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Comparison of Two Assembly Line Layouts in a Rail Vehicle Factory

Dug Hee Moon[1], Dong Su Son[2], Young Hoon Lee[2], Yang Woo Shin[3]

[1]School of Industrial Engineering and Naval Architecture, Changwon National University, 20 Changwondaehak-ro, Changwon, 51140, Korea
dhmoon@changwon.ac.kr
[2]Department of Eco-friendly Marine Plant FEED Engineering, Changwon National University, 20 Changwondaehak-ro, Changwon, 51140, Korea
{sooyanet, lyh12160}@naver.com
[3]Department of Statistics, Changwon National University, 20 Changwondaehak-ro, Changwon, 51140, Korea
ywshin@changwon.ac.kr

Abstract In this paper we will discuss two different layout concepts which can be applied to rail-vehicle assembly factory. The existing system is based on the traditional flow line, and the suggested system is based on the fixed location layout. Simulation experiments indicate that the new system is better with respect to the throughput, manufacturing lead time and on-time delivery rate, and it is also robust with respect to the shortage rate, the variance of shortage time and the variance of production cycle time. The operating cost of the new system is smaller, and thus it is sustainable for the changes in manufacturing environments.

1. Introduction

The manufacturing system of rail-vehicle (or rail-car) has many differences when it is compared to the manufacturing system of an automobile. The automobile manufacturing system is designed based on the concept of 'make-to-stock' and the layout concepts of body shop, paint shop, powertrain shop and assembly shop follow the concept of flow lines (product layout) (see Moon et al., 2006). Furthermore, most of the suppliers are located near automotive factory and thus the shortages of parts can be controllable to meet the JIT (Just-in-time) contexts.

However, rail-vehicle manufacturing system is designed based on 'make-to-order' and the layout concepts of the factories are different from factories to factories. Thus, process layouts (job shop), product layouts (flow lines) or even fixed position layouts have been applied to rail-vehicle factories. Although they adopt the product layout, the number of stations and buffer capacity are limited due to the space constraint. For example, the number of stations in the assembly shop of automotive factory is more than 100, but the assembly shop of rail-vehicle consists of about 10 serial stations. This means that the cycle time of rail-vehicle factory is very longer than that of automobile factory.

Automobile had been assembled in a shop floor of which the layout concept is fixed position layout before Ford system. However it had been changed to product layout in Ford system, and the productivity of flow lines with conveyors was proved as the powerful system. This layout concept has been used until now although there have been some modifications such as U-shaped line in Toyota production system (Monden, 1983). Furthermore the concept of Canon’s cell manufacturing system has replaced the flow lines in small batch production with high variety environments (Hisashi, 2006).

There have been many articles which compare the throughput between flow lines and cellular manufacturing systems. Kim et al. (2013) showed that the flow line concept in the automated welding line of an excavator factory was worse than cell concept when mixed model production with different cycle times were considered. However, there has not been many researches which compare flow lines and fixed position layouts. Kim (2016) analysed that flow line was better than fixed position layout in the outfitting shop of ship building industry by simulation study.

A Korean rail-vehicle factory has produced rail-vehicles in an assembly shop in which workstations are designed following to the concept of flow lines. Recently, as the competition in the global market has intensified, order prices have gradually dropped and order volumes have decreased. Thus, to achieve the yearly target sales of the company, it is necessary to make more orders, and they have considered to redesign the layout of the manufacturing system which is robust and sustainable for small quantity with various kinds of products.

In this article we will discuss the robustness between two manufacturing systems, the one is the existing system as shown in Figure 1 and the other is the new system as shown in Figure 2. The major concerns are the changes of the throughput and manufacturing lead time with respect to the changes of means and variances in shortage rate, shortage period and process time by simulation experiments.

2. Configuration of the existing system

The abstract layout model of the existing rail-vehicle assembly shop is shown in Figure 1. There are four bays in the factory, and five physical stations (spaces) including one buffer space are available for each bay. One assembly line consists of 10 stations including two buffer spaces. Since two bays are connected to form one assembly line, there are two parallel assembly lines. Although the position of the buffer is fixed as shown in Figure 1, the position of buffer may be changed depending on whether the downstream process is completed or not. The reason for this flexible buffer location is that no special facilities such as machine, jig or fixture are not required for the assembly work. Because of the long length of the rail-vehicle, it can't be moved from workstation 1.4 to workstation 1.5 directly. To solve this problem, a traverser is installed on the left and right of the factory to transfer the rail-vehicle between bays. Transportation in the horizontal direction can be carried out using cranes or assembly carts.

Eight teams of workers conduct whole assembly operations and each team is responsible for one designated operation (workstation). Thus there are 16 worker teams in the shop. We assume that line balancing is completed and the average cycle time of a station is 16 hours, but it follows a given distribution functions such as TRIA(14, 16, 18).

