of a more streamlined and effective production process, where each component of the assembly line is optimized for performance and quality output.

The manpower requirement reduction from 13 operators to 10 represents a 23% decrease in labor needed for operations. Coupled with a financial saving of approximately ₹600,000 in operational costs, these changes illustrate the dual benefits of process integration in both improving efficiency and reducing costs. Such savings not only bolster the financial position of the manufacturing entity but also provide a model for cost-effective manufacturing practices.

The strategic integration project underscored the importance of adapting manufacturing layouts to meet evolving operational needs. The application of the Plan-Do-Check-Act (PDCA) cycle facilitated continuous improvement and allowed for the fine-tuning of processes to achieve optimal efficiency. The increase in OEE and FPY post-integration reflects a more synchronized assembly process, with reduced downtime and higher quality output.

The findings from this case study suggest that the strategic integration of assembly lines and the thoughtful optimization of space can serve as a blueprint for future manufacturing practices. Manufacturers facing space constraints or looking to improve operational efficiency may find value in re-evaluating their layout plans and considering integration strategies similar to those implemented in this project.

6. Conclusion

In looking at how to make assembly lines better by putting them together, this research shows a smart way to use space more efficiently in factories. By moving from several separate lines to one combined one, not only did we save a lot of room, but we also made the whole process smoother, used our equipment better, and got more work done.

The clear results from combining these lines—like saving space and improving how the factory works—show that such smart moves are very important for factories today. This is more than just saving money and making things run better; it's about changing the way factories work for the better. With these changes, factories can quickly adjust to new market demands, use new technologies, and work in a way that's good for the planet.

This project also shows that putting assembly lines together can help create a better work culture. By making processes simpler and improving safety, it not only makes the best use of what the factory has but also builds a place where people are always looking to do things better and come up with new ideas. This new approach to working is key for factories to stay ahead in a world where things are always changing.

So, this study tells us that combining assembly lines is about more than just moving things around in a factory. It's a complete strategy for doing things better, including saving money, making work safer, and changing the factory's culture for the better. This way of doing things offers a strong example for other factories looking to improve, showing them the wide range of benefits from combining their operations in a smart way. The lessons learned here offer valuable tips for any factory ready to make big changes, pointing out the many advantages of being smart with space and how we work.

References

1. Xue, Z., Liu, J., Wu, C., & Tong, Y. (2020). Review of in-space assembly technologies. Chinese Journal of Aeronautics. https://www.sciencedirect.com/science/article/pii/S1000936120304854?via%3Dihub
2. Liu, C., Zhu, Q., Wei, F., Rao, W., Liu, J., Hu, J., & Cai, W. (2020). An integrated optimization control method for remanufacturing assembly system. Journal of Cleaner Production, 248, 119261. https://www.sciencedirect.com/science/article/abs/pii/S0959652619341319?via%3Dihub
3. Yi, Y., Yan, Y., Liu, X., Ni, Z., Feng, J., & Liu, J. (2020). Digital twin-based smart assembly process design and application framework for complex products and its case study. Journal of Manufacturing Systems. https://www.sciencedirect.com/science/article/abs/pii/S0278612520300571?via%3Dihub
4. Vilda, F., Yagüe-Fabra, J., Torrents, A., Jauregui-Becker, J., & Wits, W. (2018). A geometrical model for managing surface productivity of U-shaped assembly lines. Cirp Annals-manufacturing Technology, 67, 479-482. https://www.sciencedirect.com/science/article/abs/pii/S0007850618300714?via%3Dihub