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**Development of the Optimized Work Order Scheduling System for the Panel Welding**

**Line of Panel Assembly Shop in Shipbuilding**

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**Abstract**

In shipbuilding, a ship is divided into hundreds of blocks. A block is made up steel plates and sections. Among various operations to build ships, panel assembly shop plays an important part in producing the blocks because they are produced about 50% portions of all at panel assembly shop. Therefore, it becomes an important issue to decide work order schedule in panel assembly shop. In this paper, we study on the optimized work order schedule for the panel welding line in shipbuilding. It is important to study deeply on the optimized schedule because the productivity of the panel welding line is influenced by schedule. For improving the productivity of the panel welding line, we propose heuristic algorithm deciding optimized schedule in panel assembly shop. By using algorithm and knowledge-based database, we develop POS (the optimized Panel work Order scheduling System). Scheduler can decide schedule not to exceed capacity of the panel welding line but to be even with POS. As a result of POS, it is possible to make optimized schedule easily and the productivity of the panel welding line is improved. Also POS deals with various situations of the panel welding line, such as work delay and temporary stops of work processes, and provides other modified schedules immediately.

## 1. Introduction

In general, a ship is divided into hundreds of proper sized blocks. A block is made up several unit blocks, and each unit block is composed of steel plates and sections that are formed by cutting and bending operations. The shipbuilding processes consist of cutting and bending, assembly, outfitting, painting, and erection processes according to the necessary operations to build a ship. Among assembly processes, panel assembly shop plays an important part in producing the panel blocks because they are produced approximately 50% portions of all at panel assembly shop. Therefore, it becomes an important issue to decide a work order schedule in panel assembly shop. There are two production lines in panel assembly shop, which are composed of the panel welding line and the panel block assembly line. In the panel welding line, a main panel used in the upper and lower sides of the block is produced and moved to the panel block assembly line for assembly. Various types and sizes of panel blocks are produced in the panel block assembly line by combining the main panels and sub assembly blocks from the panel welding line and sub assembly shops. Figure 1 shows a layout of panel assembly shop and material flow status.

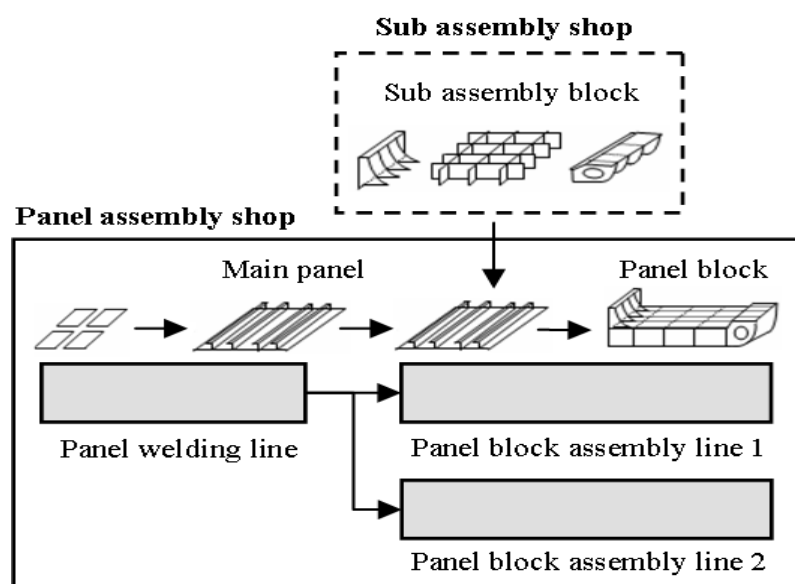


Figure 1. The layout of panel assembly shop

Because both the panel welding line and the panel block assembly line are linked as flow line, panels must be sent to the panel block assembly line after finishing their processes in the panel welding line. It is an important issue to decide a work order schedule in the panel welding line. If there is no schedule in the panel welding line, the panel block assembly line has several problems such as work delay of panels and temporary stops of work processes. Therefore, in this paper, we study on the optimized work order scheduling for the panel welding line.

