A study on the work formation assuring high efficiency
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Abstract
In this study, we propose the well-balanced line configuration that allows workers to demonstrate their capability fully, in which the work formation appropriate to the capability of workers is done on the basis of the work count of each worker. This work count methods are based on the work achievement quotient and the tendency equation. As an example, the evaluation of workers for the automobile assembly line was considered and their analytical results were sufficiently satisfied.

1. Introduction
The job within the designated work area requires well-balanced work load among workers. According to the conventional studies, the element job was assigned to each process so that the weighted average of working hours of mixed parts falls approximately evenly in the cycle time\(^1\). However, while the actual work is being done, there arises the substantial difference in the working hours between processes. Such difference is attributable to variation of the job executed by individual workers; namely to individual differences in the workers capacity due to differences in age, sex, and work experience. In particular, inexperienced workers tend to delay in the job, affecting subsequent processes, resulting in the line stop in certain cases. Enterprises arrange many relief men to absorb such differences, but increase in the number of relief men causes unfavourable cost increases.

In this study, we propose the well-balanced line configuration that allows workers to demonstrate their capability fully, in which the work formation appropriate to the capability of workers is done on the basis of the work count of each worker. This work count methods are based on the work achievement quotient and the tendency equation. Here, we mention tendency equation and work achievement quotient \(^2\),\(^3\),\(^4\).

\[
Y = aX^b \# cX^d
\]  
(1)

where
\[X, Y\text{: variables},\]
\[a \text{: the coefficient},\]
\[b \text{: the index number of tendency},\]
\[d \text{: the index number of tendency variation},\]
\[# \text{: means } \times \text{ or } \div, \text{ and}\]
\[c \text{: the initial variation}.\]

Equation (1) consists of two terms: the first term gives the tendency line and the second gives the variation of the tendency (for estimating work performance). Each important index of equation (1) is determined and, from the results, the work performance under consideration is evaluated. The aim of the tendency equation is to analyze the data as an area bounded by an upper limit line and a lower limit line. The first term of the equation shows the average of the data (tendency line); the second is used to evaluate the accomplishment of the work which can also be estimated from the coefficient of variation. In this paper, the evaluation of workers for the automobile assembly line is considered. Their analytical results were sufficiently satisfied.

2. Element job redistribution procedure
The procedure for the redistribution of element jobs is briefly described below.

1) Measurement of working time
After the distribution of element jobs, workers were placed in their respective processes and the working time required for the assembly of each model was measured using a VTR in the order in which models flow through the line.

Number of pieces of data collected: 30

2) Job evaluation
Based on the data measured, the job done by each worker was evaluated by an achievement evaluation method.

3) Setting of reference values
The degrees of achievement, variances and average working time determined through job evaluations were examined by a comparative method, and an degree of achievement, a variance and an average value that allowed each element job to be performed without using a relief man were adopted as reference values.

4) Redistribution of element jobs
Element jobs were redistributed based on the job evaluation results. To do this, element jobs were moved from one process to another in such a way as to reduce the standard working time in processes where the degree of achievement or the variance did not attain the reference value and to increase the standard working time in processes where both the degree of achievement and the variance attained the reference values.

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3. Outline of the assembly line and redistribution of element jobs

3.1 Outline of the assembly line in which workers were evaluated
Here is a brief outline of the assembly line.
(1) A main line through which multiple models flow
(2) Four types of RVs (recreation vehicle): A, Ar, B and Br are handled in the line. Models Ar and Br refer to sunroof-equipped models A and B, respectively.
(3) One worker is placed in each process.
(4) Almost all assembly work is done by hand.
(5) The cycle time is 179 seconds.

3.2 Processes between which element jobs were moved
Of the 15 processes between station No. 1 and station No. 9 in the A trim (sewing) line, 10 processes in which measurements could be made easily and the redistribution of element jobs considered necessary were selected as subjects of examinations. The placement of workers is shown in Figure 1.

3.3 Evaluation of workers
The results of evaluations of workers are partially presented below.

The worker in the 2L process was 34 years old, and had 13 years and a half of experience working in the assembly line and 3 years and a half of experience working in the current process. Both the degree of achievement and the variance in the this process were not so high compared with those in other processes. Working time in this process varied greatly from model to model. Models requiring sunroofs to be mounted on them, in particular, required a considerable number of man-hours and thus considerable working time. As a consequence, both the degree of achievement and the variance in this process were considerably low compared with those in other processes. Evaluations of jobs on models other than sunroof-equipped ones showed that both the degree of achievement and the variance were at high levels.

The worker in the 5R process was 24 years old, and had 5 years of experience working in the assembly line and 4 years of experience working in the current process. Since sunroofs needed to be mounted on some models handled in this process, working time varied greatly from model to model. Evaluations of work on models other than those with a sunroof showed that both the degree of achievement and the variance were at high levels. The average working time was also far shorter than the cycle time, and therefore he should be able to handle an increased number of element jobs.

