Transportation of part supply improvement in agricultural machinery assembly plant

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Abstract. This research focused on the problem caused by the transportation of part supply in agricultural machinery assembly plant in Thailand, which is one of the processes that are critical to the whole production process. If poorly managed, it will affect transportation of part supply, the emergence of sink cost, quality problems, and the ability to respond to the needs of the customers in time. Since the competition in the agricultural machinery market is more intense, the efficiency of part transportation process has to be improved. In this study, the process of transporting parts of the plant was studied and it was found that the efficiency of the process of transporting parts from the sub assembly line to its main assembly line was 83%. The approach to the performance improvement is done by using the Lean tool to limit wastes based on the ECRS principle and applying pull production system by changing the transportation method to operate as milkrun for transportation of parts to synchronize with the part demands of the main assembly line. After the transportation of parts from sub-assembly line to the main assembly line was improved, the efficiency raised to 98% and transportation process cost was saved to 540,000 Baht per year.

1. Introduction
Agricultural machinery assembly plant under this case study has produced and distributed products both domestically and internationally. It is a leading agricultural machinery plant in the industry in Thailand with a market share of more than 80 percent of the entire market. From the intense competition in the agricultural machinery market, the production process efficiency must be improved in order to meet the needs of customers on time. From the study, it was found that the problem of the factory used for the case study was the delivery of parts failed to meet the needs of the main assembly line, which affect the production process efficiency. The delivery process comprised of 6 part types packed into plastic boxes and transported by 3 electric carts as shown in Figure 1: Gear 1, Gear2, Brake Ass’y, Hydraulic Cylinder Ass’y, Lever and RR Axle. The data collected from the problems of delivering parts not meeting the demand on time in April and May 2017 as shown in Table1, it was found that the cause of parts not meeting the demand on time was by delayed delivery of the most as shown in Figure 2 resulting in the mean efficiency of the transportation of parts from sub-assembly lines to the main assembly was 83 %, which was efficient based on the transportation efficiency calculation from the equation.

\[
\text{Transportation Efficiency} = \frac{\text{Number of trips to deliver on time}}{\text{Total number of all delivery trips}}
\]  

(1)
Figure 1. Electric cart for part supply.

Table 1. Late parts deliver data.

| Part Supply Cycle | APRIL | MAY |
|-------------------|-------|-----|
| Detail            |       |     |
| Picking Delay     | 24    | 37  |
| Supply Delay      | 186   | 254 |
| Other             | 3     | 2   |

| Part Supply Efficiency | Percentage |
|------------------------|------------|
| APRIL                  | 82         |
| MAY                    | 84         |

Figure 2. Pareto chart of part supply problem.

2. Problem analysis
From the analysis on the parts transportation in the current Flow Process Chart and a summary of its activities in the transport process as shown in Table 2, it was found that the performance of 3 electric carts drivers cause the wastes in the process as follows.

Table 2. Part transportation process activities.

| No. | Flow Process Chart | Activity |
|-----|--------------------|----------|
|     | Brake Ass'y        | 1        |
|     | Gear1, Gear2, Hydraulic Cylinder Ass'y | 2 |
|     | Lever, RR Axle     | 3        |
|     | Total              | 23       |

2.1 Delivery routes
There are different transportation routes for the 3 electric carts to deliver small parts from the sub-assembly line to the main assembly line. The transportation routes are also not straight, which requires
more time to transport. As seen in Table 3 and Figure 3, the transportation distance of the 6 part types was a total of 622 meters. The 1st transport vehicle took 560 seconds to transport Brake Ass'y. The 2nd transport vehicle took 645 seconds to transport Gear1, Gear2, and Hydraulic Ass'y at. The 3rd vehicle took 629 seconds to transport the lever and RR Axle.

Table 3: The transportation distance and time data.

| Route | Part for Supply                  | Distance (meter) | Cycle Time (second) |
|-------|----------------------------------|------------------|---------------------|
| 1     | Brake Ass'y                      | 175              | 560                 |
| 2     | Gear1, Gear2, Hydraulic Ass'y    | 224              | 643                 |
| 3     | Lever, RR Axle                   | 223              | 629                 |
| Total |                                  | 622              | 1832                |

Figure 3. Part supply route.

2.2 Procedures
From the analysis on Flow Process Chart, the procedures required staffs to unload parts and empty containers from vehicles every time were found. The parts and empty container unloading points are in different positions. This makes employees lose more time to work. From the study on the time required to unload parts and empty containers by all 3 drivers as described in Table 4, the process took a total of 442 seconds per 1 transportation from the sub-assembly line to its main assembly line.

