Identifying Factors Reflecting Workers' Aptitude toward Assembly Tasks in Production Cells

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***Abstract*—Although major studies on cell production have put the emphasis on technical factors such as machine order/layout, family part grouping, workflow sequence, etc., it has been found that for successful implementation of cell production systems, some human issues should be treated seriously. One of these issues is that productivity of production cells depend largely on workers and therefore it is important to consider how to measure workers' aptitude and investigate how workers' aptitude affect the productivity of production cells. In this paper, we make an experimental study to identify factors influencing workers' aptitude toward assembly tasks and productivity in production cells. Our study is different from researches reported so far in that we carry out a laboratory experiment of cell production to measure the productivity of the workers in production cells. Meanwhile we designed a self-evaluation sheet to measure the workers' aptitude from three viewpoints: growth-need strength, self-efficacy and core self-evaluation. It was clarified that only one factor: growth-need strength has significant relations to productivity of the production cells, and there are some issues to be dealt further.**

***Index Terms*—cell production, cellular manufacturing, growth-need strength, self-efficacy, workers' aptitude**

I. Introduction

Cellular manufacturing, often called cell production in Japan, arranges factory floor labor into semi-autonomous and multi-skilled teams, or work cells, who manufacture complete products or complex components. Properly trained and implemented cells are more flexible and responsive than the traditional mass-production line. Cell production has become an integral part of lean manufacturing systems; many organizations have applied cell production concepts in manufacturing and service processes. The effects of cell production are including reduction in setup time, cycle time, tooling requirements and material handling. Furthermore, implementation of cell production has been shown to achieve significant improvements in product quality, scheduling, space utilization, control of operations and employee morale [1].

Over the past 30 years, many manufacturing companies are adopting a cellular manufacturing approach in an attempt to improve their competitiveness. Meanwhile, many researchers have paid a lot of attention to cell production system design problems, such as the best groupings for products, parts, or machine clusters. Some studies have also addressed problems of selecting tools, jigs, and fixtures, determining process flow, determining cell capacity and selection of equipment. However, it has been reported that for successful implementation of cells, people who will eventually operate, manage, support and maintain the manufacturing cells should actively participate in their design and development. It is essential to focus both on technical issues (cell formation and design) and human issues including worker assignment strategies, skill identification, training (workforce multi-functionality), communication, reward/compensation system, defining worker roles, teamwork, and conflict management [2]-[3].

Wemmerlov & Johnson [4] surveyed 46 user plants with 126 cells and concluded that substantial benefits could be achieved from cellular manufacturing but that implementation is not simply a rearrangement of the factory layout; it is a complex reorganization that involves organizational and human aspects. They emphasized that most of the problems faced by companies implementing cells were related to people, not technical issues. In our previous studies [5]-[6], it has been clarified that both the experience (learning effect) and workers have significant impacts on the productivity of production cells, the impact of the experience and workers on the productivity of production cells are 19.63% and 67.01% respectively. As two-thirds of variance of the assembly times was decided by workers, the aptitude or ability of workers has a stronger impact than the experience. In order to implement cell production systems successfully, it is very important to measure the workers' aptitude and assign the right workers in the right place.

As major studies have put their emphasis on technical factors (machine order/layout, family part grouping, workflow sequencing, etc.), there is a singular absence of articles of investigating the impact of workers' aptitude on production cells because human related issues are typically difficult to quantify [7]. Furthermore, the fundamental problem that confronts us is how to measure workers' aptitude. It remains an issue to develop an effective approach for measuring workers' aptitude.