## **2. Problem analysis**

There are several processes to produce panels in the panel welding line. Because each process in the panel welding line is composed as flow line and has its own sequence, a panel is produced at each process in order. As each process uses different machine, the processing time of each process is different. Also each panel has different processing time for each process. If there are some changes of panel work order in the panel welding line, the productivity of the panel welding line can be influenced. Therefore, it is important to decide a work order schedule in the panel welding line.

We analyze processing time for each process in order to find process influencing the productivity of the panel welding line primarily. Figure 2 shows the graph analyzing processing time at each process for four panels that are made most frequently in the panel welding line. From figure 2, processing time at process 6 is the largest among all processes. (Average 1 hour 18 min.) Therefore, in order to improve the productivity of the panel welding line, we develop a system that decides a panel work order schedule minimizing the idle time at process 6.

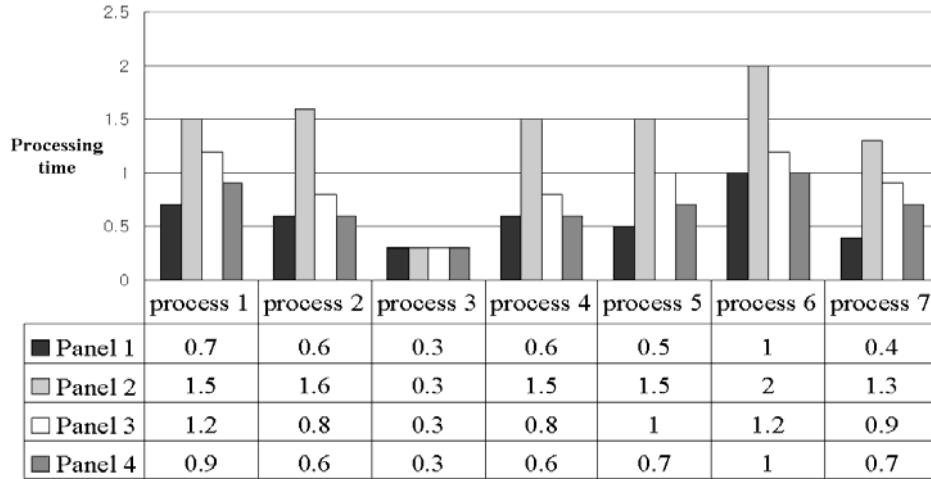


Figure 2. The processing time analysis graph

We also analyze processing time of panels at process 6 in order to confirm whether changes of panel work order schedule can improve the productivity of the panel welding line or not. Figure 3 shows the graph analyzing distribution of processing time at process 6. The average and standard deviation are 1 hour 7 min. and 25 min. From figure 3, the distribution of graph is not uniform. Therefore, the productivity of the panel welding line can be influenced by how to decide a work order schedule of panels because distribution of processing time is not uniform.

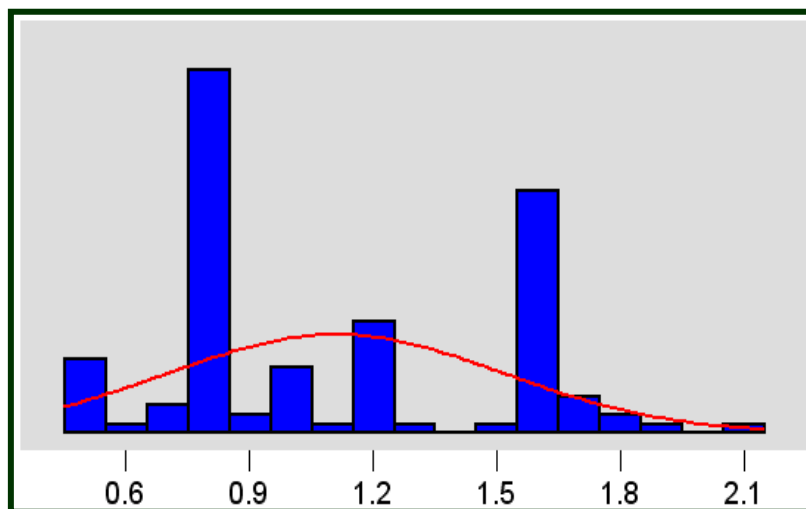


Figure 3. The processing time distribution graph

It is important to study broadly and deeply on the optimized schedule because the productivity of the panel welding line is influenced by scheduling. Meanwhile, there is no study on the optimized schedule in panel assembly shop to increase the productivity and deal with unexpected situations flexibly. The meantime a scheduler decides work order schedules only by his experiences without efficient operation strategies based on the optimized schedule. However, these schedules can not deal with various situations of the panel welding line, such as work delay of panels and temporary stops of work processes, immediately. Also it spends much time to make work order schedules by manual. Therefore, we propose a solution to solve these problems.

