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Applying *New JIT*—Toyota's global production strategy: Epoch-making innovation of the work environment

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Abstract

In order to strengthen management technology strategy, the author has recently developed a new management technology principle, *New JIT,* based on TMS, TDS, TPS and TQM-S. In developing "Global Marketing" that can win the global competition for quality and cost, the key for domestic and foreign companies is to successfully achieve "Global Production" that enables simultaneous production start-up (the same quality and production at optimal locations) throughout the world. This paper analyzes and proves the significance of strategically applying *New JIT*—a global production strategy activity called *AWD6P/J*—for epoch-making innovation of the work environment, as verified at Toyota. While many vehicle assembly shops depend on a young, male workforce, innovation in optimizing an aging workforce is a necessary prerequisite of TPS—a production strategy of *New JIT*. Elements necessary for enhancing work value and motivation, and work energy, including working conditions and work environment (amenities and ergonomics), were investigated through objective survey and analyzed from labor science perspectives.

Keywords: New JIT; Toyota's global production strategy; Epoch-making innovation; Work environment; AWD6P/J; TPS

1. Introduction

Today's challenge for business management lies in providing customers with products of excellent quality, cost and delivery (QCD) performance in the pursuit of customer satisfaction (CS) and staying ahead of competitors through market creation activities. To do this, *New Just in Time* (*JIT*) was proposed as a new management technology principle for 21st century manufacturing [1]. This is configured with a hardware system that has three core elements: TMS (Toyota Marketing System), TDS (Toyota Development System) and TPS (Toyota Production System); and a software system of TQM-S [2] (Total Quality Management (TQM), utilizing *Science SQC* (Statistical Quality Control) [3]) that enables the application of scientific TQM. In previous studies, the effectiveness of *New JIT* was successfully proven through its application at Toyota Motor Corporation (Toyota) [4–6]. The important mission of *New JIT* is to achieve successful global production and quality assurance. Production shops should be the focus of *New JIT* implementation among jobs that exist in manufacturing companies. The author believes that the key to a company's prosperity is a global production strategy that enables supply of leading products with high quality assurance and simultaneous global production start-up (the same quality and production at optimal locations) in both developed and developing countries. Innovation for optimizing an aging workforce is a necessary prerequisite of TPS. It is essential to identify elements necessary for enhancing work value, motivation and work energy, as well as an optimum work environment (amenities and ergonomics), through objective survey and analysis from labor science perspectives.

This study, "Epoch-making Innovation of the Work Environment", was carried out based on the concerns of automotive manufacturers. In the Japanese automobile industry, the aging society and expansion of overseas production is resulting in a decrease of new employment of young workers in automobile production shops. *Aging & Work Development 6 Project* (*AWD6P/J*) has been promoted in the areas of human resources, labor, and

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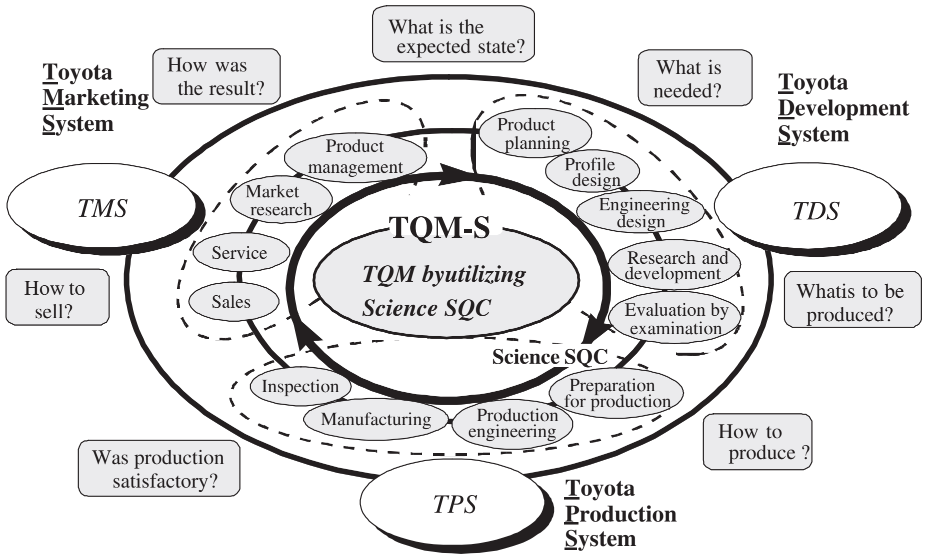