The results of evaluations of workers are summarized in Table 1. The symbols “L” and “R” in the table denote the left and right sides of the line, respectively. The numbers within parentheses in the lower row refer to the results of evaluations on models other than sunroof-equipped ones.

3.4 Setting of reference values
The reference values shown below have been set based on the worker evaluation results and the average working time in each process.

<table>
<thead>
<tr>
<th>Process</th>
<th>Work achievement quotient (%)</th>
<th>Difference of variation</th>
<th>Mean value (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2L</td>
<td>35.34~46.69</td>
<td>0.380</td>
<td>178.8 (145.53)</td>
</tr>
<tr>
<td>2R</td>
<td>65.55~39.74</td>
<td>0.436</td>
<td>189.13 (169.17)</td>
</tr>
<tr>
<td>3L</td>
<td>68.16~60.3</td>
<td>0.074</td>
<td>177.97</td>
</tr>
<tr>
<td>4R</td>
<td>54.1~67.96</td>
<td>0.1525</td>
<td>182.70</td>
</tr>
<tr>
<td>5R</td>
<td>44.32~27.07</td>
<td>0.687</td>
<td>161.27</td>
</tr>
<tr>
<td>6L</td>
<td>70.87~53.69</td>
<td>0.180</td>
<td>182.43</td>
</tr>
<tr>
<td>6R</td>
<td>65.22~50.46</td>
<td>0.188</td>
<td>190.67</td>
</tr>
<tr>
<td>7R</td>
<td>68.12~64.34</td>
<td>0.033</td>
<td>178.90</td>
</tr>
<tr>
<td>8L</td>
<td>22.26~36.56</td>
<td>0.854</td>
<td>178.80 (112.0)</td>
</tr>
<tr>
<td>9R</td>
<td>63.35~50.64</td>
<td>0.167</td>
<td>188.97</td>
</tr>
</tbody>
</table>

The worker in the 5L process was 24 years old, and had 5 years of experience working in the assembly line and 4 years of experience working in the current process. Since sunroofs needed to be mounted on some models handled in this process, working time varied greatly from model to model. Evaluations of work on models other than those with a sunroof showed that both the degree of achievement and the variance were at high levels. The average working time was also far shorter than the cycle time, and therefore he should be able to handle an increased number of element jobs.

The results of evaluations of workers are summarized in Table 1. The symbols “L” and “R” in the table denote the left and right sides of the line, respectively. The numbers within parentheses in the lower row refer to the results of evaluations on models other than sunroof-equipped ones.
Degree of achievement: Not less than 60%
Variance: Not more than 0.3
Average working time: Not longer than the cycle time

4. Redistribution of element jobs

As an example, how element jobs were redistributed is shown below.
Element jobs requiring the shortest working time were moved from one process to another with consideration given to the order in which they were performed and the equipment conditions. For example, job No. 7 in the 2R process where either the degree of achievement or the variance did not attain the reference value was replaced with job No. 5 in the 5R process where both the degree of achievement and the variance attained the reference values and the worker was performing the job with plenty time to spare. The standard working time in the 8L process was reduced, because either the degree of achievement or the variance did not meet the reference value in this process, although the average working time did not exceed the cycle time. Furthermore, job No. 17 in the 7R process was moved to the 8L process, and instead job No. 9 in the 8L process was moved to the 6L process. Since the time required for job No. 9 in the 8L process was longer than the time required for job No. 17, the total working time was reduced by moving element jobs in this way. Similarly, other element jobs were moved from one process to another to redistribute them.

The worker in the 9R process was a quite unskilled worker, and element jobs assigned to him had been reduced in number at the time of the first distribution of element jobs and there were no more element jobs that could be moved to other processes, and therefore his jobs were not moved.

The results of the redistribution of element jobs are shown in Table 2. The redistribution of element jobs, which caused an increase in the number of element jobs assigned to skilled workers and a reduction in those assigned to unskilled workers, made the flow of products through the line smooth.

The numbers in the upper and lower rows refer to the working time and its weighted averages in each process before and after the redistribution of jobs, respectively.

5. Conclusions

(1) This paper presents a method of distributing jobs according to the skill of each worker in an automobile assembly line.

(2) The jobs performed by the worker belonging to each process were evaluated.

(3) Based on the job evaluation results, reference values were set for future evaluations and element jobs were redistributed with consideration given to the performance of each worker.

(4) The job redistribution method presented in this paper makes it possible to reduce the number of line stops and the number of relief men more efficiently than conventional studies to enlarge the working area of each process or a method of making up for lost time by using relief men, and we consider that this method is useful in reducing costs and improving the line balance.

References