Internal Logistics Improvement of Automotive Parts in an Assembly Plant

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Abstract

Overprocessing in the internal logistics of an automotive assembly plant occurs in the part sorting process identified at two sorting levels: The first level involves forklift drivers sorting parts at the skid level. In contrast, the second level entailed operators manually sorting box parts by assembly line addresses which supply by electronic car drivers via limited electronic cars and fixed routes that are unstable workloads and are inoperative under cycle time. This paper provided an approach to redesign internal routes with the Google Operation Research Tools (OR-Tools) to optimize route grouping for a balanced workload under cycle time. The simulation technique is applied to evaluate the performance of electronic car loaded capacity utilization and working under cycle time. The consequence of the calculation is the new route supply, which requires two modifications, i.e., to assign suppliers to allocate the parts boxes on the skid at a ratio of 1 skid per 1 new route to eliminate the manual box sorting process and to design the layout in transfer areas by new route for using the Automatic Guided Vehicle (AGV) system that instead of box parts sorting worker with lean manufacturing principles. The work finally concludes with a summary and outlook for the future.

Keywords
Internal Logistics, Automotive Parts, Assembly Plant, OR-Tools, and Lean Manufacturing

1. Introduction
Over the past few years, demand for automobiles or rapid innovations in the automotive industry had been burgeoning before it was put to a halt by the COVID-19 outbreak (Kaitwade 2021). However, the industry faced critical challenges before the pandemic began, significantly affecting the automotive production volume. Jehan (2021) proposed to maintain profitability despite seasonal demand changes. Manufacturers must adapt and efficiently manage their processes flexibly. The automotive assembly plant always tries to adapt to changing situations by applying a lean manufacturing concept. It means producing goods using fewer resources, such as human labor and manufacturing space. To reduce waste and improve customer satisfaction.

Automotive parts management is one of the internal logistics activities in the assembly plant. The case study consists of four departments: Production Planning, Part Planning, Part Manufacturing/Suppliers, and Assembly Plant. The Production planning department is responsible for creating the monthly production plan for the Part planning department. Once the plan is created, the part planning department implements the plan for daily part ordering to suppliers who prepare the parts. The automotive parts are then set in boxes and arranged on skids for delivery to the assembly plant. The assembly plant receives 4,738-part numbers from 230 suppliers, which is a significant amount to manage. Especially internal logistics operations manage parts delivered from suppliers at the receiving dock in the assembly plant to the assembly line.

According to automotive parts that are delivered to the assembly plant by suppliers. Suppliers consider correct quantity, good quality, and timely delivery following parts ordering by the part planning department. The assembly plant receives mixed box parts on the skids. It means box parts on a skid need to be delivered to multi-lineside. That is why the assembly plant needs to have a manual box part-sorting process by assembly line addresses. However, internal logistics processes are in the assembly plant from a Lean manufacturing perspective. Overprocessing occurs in the part sorting process, as Figure 1. identified at two sorting levels: The first level involves forklift drivers sorting parts at the skid level. While the second level entailed operators manually sorting box parts by assembly line addresses. Moreover, electronic car drivers supplied box parts to the assembly line in a fixed routes pattern. Electronic car drivers did not only drive to assembly lines but also put away boxes part to lineside. However, fixed routes supply pattern affects drivers' workload and electronic car-loaded capacity utilization. This process focuses on correct quality and timely delivery. Electric car drivers must operate within a set cycle time, which presents a challenge for improvement.