We have designed a self-evaluation sheet to measure the workers' aptitude from the viewpoints of the deftness and the ability for fine work, and our previous researches demonstrated that it is necessary to apply the valuable

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results in the field of industrial and organizational psychology [8]. In this paper, we design a new self-evaluation sheet from three viewpoints: growth-need strength, self-efficacy and core self-evaluation to measure the workers' aptitude. We further investigate how these aptitudes relate to the productivity of production cells. We put our emphasis on identifying the factors that are available to measure workers' aptitude toward assembly tasks in production cells and making the following contributions:

- As most of previous researches applied questionnaire survey or case study methods, it is only possible to evaluate the impact of the workers' aptitude comparatively and empirically. Different from previous researches, this paper will apply the experimental study method to clarify quantitatively the relationship between the workers' aptitude and productivity of production cells.
- We design a new self-evaluation sheet to measure the workers' aptitude toward the assembly tasks in production cells and apply the regression analysis method to examine the validity of the self-evaluation sheet for measuring workers' aptitude.

The remainder of this paper is organized as follows. At first, we describe the experiment and self-evaluation sheet design. Then we conduct a factor analysis to measure the worker' aptitude based on the answers to the self-evaluation sheet. Furthermore, we apply the regression analysis method to examine the relation between the productivity of production cells and the measurement of worker' aptitude. At last, we give some discussions and issues about our results, and then show some concluding remarks.

II. Cell Production Experiment Design

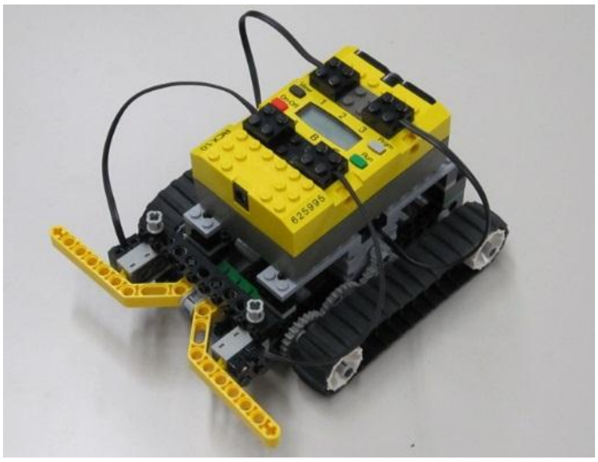

Figure 1. The toy robot as the virtual good

We designed a laboratory experiment that a toy robot built up of the LEGO Mindstorms (see Fig. 1) is used as the virtual good. It consists of 106 pieces of parts and the assembling process is divided into 17 tasks. The performance of production cells is evaluated by the assembly time to complete one toy robot. Considering more non-permanent employees work in the shop floor of cell production systems, we designed the experiment on the assumption that the workers have no any experience of assembling the toy robot.

The experiment is carried out along with the following three steps:

- Step 1: we give the workers an assembly manual and then, the instructor demonstrates the assembly tasks of the toy robot through assembling it practically in front of the workers. Following the instructor's demonstration, the workers learn the sequence and techniques to assemble the toy robot, and each worker assembles one toy robot respectively.
- Step 2: after the pre-learning at the step 1, the workers assemble the toy robot in the mode of one-person cell. When doing the assembly tasks, the workers measure the operation time needed to complete every task, which the time required for preparing parts and other non-assembly task is not included. During the operation, the workers have not been given a standard time for the assembly tasks.
- Step 3: the assembly time to assemble one toy robot is calculated as the sum of operation times of all tasks. In order to investigate the learning effect, the assembly and time measurement are repeated five times.

III. Designself-Evaluation Sheet

In order to identify the factors that are available to measure effectively workers' aptitude toward assembly tasks in production cells, we intend to apply the valuable results in the field of industrial and organizational psychology, and design a new self-evaluation sheet from the following viewpoints:

- Growth-need strength: employees' growth need strength was operationalized using the Job Diagnostic Survey (JDS) originally developed by Hackman and Oldham in 1980 [9]. It is a concept that describes the variability in growth needs among different people. People with strong growth needs should respond more positively to job high in motivating potential than people with weak growth needs.
- Self-efficacy: it was developed by Albert Bandura's [10] as part of a larger theory, the Social Learning Theory. Self-efficacy is the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations. In other words, self-efficacy is a person's belief in his or her ability to succeed in a particular situation.
- Core self-evaluation (CSE): it represents personality traits which include individual's evaluation of self, their abilities and control on their abilities. People with high core self-evaluation feel confident and think positively of themselves whereas people with low core self-evaluation will lack confidence [11].