### **3. Solution**

For improving the efficiency and the productivity of the panel welding line, we propose a heuristic algorithm that can decide the optimized work order schedule in the panel welding line. The devised algorithm considers the delivery date of each panel, the work constraints of the panel welding line and work load balance. Also by using this algorithm and establishing knowledge-based processing time database, we develop POS (the optimized Panel work Order scheduling System).

#### **3.1 Improvement of work order scheduling process**

In order to develop POS, we analyze work order scheduling process and improve existing process to using POS. The work order schedule is established immediately by improved scheduling process and a scheduler can establish revised work order schedule reflecting variations of the panel welding line. Furthermore, we can make efficient operation strategies

in the panel welding line by establishing weakly and monthly schedules.

### 3.2 Optimized algorithm

For reflecting various constraints of the panel welding line effectively, heuristic algorithm is applied. By using heuristic algorithm, we can add constraints of the panel welding line and reflect variations of constraints easily. Figure 4 and 5 show the flow charts of the algorithm. Figure 5 shows ‘Optimized algorithm’ of Figure 4 in detail.

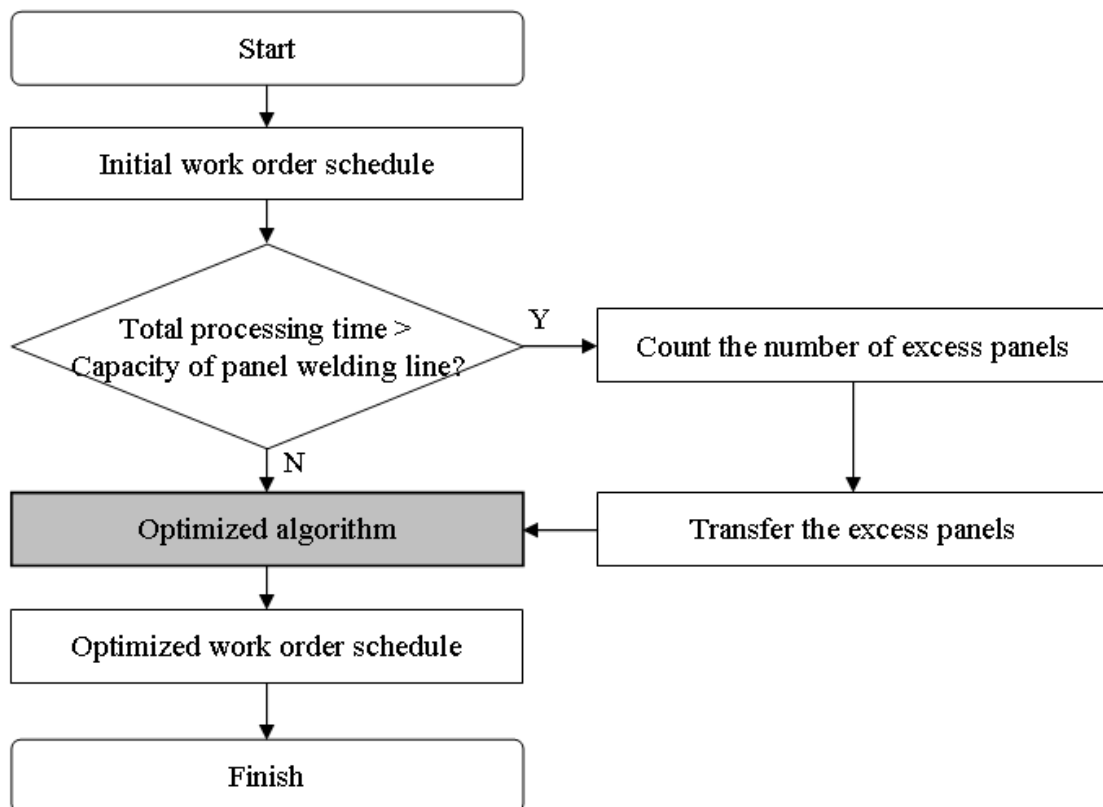


Figure 4. The flow chart of the algorithm (1)