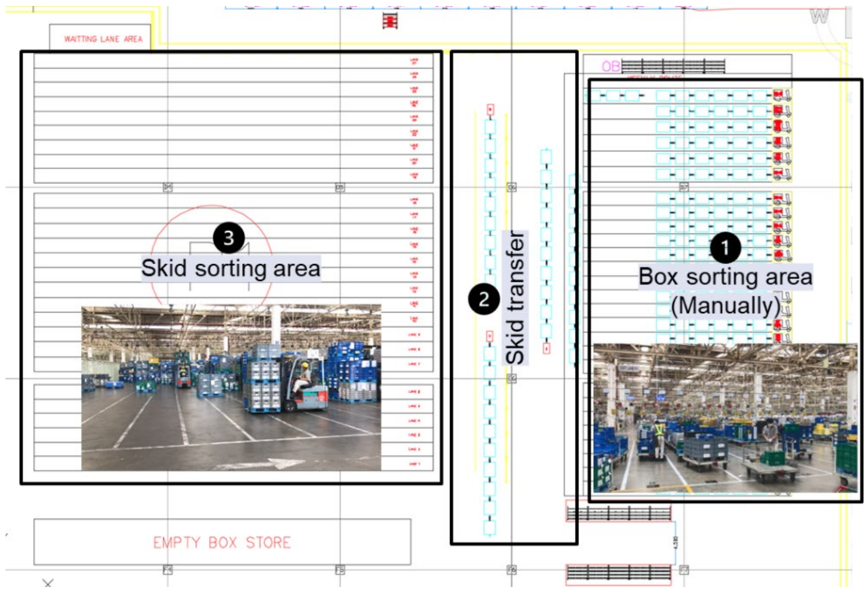

Figure 1. Part sorting process area

1.1 Objectives

This paper aims to internal logistics improvement of automotive parts in the assembly plant with Lean manufacturing concept. To eliminate overprocessing in manual automotive parts sorting with operators and to replace with the Automatic Guided Vehicle (AGV) system. which handles sorting box parts without workers. The modifications have effectively enhanced the internal logistics operation. The proposed approach is to redesign internal routes for a balanced workload under cycle time. To evaluate the consequences of the new route by simulation technique to ensure the new route be able to be running under cycle time and to enhance the efficiency of electronic car-loaded capacity utilization. The implementation of new routes for the redesigned layout has resulted in improved internal logistics.

2. Literature Review

The main basis of this theoretical review is the practices of Lean manufacturing. Lean manufacturing is a method of producing goods using minimal resources instead of mass production. This involves reducing waste, minimizing human effort, using less manufacturing space, and spending less time on engineering for new product development (Wang 2010). Overprocessing is one of the seven types of waste. This happens when activities are done excessively without adding value to the customer or the business. This waste is often caused by unnecessary attention to detail or accuracy, using tools or methods that require too much effort, or doing unnecessarily (Verenich et al. 2016). Lean thinking prioritizes creating value for the customer and reduces wasteful spending. It can also aid in decreasing overprocessing. It is a basic specific level of lean manufacturing stability (Pampanelli et al. 2014).

Sivakumar and Chong (2001) point out that the manufacturing industry is experiencing increased competition due to more global capacity. As a result, electronic component manufacturers are implementing programs to improve their market responsiveness by reducing cycle time. Efficient equipment uses through maintenance scheduling, accurate predictions, and data analysis can increase productivity, profitability, safety, and quality standards. Considering a couple of constraints in manufacturing motivates us to concentrate on vehicle travel time minimization as the objective. It would be beneficial to consider the travel time and distribution system cost when balancing the options. Evaluating the correlation between time and cost is essential to ensure a decision (Li et al. 2014).

Huang et al. (2022) explain that the process improvement method enhances subcontract manufacturing. This method involves identifying internal operational problems and analyzing manufacturing processes to determine potential

causes. Improvement actions are taken, and the process is verified for improvement. Process improvement focuses on manufacturing and customer satisfaction. Burganova et al. (2021) study design of effective internal logistics for decreasing transport time. The solution involves reorganizing the warehouse, using the systems for reorganization by turnover. This corrective action change worker utilization. The Supply plan of specific components. There is a design of a Kanban system and a necessary Kanban card. Additionally, the Milk Run System offers alternative routes with different stops and schedules. The supply system has achieved an increase in productivity.
Robotics solutions for internal logistics (Bernardo et al. 2022). It contains four topics: localization and path planning, task planning, optimization, and applications. Industry has utilized automation to enhance operational efficiency, particularly internal logistics. This advancement provides numerous benefits, including real-time loading and data analysis access, reduced errors, better managerial control, improved customer service, and increased scalability and speed. Automated Guided Vehicles (AGVs) are driverless vehicles used for horizontal material transportation (Boccia et al. 2023). They offer benefits like increased productivity, safety, and reduced costs, making them popular in manufacturing, logistics, and healthcare industries.