Fig. 1. *New JIT*, a management technology principle.

workplace environment to innovate the workplace to respond to an increasing number of older and female employees. Under *AWD6P/J*, the Total Task Management Team was formed mainly by members of the production engineering and plant divisions to promote scientific approaches to (1) motivation, (2) fatigue, (3) physical strength, (4) tools and equipment, (5) temperature conditions, and (6) disease prevention. This study selected final vehicle assembly lines as the model and investigated a production line, employing a comprehensive analysis that incorporated ergonomics, physiology, and psychology. Measures for an aging workplace developed by this activity yielded practical results and are being applied to both domestic and overseas operations to improve productivity.

2. Strategic application of next-generation management technology, *New JIT*

To win the global competition, big enterprises both in Japan and overseas are actively promoting global marketing that aims to achieve the same quality and production at optimal locations (simultaneous start-up) throughout the world. Manufacturing companies, in particular, are required to grasp customer needs and provide products responsibly to the market through global production without falling behind their competitors. Therefore, new strategic management technologies that drive a company to lead the competition have become increasingly essential on a global scale.

2.1. Establishment of next-generation management technology, New JIT

The mission of enterprises is to provide customers (consumers) with products that delight them. Fulfilling that mission is the key to the continuation of a corporation. To this end, the author has recently developed the *New JIT* a new management technology principle [1] as shown in Fig. 1 and has shown its validity as a new management technology strategy for 21st century manufacturing.

New JIT is a next generation management technology that innovates the business processes of each division, including sales, development and production. *New JIT* includes hardware and software systems developed according to new principles to link all activities throughout a company. The hardware system consists of three core elements: TMS, TDS and TPS. Collectively this system is called *New JIT*, with an excellent reputation worldwide as a *lean system*. The software system deploys TQM-S [2], which is a new principle for quality management, utilizing *Science SQC* [3] from a scientific viewpoint. An organizational way of proceeding with jobs under Japanese style management and strategic development was considered in this TQM-S. It has demonstrated enhanced effectiveness in the respective divisions of engineering design, production and business-sales and others) [4–6]. In this sense, the whole company consistently deploys total marketing [1,2].

2.2. TPS, the key to strategic application of New JIT

Observation of the automotive industry, which is showing an increase in global business expansion, suggests that it is representative of the general condition of various industries throughout the world. For example, while Japanese automotive companies expanded the application of digital engineering innovated manufacturing in their shops, the reduction of Quality Circle (QC) activities and increased overseas production resulted in a decline of technical skills, problem detection and problem solving capabilities in workshops. This ultimately has lowered the workshop's ability to build in quality during each process.

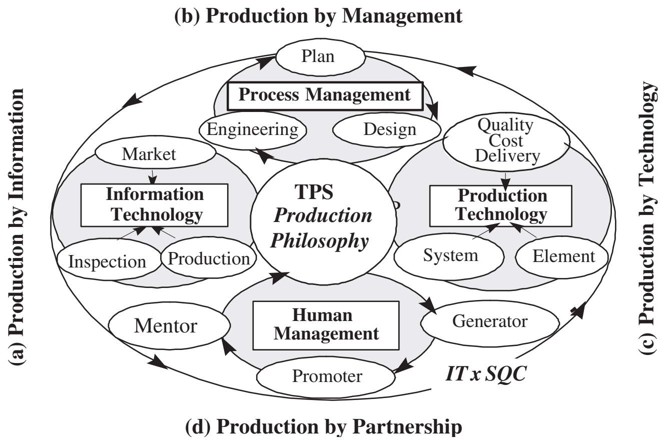

Fig. 2. TPS model concept.

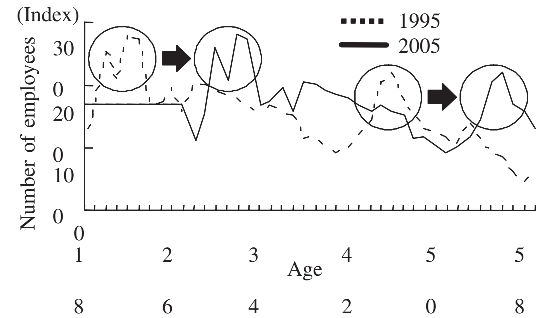

Fig. 3. Variation of aging workers.