TABLE I. SELF-EVALUATION SHEET

No	Evaluation Item
Q_1	I like and have the courage to challenge the difficult goals.
Q_2	I am willing to work hard and achieve the goal
Q_3	I am very satisfied and proud when I finish the difficult work.
Q_4	I doesn't like mechanical repetitive work, I hope that often changes the contents of my work
Q_5	I like to do the new and difficult work
Q_6	I can get what I want because of my hard work.
Q_7	When I make a plan, almost sure it can achieve
Q_8	As long as I make my mind, I can learn anything
Q_9	My success depends on my hard work and ability
Q_{10}	I believe that the external environment has a great influence on my success.
Q_{11}	I can calmly face the difficulties, because I can rely on my ability to solve problems
Q_{12}	I'm good at finding new ways to streamline work processes and improve efficiency.
Q_{13}	I feel very confident when I make a suggestion.
Q_{14}	When I'm with successful people, I can not only keep my confidence, but also be able to do better.
Q_{15}	Participate in team task, I can very good finish my work
Q_{16}	I would like to give up a comfortable working environment for the purpose of achieving a goal
Q_{17}	I rarely accept the advice of others

As showed in Table I, the self-evaluation sheet consists of 17 items and the workers are required to answer these self-evaluation items before starting the assembly tasks. When answering the self-evaluation sheet, a five-point Likert scale was applied.

IV. EXPERIMENT RESULT

We conducted the experiment during the period from October 2014 to January 2015. As the workers, there are 67 students in Fukushima university participated the experiment, 59 of them could complete the assembly and time measurement five times, and return valid answers to the self-evaluation sheet. The basic statistics of the assembly times for all of one person cell are shown in Table II, where the experience represents the order of the assembly and time measurement.

TABLE II. BASIC STATISTICS OF THE ASSEMBLY TIMES (min)

Statistics	Experience				
	1st	*2nd*	*3rd*	*4th*	*5th*
Sample size	59	59	59	59	59
Mean	10.10	8.32	7.49	6.81	6.44
Std. deviation	3.33	2.53	2.08	1.68	1.71
Minimum	5.43	4.83	4.03	3.97	3.48
Maximum	21.03	16.68	14.17	14.20	13.95
Range	9.27	7.80	7.03	6.53	6.38

From Table II, it is clear that the average time to assemble one toy robot at the first experience was 10.10min and it got shorter into 6.44min at the fifth experience. As the assembly times decreased along with the increase in the workers' experience, learning effect could be confirmed statistically. The range of the assembly times is from 9.27min to 6.38min and there is a difference more than three times between the slowest worker and the fastest one. Therefore the workers' aptitude gives a strong impact to performance of production cells.

V. WORKERS' APTITUDE

In order to measure the workers aptitudes, a factor analysis was conducted, where the observed variables are the 59 workers' answers to the self-evaluation item Q_j (j=1, 2, … 17). The extraction method is maximum likelihood and the value of KMO and Bartlett's Test is 0.591. As the result shown in the Table III, we could extract three factors according to Kaiser Criterion (eigenvalue >= 1.0). After conducting a promax rotation, the rotated factor matrix (structure matrix) was obtained and shown in Table IV.