3. Proposed Methods

A lean organization understands customer value and focuses its key processes on increasing continuously. The goal is to provide customers with a perfect value-creation process with zero waste activities (Adeodu et al. 2023). To identify and eliminate non-value processes while providing continuous improvement. The customer defines value and develops and maintains operations to provide this value in each process. The perspective of operators is in the assembly line. Assembly operators also want to receive parts in the correct quantity, good quality, and timely delivery. At the same time, electronic car drivers must supply parts to assembly lines on time.
The Assembly plant receives mixed box parts on the skids from suppliers, which prepare parts following part order by the part planning department. Overprocessing occurred in part sorting processes. There are two levels of part sorting processes before supply to the assembly line. In the first level, forklift drivers sorted skids by lane numbers. And then, in the second level, the operators manually sorted boxes on the skids by assembly line addresses. Before the automotive part arrives at the assembly plant, several departments are involved in the process. To manage this challenge, we will implement a four-step approach in Figure 2.

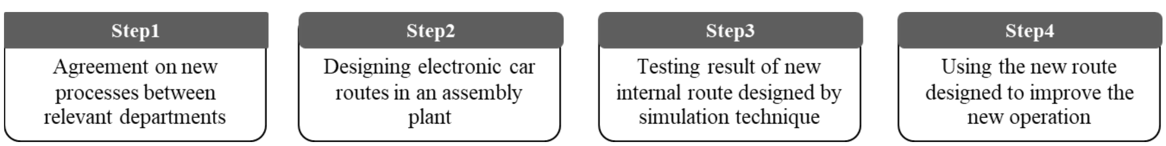

Figure 2 Four-step implementation

Step 1 Agreement on new processes between relevant departments. According to the study of the current process, it needs to improve cooperation between departments. The production planning department and the parts planning department are the departments that manage the automobile parts ordering for the assembly plant, which is directly affected by the planning of other departments. Consequently, starting from studying the limitations of the assembly plant, the assembly plant must design a new electronic car route to supply parts to assembly line addresses. Set up one new route supply per skid. And then, internal route information is sent to the part planning department to bring that information to the supplier to arrange box parts on skids as specified by the assembly plant to eliminate the manual sorting process at the part box level. Each department needs to make an agreement together for this requirement for the assembly plant.
Step 2 Designing electronic car routes in an assembly plant. Google for Developers (2021) develop Operation Research Tools (OR-Tools), an open-source software for combinatorial optimization, that seeks to find the best solution to a problem out of a vast set of possible solutions. To execute commands, use the Python programming language to apply mathematical models in the form of Capacitated Vehicle Routing Problem (CVRP) to find the "best possible value" for the function. The purpose (Objective function) on the condition (Constraint set). The procedure for using OR-Tools in Python language has the following steps.

1. Import the required libraries.
2. Enter the command that the solver type to solve that problem.
3. Define program variables
4. Set program conditions (Constraint set)
5. Define the objective function

6. Generate commands for the Solver to run and display the results.

Step 3 Testing the result of the new internal route designed by a simulation technique. The method focuses on two approaches. Firstly, Electronic car drivers can supply parts whose volume fluctuates under cycle time. In this section, we first define the following variable for calculation. We analyze the total cycle time simulation following formula (1) as the sum of traveling time and operation time.