Table 4: Time spent to unload parts and empty containers.

| Cart | Part                        | Time (sec) |
|------|-----------------------------|------------|
| 1    | Brake Ass'y                 | 90         |
| 2    | Gear 1                      | 131        |
|      | Gear 2                      |            |
|      | Hydraulic Cylinder Ass'y    |            |
| 3    | Lever                       | 221        |
|      | RR Axle                     |            |

3. Process improvement
Wastes removal tool based on ECRS and pull system were used to improve the efficiency of the transportation process of agricultural machinery parts for the part transport process to synchronize with the demand of the main assembly line. There were totaling four approaches to the improvements as follows:

3.1. Improving the transport routes
The objective was to reduce the distance between the sub-assembly line to the main assembly line by improving the layout of the sub-assembly line location and defining the receiving point to be facing the road used for the transportation of all the components as shown in Figure 4. So the Milkrun car will pick up the parts in a single route and straight line. This results in the transport routes after the improvement be at a distance of 250 meters, as shown in Figure 5, down from the original 412 meters.
3.2 Improving the parts loading/unloading system

The objective was to reduce the loading/unloading process of return boxes and part boxes with the staffs having to park the vehicle each and every time to load empty containers and drive to the part loading point to load the parts into vehicles (Receive) or the delivery point, which is a waste that occurs in the process. Therefore, the concept of preparation and loading empty containers and part container in the same position was used to solve such problems and it is also automatically loaded as shown in Figure 6. This results in the drivers not having to get out of the vehicle to perform the loading or hooking up with another vehicle. It could reduce the time the process of loading return box and part box from 442 seconds to 150 seconds per transportation.

Figure 4. Sub assembly layout.

Figure 5. Part supply route for milkrun.

Figure 6. Auto load system.
3.3 Improving the transport system to Milkrun
Milkrun vehicle concept is from the need to deliver the required number of parts to synchronize with the main assembly line demand to solve the problem of on time delivery or not exceeding the required number. This affects performance, cost of production in this agricultural machinery factory. The design of the Milkrun principle for the transportation of parts from the sub-assembly line to the main assembly line is to deliver parts that need to be delivered to the destinations that are on the same route to be delivered by the same vehicle. However, with the limitation that not all parts can be placed on the same Milkrun vehicle because of the length of the Milkrun, which affects the efficiency of the control of the vehicle turning into curves. Therefore the vehicles are split into 2 units: the 1st vehicle would transport Gear 1, Gear 2 and Brake Ass'y parts as shown in Figure 7 cars. The 2nd one would transport Lever and RR Axle parts as shown in Figure 8.

![Figure 7. Milkrun No.1.](image1)
![Figure 8. Milkrun No.2.](image2)

3.4. Visual control system
This was designed to synchronize a form of parts transport between the vehicles and the main assembly line so the idea of changing transportation system parts from push system a production system to push to pull system to achieve a transport system that automatically meets the needs of customers. If the customer does not pull the parts to assemble, the transportation will not happen. Visual Control system was set up by empty containers at the main assembly line to set the part transportation, which can be calculated from the number of boxes in the part transportation system resulted in 10 containers from the equation as follows:

\[
\text{number of part box in system} = \text{number of parts box at the receiving} + \text{number of parts box at the delivery} + \text{number of part box on milkrun} \quad (2)
\]

\[
\text{number of parts box at the receiving/delivery} = \frac{\text{Cycle time}}{\text{Take time}} + \text{Safety Stock}
\]

This also made it possible to determine Visual Control method as shown in Figure 9.
4. Results and discussion
After performing the improvement with ECRS and pull production system as tools to get rid of wastes, the time spent to transport part from a sub-assembly line to the main assembly line dropped from 1,812 seconds to 625 seconds. It was 65.5% working time reduction from the original work as seen in Table 5 and resulted in the need for only 2 electric carts from originally needing 3 carts so it the cost of transportation could be saved by 540.00 baht per year.

Table 5. Flow process chart after improvement.
For the implementation of the improvements, the mean efficiency of the transportation of part supply in agricultural machinery assembly plant was about 98 %, which was higher than the original being at approximately 83% as information on part delivery problems shown on Table 1. The improvements has also made the transportation systems to synchronize between parts delivering vehicles and the main assembly line. And all result show as Table 6.

Table 6. Result after improvement.

| Event Description                              | Time (Second) | Distance (Mile) | Method Recommendation |
|-----------------------------------------------|---------------|-----------------|-----------------------|
| Receive part box and delivery return box of RR Axle at receiving station | 30            |                |                       |
| Transport to receive RR Axle                  |               |                |                       |
| Receive part box and delivery return box of Lever at receiving station | 35            |                |                       |
| Transport to receive Lever                    |               |                |                       |
| Receive part box and delivery return box of Hydraulic Assy at receiving station | 35            |                |                       |
| Transport to receive Hydraulic Assy          |               |                |                       |
| Return to receiving station of Gear           | 160           | 98             |                       |
| Transport to receive Gear                     |               |                |                       |
| Receive part box and delivery return box of Gear at delivery station | 95            |                |                       |
| Transport to delivery Gear                    |               |                |                       |
| Delivery part box and receive return box of RR Axle at delivery station | 95            |                |                       |
| Transport to delivering RR Axle              |               |                |                       |
| Delivery part box and receive return box of Lever at delivery station | 35            |                |                       |
| Transport to delivering Lever                |               |                |                       |
| Delivery part box and receive return box of Hydraulic Assy at delivery station | 35            |                |                       |
| Transport to delivering Hydraulic Assy        |               |                |                       |
| Return to receiving station of Gear           | 160           | 98             |                       |
| Transport to receiving station of Gear       |               |                |                       |
| Receive return box of Lever                  | 35            | 75.9           |                       |
| Transport to receiving station of Lever      |               |                |                       |
| Return to receiving station of Gear           | 123           | 625            |                       |