TABLE III. TOTAL VARIANCE EXPLAINED

Factor	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	2.30	16.43	16.43
2	2.00	14.26	30.70
3	1.75	12.52	43.21
4	0.98	7.01	50.22
5	0.77	5.51	55.73

TABLE IV. STRUCTURE MATRIX

Question	Factor		
	1	2	3
Q_1	.011	**.880**	.237
Q_2	.063	**.675**	.118
Q_3	-.169	**.401**	.184
Q_5	.115	**.646**	.259
Q_6	.175	.220	.053
Q_7	.047	.030	.047
Q_8	**.476**	.283	**.852**
Q_9	**.952**	.074	.337
Q_{10}	**.430**	.143	.092
Q_{11}	.188	.283	.355
Q_{12}	.200	**.623**	-.111
Q_{15}	.058	.157	.221
Q_{16}	-.049	-.066	.338
Q_{17}	.088	.048	.131

From Table IV, the factor 1 has a high correlation to Q_9 (My success depends on my hard work and ability), we can give a name to the first factor as "Self-efficacy". Meanwhile, the factor 2 has a high correlation to Q_1 (I like and have the courage to challenge the difficult goals), Q_2 (I am willing to work hard and achieve the goal), Q_5 (I like to do the new and difficult work) and Q_{12} (I'm good at finding new ways to streamline work processes and improve efficiency), it represents the workers' "Growth-need strength". Furthermore, as the factor 3 gives the highest loading on Q_8 (As long as I make my mind, I can learn anything), we can interpret this factor as "Core self-evaluation".

VI. PRODUCTIVITY AND WORKERS' APTITUDE

As we have extracted three factors of the workers' aptitude in the previous section, we ought to investigate how these workers' aptitude affect the performance of production cells. To do this investigation, we conduct a regression analysis where the dependent variable is the assembly time t_5 at the fifth experience, and the independent variables are the factor scores of the three factors extracted above for the 59 workers. Since our aim is to investigate the relationship between the workers' aptitude and the productivity of production cells, the assembly times and the factor scores were standardized, and then we could derive the standardized regression coefficients according to the least squares method. The results are shown in Table V.

TABLE V. RESULT OF REGRESSION ANALYSIS (DEPENDENT VARIABLE: T5)

Factor	Standardized regression coefficient	*t*-value	*p*-value
1	0.066	0.506	0.615
2	**-0.301**	**-2.297**	**0.025**
3	0.199	1.492	0.141

From Table V, it is clear that the assembly time t_5 at the fifth experience has a significant positive correlation to the factor 2: "Growth-need strength". That is, the workers' "Growth-need strength" has negative effect on the assembly time and therefore has a positive contribution to the productivity of production cells. In contrast, the correlation between the performance of production cells and factor 1, factor 3 couldn't be verified significantly because the *p*-values are more than 5%.

VII. DISCUSSION AND ISSUES

From Table IV, there are 7 questions (Q_6, Q_7, Q_{10}, Q_{11}, Q_{15}, Q_{16} and Q_{17}) that have a very low correlation to all of three factors. In addition to that Q_4, Q_{13} and Q_{14} had been removed from the factor analysis because of their low communality; it is obvious that many items (questions) of the self-evaluation sheet designed previously were not available to measure the workers' aptitudes. It is necessary to refine the self-evaluation sheet and update the items (questions) to be suitable to measure workers' aptitude in production cells.

Meanwhile, as we could not verify statistically that the factor 1 ("Self-efficacy") and factor 3 ("Core self-evaluation") have significant correlation to the productivity of production cells, it is necessary to amend the self-evaluation sheet from some new viewpoints.

VIII. CONCLUDING REMARKS

This paper designed a new self-evaluation sheet to measure the workers' aptitude from three viewpoints: growth-need strength, self-efficacy and core self-evaluation, and then conducted regression analysis to examine the relation between the productivity of production cells and the measurement of worker' aptitude. The main results of this study can be summarized as the following:

- The growth-need strength, self-efficacy and core self-evaluation of the workers could be extracted from the answers to the self-evaluation sheet.
- The performance of production cells has a significant correlation with the workers' "Growth-need strength".
- Self-efficacy and core self-evaluation could not be verified significantly relating to the productivity of production cells.

There are some issues that should to be considered further to measure workers' aptitude effectively. It is necessary to update the items (questions) to be suitable to measure workers' aptitude in production cells, and further amend the self-evaluation sheet from other viewpoints.

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