S_i	Traveling distance of new route
V	The speed of electronic car
i	Route number, where $i = 1,2,3 \dots I$
BP_i	The Number of box part in route number i
EB_i	The Number of empty boxes in route number i
T_{BP_i}	Put away box parts time per BP_i
T_{EB_i}	Put away empty box time per EB_i
C_i	The Number of electronic cars in route number i
TR_i	The Number of trips in route number i
CT_i	Total cycle time for route number i
D_i	The Number of part volumes in route number i
CP_i	Capacity of electronic car in route number i
UT_i	The electronic car-loaded capacity utilization car for route number i

Based on our definition

$$CT_i = \left[\sum_{i=1}^{I} \frac{S_i}{V} + \sum_{i=1}^{I} \frac{BP_i T_{BP_i} + EB_i T_{EB_i}}{C_i} \right] TR_i \tag{1}$$

And secondly, electronic car-loaded capacity utilization is fully efficient following formula (2)

$$UT_i = \sum_{i=1}^{I} \frac{D_i}{CP_i TR_i} \times 100 \tag{2}$$

Step 4 Using the new route designed to improve the new operation. After an agreement with suppliers for arranged boxes part on the skids, one route per skid following the assembly plant condition, the manual box sorting was unnecessary. We must convey parts for the skid sorting area to the original manual boxes sorting area without workers. An automated Guided Vehicle (AGV) is a portable robot that follows along marked long lines. We considered the AGV system for conveying parts instead of box sorting operators.

4. Results and Discussion

The company of automotive manufacturing enterprise in Thailand was studied. The company operates with modern production capabilities and high experience in automotive assembly manufacturing. For this implementation, highly have made efforts to agree with 250 suppliers for new requirements established by the assembly plant.

4.1 Agreement on new processes between relevant departments

Following Figure 3, New internal route data has been added to the part ordering data, revealing that new requirements from the assembly plant will impact multiple departments. Especially suppliers need to adjust their operations. To ensure a successful transition to the new process, we suggest studying the effect on each department and implementing a pilot phase where potential issues can be tested and addressed. This approach will lead to a smoother transition and better overall outcomes.

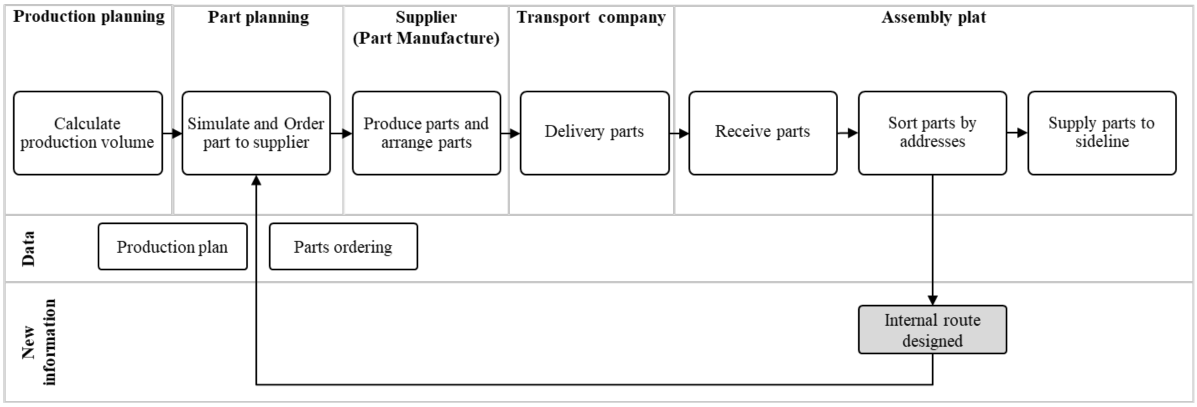

Figure 3. Operation flow

4.2 Designing electronic car routes in an assembly plant.

The results from the OR-tool calculation will show the total distance of all routes, the sequence of transport from the beginning to the destination of each route, the total distance of each route, The electronic car-loaded capacity, and the total electronic car-loaded capacity. The researcher has created Table 1. to collect data and consider it according to the program running time according to the following topics.