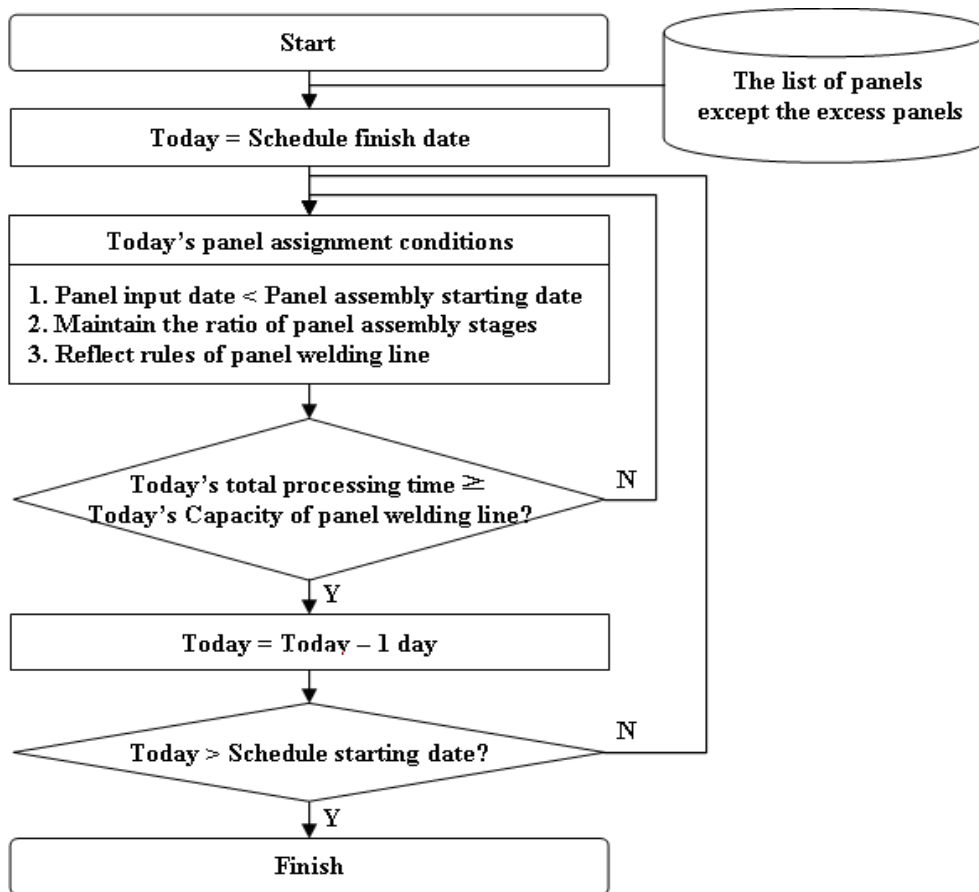


Figure 5. The flow chart of the algorithm (2)

The capacity of the panel welding line is not considered in the initial work order schedule. The initial schedule is lack of reality because the schedule exceeds the capacity of the panel welding line. The algorithm makes optimized work order schedule that is based on the initial schedule and balances the capacity of the panel welding line. Moreover, the algorithm can decrease work burden of a scheduler and increase the productivity of the panel welding line by counting and reporting the number of excess panels.

Meantime, from figure 5, the algorithm reflects mainly three situations of the panel welding line. First, each panel has its own panel input date when panel is assigned in the panel welding line and panel assembly starting date when panel is assigned in the panel block assembly line. Panel input date must not exceed panel assembly starting date because panel can not be inputted in the panel block assembly line first. Second, each panel is assigned to

one of the two panel assembly stages and assembled in its assigned stage. The algorithm inputs panels so as to maintain the ratio of both assembly stages. Third, the algorithm reflects several rules applied in the panel welding line.

### **3.3 POS (the optimized Panel work Order scheduling System)**

We develop POS with optimized algorithm. Also we construct knowledge-based database storing various needs of a scheduler and processing time of the panel welding line. Considering the convenience of a scheduler, POS is designed in Microsoft visual basic and excel. Also it can be easy to modify database and output files. Figure 6 shows the framework of POS. After receiving the initial schedule as input data, POS is performed by using process time stored in database.