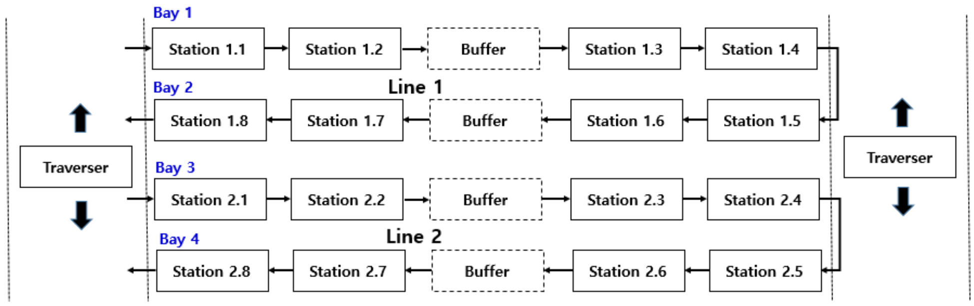


Figure 1. Layout of the existing system (flow line)

3. Configuration of new system

There have been frequent changes in design during a production period, and it results in inevitable shortages of parts. This shortage problem is the main reasons of frequent idle times of workers, blockings between stations and delays in due dates. Thus, the labour costs and the penalty cost for delays have increased gradually, and the company decided to change the layout concept from the flow line to the fixed position layout as shown in Figure 2.

In the new system the buffer spaces allowed in existing system are removed and a new traverser is installed for increasing accessibility to the workstations. When a rail-vehicle enters to the shop, a workstation is assigned to the vehicle, and the vehicle stays at the same workstation until whole assembly operations are finished. Instead of moving vehicle, worker teams moves among stations following to the assembly sequence. The company expects that the new system can enhance the productivity and cost savings, and it is also robust to the variances of shortage rate, shortage time and production cycle time.

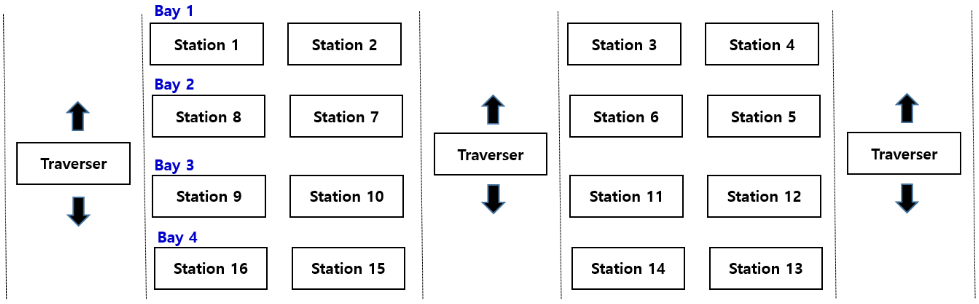
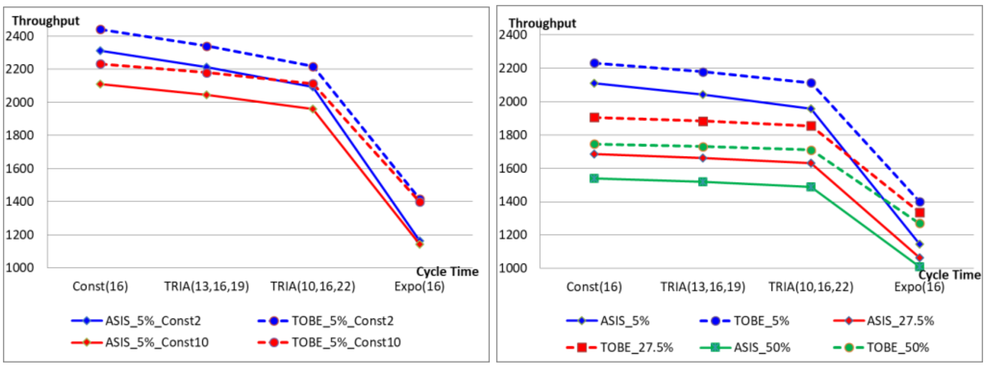


Figure 2. Layout of the new system (fixed position layout)

4. Simulation experiments and results

Various comparisons between the two systems are conducted by simulation experiments. Our concerns are which system is efficient and robust with the variations of factors which affect the system performances.



(a) Cycle time and shortage time (b) Cycle time and shortage rate

Figure 3. Comparison of throughput

Figure 3(a) shows the throughputs of two systems when shortage rate is fixed as 5%, and the cycle time and shortage period (2 and 10 hours) are varied. Figure 3(b) shows the throughputs of two systems when shortage period is fixed as 10 hours, and the cycle time and shortage rate (5%, 27.5% and 50%) are varied. From the various simulation experiments we obtained some observations.

①Both throughput and manufacturing lead time in the new system are better than those of existing system.

②The decrease of throughput is less sensitive in the new system with respect to the increases of shortage rates (mean) and shortage times (both mean and variance).

③The decreasing rate of throughput in the new system is less sensitive when the variance of production cycle time increases.

④On-time delivery rate in the new system is higher than that of current system.

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