1. Total distance of all routes
2. The most significant number of drop-off points in each transport route
3. Average distance of each transport route
4. The longest distance in transportation

Teble1. Result of OR-tools running time of 60 seconds

Route No.	Route name	Sequence	Seq.1	Seq.2	Seq.3	Seq.4	Seq.5	Distance	Loading	Delivery Point
1	A	0 Load(0) -> 20 Load(4) -> 1 Load(9) -> 14 Load(16) -> 0 Load(16)	B-Lane	T2	RSB	SX	B-Lane	1320	16	3
2	B	0 Load(0) -> 19 Load(9) -> 18 Load(16) -> 0 Load(16)	B-Lane	FB	FA	B-Lane		920	16	2
3	C	0 Load(0) -> 21 Load(12) -> 17 Load(14) -> 16 Load(15) -> 0 Load(15)	B-Lane	F1	EG	C2	B-Lane	840	15	3
4	D	0 Load(0) -> 26 Load(5) -> 11 Load(16) -> 0 Load(16)	B-Lane	C1	SJ	B-Lane		820	16	2
5	E	0 Load(0) -> 4 Load(4) -> 22 Load(8) -> 25 Load(16) -> 0 Load(16)	B-Lane	SC	F3	F2	B-Lane	580	16	3
6	F	0 Load(0) -> 5 Load(11) -> 24 Load(16) -> 0 Load(16)	B-Lane	SD	AX	B-Lane		500	16	2
7	G	0 Load(0) -> 15 Load(6) -> 23 Load(15) -> 0 Load(15)	B-Lane	SY	T1	B-Lane		340	15	2
8	H	0 Load(0) -> 8 Load(11) -> 12 Load(14) -> 0 Load(14)	B-Lane	SG	SK	B-Lane		290	14	2
9	I	0 Load(0) -> 10 Load(7) -> 13 Load(16) -> 0 Load(16)	B-Lane	SI	SW	B-Lane		240	16	2
10	J	0 Load(0) -> 6 Load(10) -> 3 Load(15) -> 0 Load(15)	B-Lane	SE	SB	B-Lane		220	15	2
11	K	0 Load(0) -> 2 Load(15) -> 0 Load(15)	B-Lane	SA	B-Lane			200	15	1
12	L	0 Load(0) -> 9 Load(7) -> 7 Load(14) -> 0 Load(14)	B-Lane	SH	SF	B-Lane		190	14	2

4.3 Testing result of new internal route designed by a simulation technique.

To ensure the efficient operation of our new internal route, we used 24 real demand data sets to simulate. That represents the feasibility of working in the process with new routes designed. We calculated the total cycle time by factoring in operation and traveling time using the formula (1). We established a cycle time of 2400 seconds for the route based on our calculations. The simulation result is shown in Table 2. Suppose results are over the cycle in each route of highlighted data sets. Considering the average cycle time of each route is not over the cycle time. That means feasible using this new internal route.