Considering the recent increase of recalls with respect to Japanese vehicles and the improving quality of vehicles produced in developing countries, the position of the Japanese automotive industry as an expected leader in global production is threatened [7]. To break through this situation, it is essential to eschew conventional production management and establish a new management technology principle suited to computerized workplaces. In order to achieve this for global production, production engineering and manufacturing divisions are expected to achieve high-level quality assurance and productivity by using digital engineering-planning and implementation of (i) intelligence production systems, (ii) operations and maintenance skills, and (iii) the evolution (training and development) of manufacturing skills and training [8].

Recently, Amasaka [1] referred to the effectiveness of TPS, applying *Science SQC* as a positive way of improving the quality of business processes in workshops, the sites at which Toyota's *New JIT* activities take place. TPS, with its concept illustrated in Fig. 2, uses both Information Technology (IT) and SQC in combination in order to produce generalizations about behavior patterns for practicing customer-oriented quality and production management that the production workshop or production engineering department builds into the processes, using core technologies (a) – (d). What is essential here is to circulate the four core technologies, which are (a) production by information-information technology, (b) production by management-process management, (c) production by technology-production technology, and (d) production by partnership-human management.

3. Prerequisite of strategic global production by *New JIT*—innovation in work quality

Major manufacturing companies are facing the strong need to innovate their businesses for global production. The current and future health of manufacturing performance in Japan, as well as the possibility of simultaneously attaining the same quality level in overseas plants, remains unanswered. Depending on the situation in each country, including product specifications, production volume and market conditions, manufacturing may be fully automated or require manual labor. If so, the success of global production is highly dependent upon the quality of workers, indicating the necessity of work innovations. In addition, to achieve long-term growth, companies should also undertake drastic improvement of the work environment [9].

3.1. *Background of concepts regarding consideration for older workers*

Japan, with the fame of its big manufacturing businesses, faces industrial changes-expansion of overseas production, stagnant domestic demand, and diminished recognition of manufacturing due to changing preferences of young people. This has resulted in reduced employment of new, young workers.

In the case of Toyota, the average and oldest age of workers on vehicle assembly lines has been on the rise for the past decade (1995–2005), as shown in Fig. 3. To cope with this trend, more extensive consideration of worker motivation and physical condition is essential. In other words, manufacturers should shift from work-oriented shop designs to people-oriented shop designs that put more focus on the work environment [10–12]. As an example of manufacturing innovation in overseas countries, various governmental actions for older workers have been taken in Scandinavian countries that have aging workforces. Though the necessity of such actions has been advocated in Japan, action has been relatively modest compared with that in Scandinavian countries [1] [13,14]. At Toyota, improvements have been based mainly on *TVAL* (Toyota-Verification Assembly Load) [2] [15] for quantitative evaluation of workloads. At its Kyushu Plant, Toyota has also implemented a worker-oriented line for the assembly

[1]An example, Finnish Institute of Occupational Health (Finland) and Institute for Gerontechnology (Eindhoven University of Technology (Netherlands), etc. [14]).

[2]Quantitative evaluation of assembly workloads, using electromyographic values.

process based on the new concept shown in Table 1 [10]. Further enhancement of these activities for aging workers will be indispensable in the future.

3.2. Consideration for older workers according to Toyota's New JIT strategy

In order to create a workplace that is friendly to aged workers, four steps were planned as shown in Fig. 4 [16]. Step (1) was to interview middle-aged and elderly workers engaged in the assembly process. The interview brought to light positive and negative aspects as shown in Fig. 4. The first-hand information obtained from middle-aged and older workers was then classified according to body functions. In order to ensure accurate interpretation of responses collected during the interviews, the study members participated in actual line operations for 5 weeks. In Step (2), objective data concerning body function were collected by investigation and from various documents in order to clarify the implications of the interview results. Step (3) was an investigation and evaluation of existing measures for improving conditions related to the physical attributes classified in Step 1. In Step (4), areas were identified in which countermeasures are necessary: (i) workers, (ii) car and equipment, and (iii) management. For example, to complement insufficient muscular strength due to unnatural working posture and heavy work, assisting devices were introduced that remarkably improved the situation.