| Event Description                              | Time (Second) | Distance (Mile) | Method Recommendation |
|-----------------------------------------------|---------------|-----------------|-----------------------|
| Receive part box and delivery return box of RR Axle at receiving station | 30            |                |                       |
| Transport to receive RR Axle                  |               |                |                       |
| Receive part box and delivery return box of Lever at receiving station | 35            |                |                       |
| Transport to receive Lever                    |               |                |                       |
| Receive part box and delivery return box of Hydraulic Assy at receiving station | 35            |                |                       |
| Transport to receive Hydraulic Assy          |               |                |                       |
| Return to receiving station of Gear           | 160           | 98             |                       |
| Transport to receive Gear                     |               |                |                       |
| Receive part box and delivery return box of Gear at delivery station | 95            |                |                       |
| Transport to delivery Gear                    |               |                |                       |
| Delivery part box and receive return box of RR Axle at delivery station | 95            |                |                       |
| Transport to delivering RR Axle              |               |                |                       |
| Delivery part box and receive return box of Lever at delivery station | 35            |                |                       |
| Transported receive return box of RR Axle    | 95            | 98             |                       |
| Receive return box of RR Axle                | 35            | 75.9           |                       |
| Transport to receiving station of Gear       | 160           | 98             |                       |
| Return to receiving station of Gear           | 123           | 625            |                       |

| Event Description                              | Time (Second) | Distance (Mile) | Method Recommendation |
|-----------------------------------------------|---------------|-----------------|-----------------------|
| Receive part box and delivery return box of RR Axle at receiving station | 30            |                |                       |
| Transport to receive RR Axle                  |               |                |                       |
| Receive part box and delivery return box of Lever at receiving station | 35            |                |                       |
| Transport to receive Lever                    |               |                |                       |
| Receive part box and delivery return box of Hydraulic Assy at receiving station | 35            |                |                       |
| Transport to receive Hydraulic Assy          |               |                |                       |
| Return to receiving station of Gear           | 160           | 98             |                       |
| Transport to receive Gear                     |               |                |                       |
| Receive part box and delivery return box of Gear at delivery station | 95            |                |                       |
| Transport to delivery Gear                    |               |                |                       |
| Delivery part box and receive return box of RR Axle at delivery station | 95            |                |                       |
| Transport to delivering RR Axle              |               |                |                       |
| Delivery part box and receive return box of Lever at delivery station | 35            |                |                       |
| Transported receive return box of RR Axle    | 95            | 98             |                       |
| Receive return box of RR Axle                | 35            | 75.9           |                       |
| Transport to receiving station of Gear       | 160           | 98             |                       |
| Return to receiving station of Gear           | 123           | 625            |                       |

| Event Description                              | Time (Second) | Distance (Mile) | Method Recommendation |
|-----------------------------------------------|---------------|-----------------|-----------------------|
| Receive part box and delivery return box of RR Axle at receiving station | 30            |                |                       |
| Transport to receive RR Axle                  |               |                |                       |
| Receive part box and delivery return box of Lever at receiving station | 35            |                |                       |
| Transport to receive Lever                    |               |                |                       |
| Receive part box and delivery return box of Hydraulic Assy at receiving station | 35            |                |                       |
| Transport to receive Hydraulic Assy          |               |                |                       |
| Return to receiving station of Gear           | 160           | 98             |                       |
| Transport to receive Gear                     |               |                |                       |
| Receive part box and delivery return box of Gear at delivery station | 95            |                |                       |
| Transport to delivery Gear                    |               |                |                       |
| Delivery part box and receive return box of RR Axle at delivery station | 95            |                |                       |
| Transport to delivering RR Axle              |               |                |                       |
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| Receive return box of RR Axle                | 35            | 75.9           |                       |
| Transport to receiving station of Gear       | 160           | 98             |                       |
| Return to receiving station of Gear           | 123           | 625            |                       |

5. Conclusion
The objective of this research was to improve the efficiency of the part transportation process caused by delayed transportation and the inability of the main assembly line using the ECRS principle of eliminating waste and pull production systems to synchronize transport system. This could lead to the
improvement of the efficiency of systems and processes, transportation to 98%. This results in the ability to improve the transportation system deliver the parts to meet the customer demand on time and at the desired location.

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