Table 2. Cycle time simulation results

Route	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Data 8	Data 9	Data 10	Data 11	Data 12	Data 13	Data 14	Data 15	Data 16	Data 17	Data 18	Data 19	Data 20	Data 21	Data 22	Data 23	Data 24	Average
A	2998	1141	1209	2618	2753	1066	1224	2833	2923	1199	3128	1359	1334	1029	1311	1344	3253	1049	1206	3118	1209	1294	1339	1329	1803
B	1011	2576	2231	976	846	2291	886	776	3166	2666	966	908	823	1031	911	1013	2286	2266	1021	628	2506	2796	663	2311	1565
C	870	2049	935	2404	2304	947	2129	895	797	2134	2374	970	957	1035	1027	1087	922	847	1137	1105	867	2274	2459	865	1391
D	2458	2263	1054	1064	2248	834	912	2038	1034	879	2388	1099	947	1174	1144	1039	974	992	944	1137	932	1119	1027	814	1272
E	831	843	1947	1767	1802	2447	2022	2167	923	866	901	1131	836	823	1091	1003	838	2287	963	936	1053	916	1063	978	1268
F	742	1904	605	2149	602	1849	1664	2159	625	1764	570	2104	627	2024	605	917	640	850	835	2254	610	832	605	2654	1258
G	800	1670	1690	680	1820	575	2130	1535	550	707	1850	665	1910	775	747	855	740	665	2005	835	570	615	792	570	1073
H	587	624	617	634	1588	634	657	1793	654	749	787	1723	594	747	724	684	812	704	679	674	674	742	694	1448	843
I	1562	2037	1897	1442	1707	1612	1397	1412	788	1622	2032	678	756	831	931	698	896	2092	813	583	786	748	2197	653	1257
J	688	666	1681	2036	1766	666	1596	653	713	798	1601	798	666	613	736	846	706	661	783	871	691	736	708	1656	972
K	1646	1591	435	570	1546	1601	1726	1411	575	723	530	553	1961	1736	710	573	663	798	618	570	793	798	1901	688	1030
L	1430	645	738	493	503	1390	673	480	668	518	380	1670	695	673	1525	468	430	658	665	433	738	540	423	1610	769

Moreover, it is essential to balance the workload in each route. The calculation was based on volume demands. We can simulate the electronic car-loaded capacity as per formula (2) for evaluation, as shown in Figure 4. On the new internal route, the average utilization of electric cars is 90%, meaning a well-balanced load capacity.

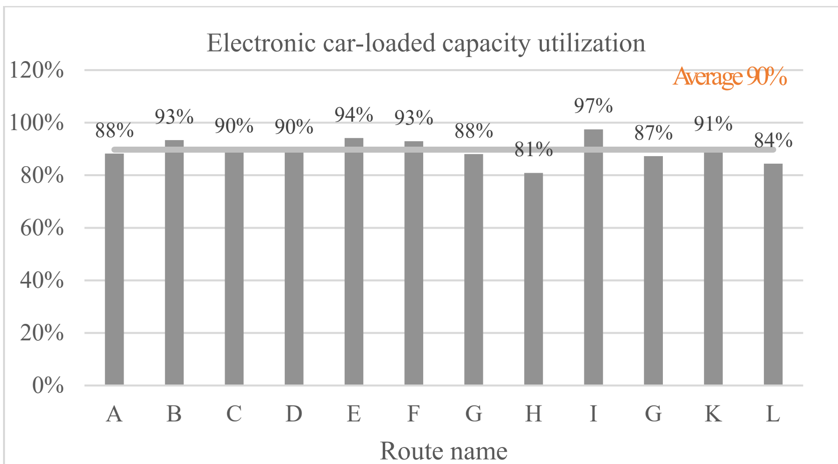

Figure 4. Electronic car-loaded capacity stimulation

4.4 Using the new route designed to improve the new operation.

The results of designing 12 new routes have been organized into three areas.

1.The transport lanes area is divided into 12 lanes, as shown number 1 in Figure 5. Each lane is labeled from Route A to L, representing the total distance of each route. Route A is the longest distance, while Route B is shorter than Route A respectively. Skid was transferred to this area by AGV.

2. The skid transfer area used for transferring skids from the skid sorting area to transport lanes area. Before improving this process, electronic cars haul skids to the manual box soring area. After improvement, AGV used for transferring skids instead of electronic car drivers. Magnet tape was attached to the floor for guild AGV moving to the transport lane area as a green line in Figure 5.

3. There are 12 lanes in the skid sorting area, separated into two sets that follow a new route as number 3 Figure 5. The forklift drivers are responsible for sorting the skids per the new route. After sorting, each skid is transferred individually to the skid transfer area.