POS is composed of three modules which are scheduling module, optimizing module, and load balance analyzing module. Scheduling module is making daily and monthly work order schedules in the panel welding line with the initial or revised schedule. From this module, POS can decide an optimized work order schedule in the panel welding line immediately. Optimizing module makes an optimized work order schedule with optimized algorithm and proposes the number of excess panels. Load balance analyzing module analyzes daily and process work load of schedules. From this analysis, POS can predict which process has more work load. Also, the optimized work order schedule can be printed as various forms of output data.

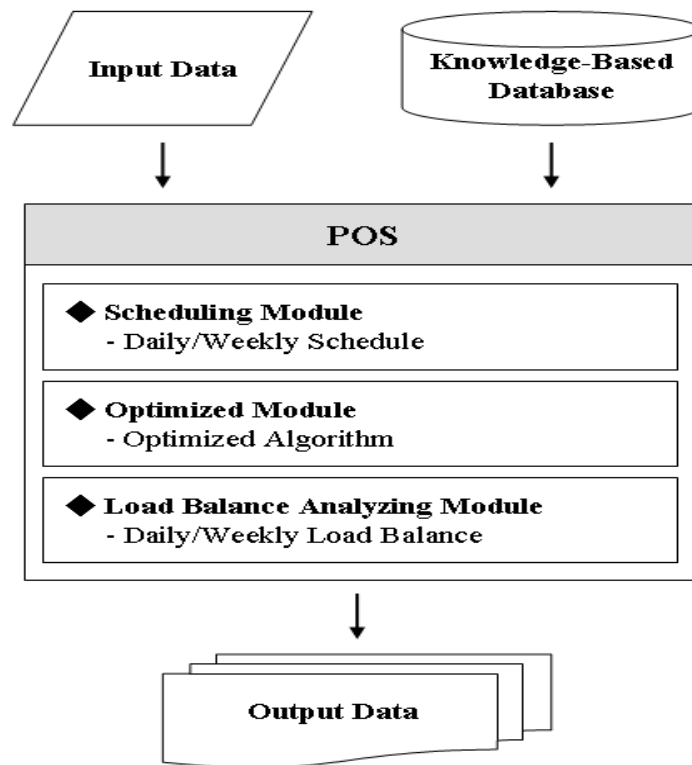


Figure 6. The framework of POS

Figure 7 and figure 8 show the results of work order schedules with POS in same period. Using bar graphs, it is easy to compare schedules with the capacity of the panel welding line. Figure 7 shows the result of initial work order schedule and figure 8 shows the result of optimized work order schedule using optimized algorithm.

From figure 7, there is no consideration about making work order schedule reflecting the capacity of the panel welding line. Therefore, the numbers of panels inputting the panel welding line is not even and several problems can occur such as work delay of panels and temporary stops of work processes. Meanwhile, from figure 8, optimized work order schedule is made reflecting the capacity and situations of the panel welding line such as the ratio of assembly stages. Furthermore, by presenting the number of panels exceeding the capacity of the panel welding line, a scheduler can check on excess panels immediately and transfer excess panels to other shops.

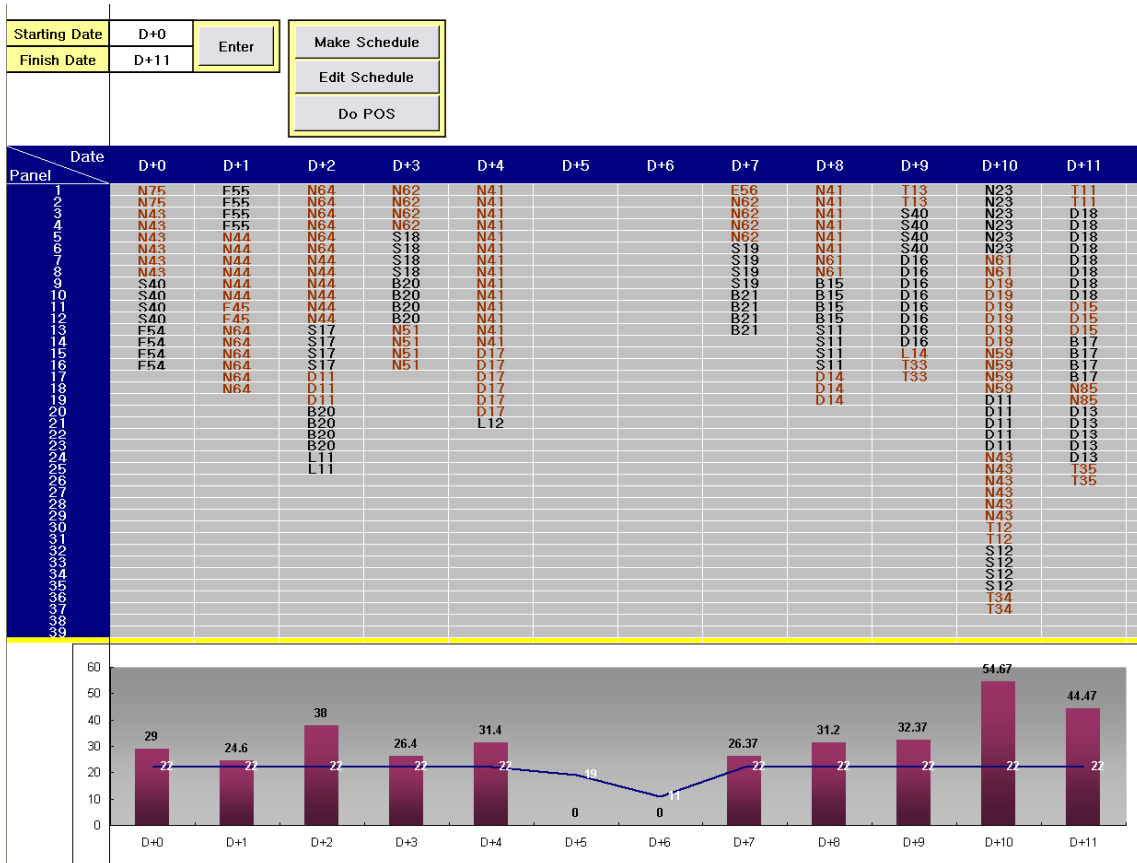


Figure 7. The result of initial work order schedule

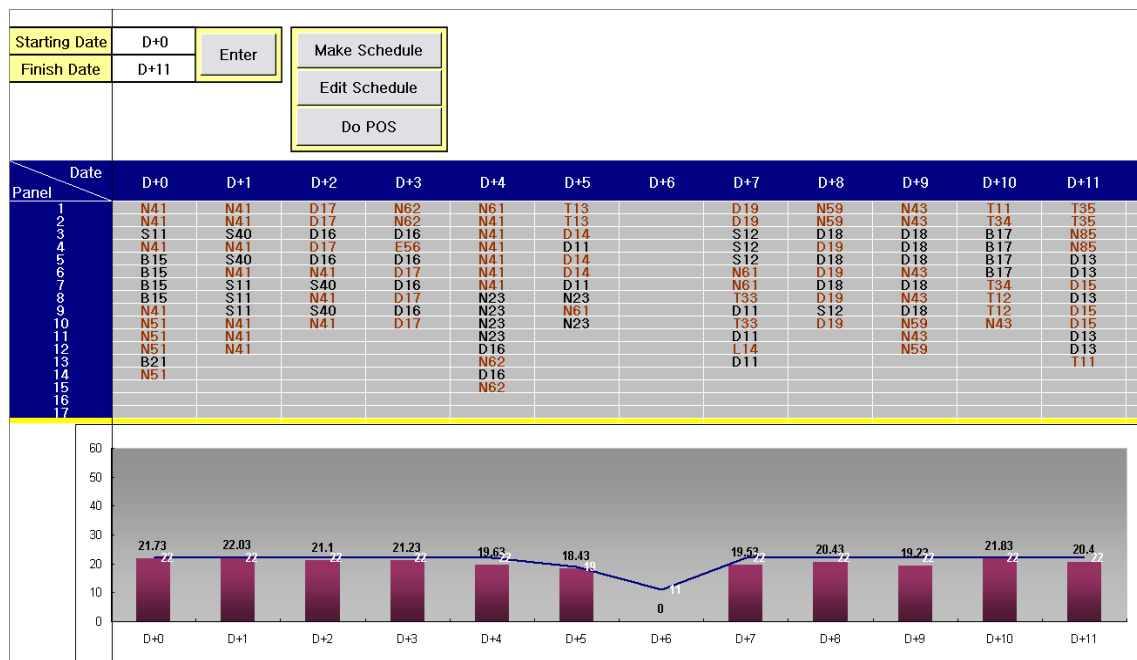


Figure 8. The result of optimized work order schedule

#### 4. Result

Figure 9 and figure 10 compare the result of POS to the results of initial schedule and actual production. From figure 9, we compare initial schedule, optimized schedule and actual production. Because initial schedule is made by experiences of a scheduler, there is gap between initial schedule and actual production. Initial schedule can't deal with the capacity and situations of the panel welding line. Meantime, there is little gap between optimized schedule made by POS and actual production. Therefore, it is helpful to improve the accuracy of schedule and relieve a scheduler from making an effort to revise schedule by using POS.

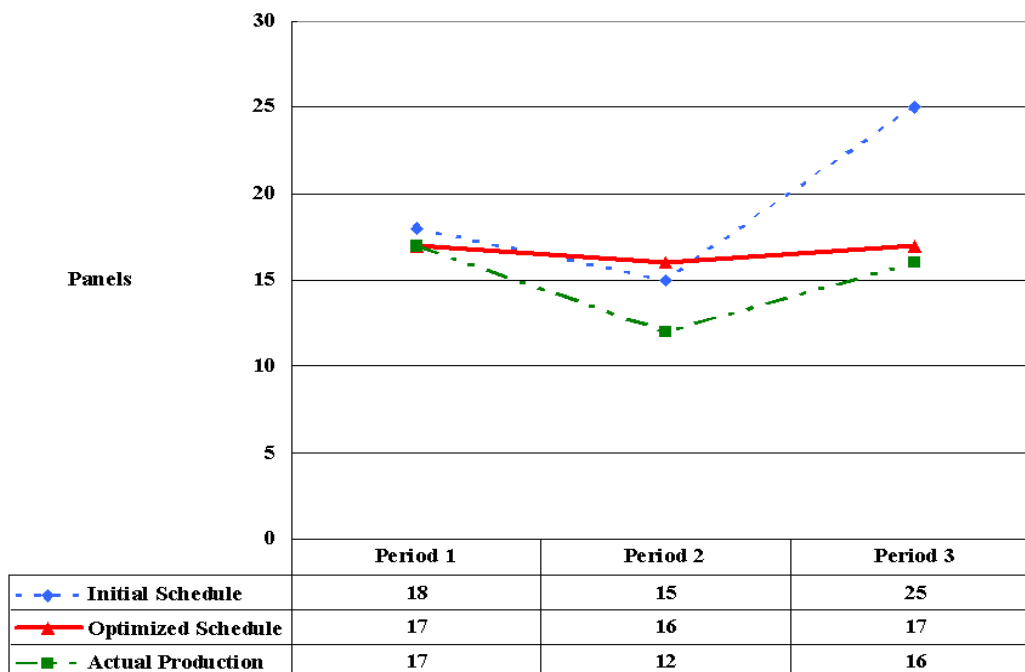


Figure 9. The comparison of results (1)

Figure 10 shows an average production of panels both in actual production and POS. The average production from POS is greater than those from actual production. If we achieve to produce 95% portion of optimized schedule from POS, then we can produce average 15.9 panels per day. The average production of POS is still greater than those of actual production. Therefore, the improvement of the productivity is expected by using POS.

Result	Ave. Production of Panels	Achievement Ratio to Goal (95%)
Actual Production	15.1 PL/day	-
POS	16.7 PL/day	15.9 PL/day (0.8 PL increase)

Figure 10. The comparison of results (2)

## 5. Conclusion

As a result of applying POS, it is possible to make an optimized schedule easily and the productivity of the panel welding line is improved. Also POS can deal with various situations of the panel welding line, such as work delay of panels and temporary stops of work processes, and provide other modified work order schedules immediately. Moreover, we analyze load balance in the panel welding line and make efficient operation strategies not to exceed capacity of the panel welding line but to be even with POS.

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