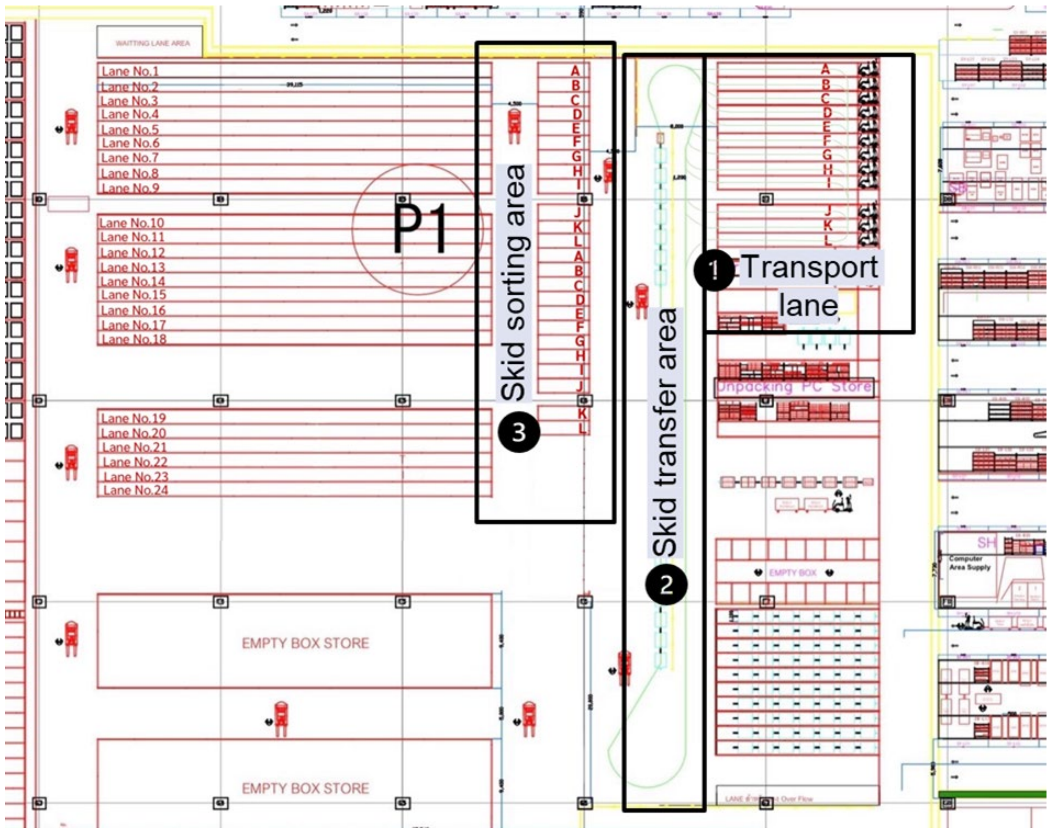

Figure 5. New layout for operation improvement

5. Conclusion

This paper presented a four-step implementation approach to eliminate overprocessing in the manual box sorting process. It has been identified that there is a need to improve the cooperation between departments, particularly between the production planning and the parts planning department. These two departments are responsible for managing the automobile parts ordering for the assembly plant, which is directly affected.

The assembly plant must design a new electronic car route to supply parts to assembly line addresses to address this issue. To develop a new route supply per skid sent to the part planning department to coordinate with the supplier to arrange box parts on skids as specified by the assembly plant. The proposed approach can eliminate the manual sorting process at the part box level. All departments must agree to this requirement together. New internal route data needs to be added in part ordering data. It will impact multiple departments, particularly the suppliers, who need to adjust their operations. We recommended studying the effect on each department and implementing a pilot phase to lead to a smoother transition and better overall outcomes.

The simulation results confirm the feasibility of the new internal route that works under cycle time. Workload balance is efficient in routes, mainly when calculating based on volume demands. The electronic car-loaded capacity utilization is significant for evaluation. In conclusion, balancing the workload in each route is essential for optimal electronic car-loaded capacity utilization.

We need to understand the current situation before operation improvement. In this case, the study parts condition is managed by another department. We consider internal factors regarding the assembly plant in the current situation. The assembly plant needs to eliminate a manual box sorting process and change direct supply to lineside if we have a precise requirement. We can generate ideas for improvement.

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Biography

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