However, the workshop still had a problem in terms of work speed and there were no measures taken to assist work speed. In terms of endurance, there was no study for assigning jobs according to the work speed of individual operators and establishing effective breaks. In terms of basic physical strength, early detection and prevention of adult diseases had been the primary consideration, while maintaining and improving physical strength had not been emphasized much. From the perspective of mental health,

Table 1
New concept for assembly lines [10]

New concept	
1.	Increase worker motivation
2.	Reduce workload
3.	Automation that people want to work with
4.	Comfortable work environment

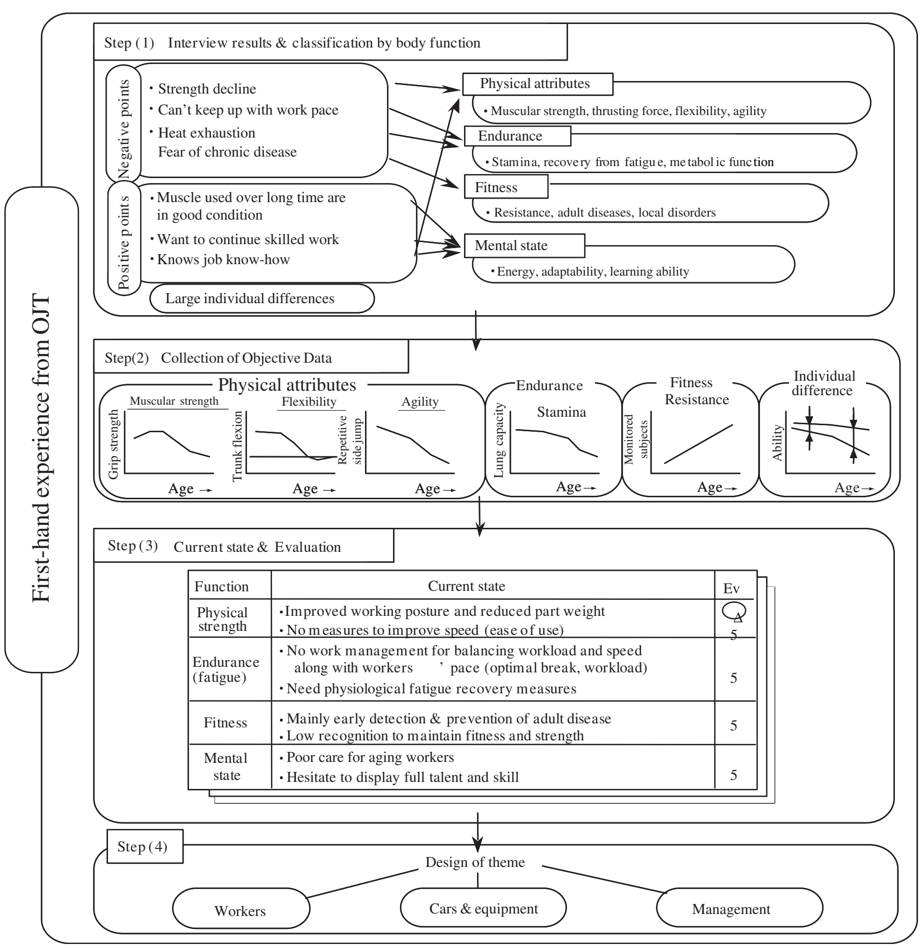

Fig. 4. Method of setting concept of consideration for aged workers.

care for new employees was sufficient, but the care for older employees was not. From these analyses, the following imperatives were selected: (I) boost morale, (II) study work standards to reduce fatigue, (III) build up physical strength for assembly work, (IV) alleviate heavy work by employing easy-to-use tools and devices, (V) ensure temperature conditions suited to assembly work characteristics, and (VI) Reinforce preventative measures against illness and injury.

4. Definite plan for concept actualization

In recent Japanese automobile industry, the work force is aging by decrease in young worker. Especially, the final assembly process is a labor-intensive process and dependent on young workers, the development of a working environment where anybody can work comfortably is desired. Under these circumstances, the authors [10] took up the six themes: (1) increasing worker motivation, (2) development of working system for low fatigue, (3) maintenance of the physical strength for assembly work, (4) development of tools and machines which are more ergonomic for aged worker, (5) improvement of a thermal environment to be in conformity with assembly work, and (6) development of program to prevent physical disorder and started a company-wide project.

4.1. Formation of project team, AWD6P/J, and activity optimization

It was concluded that tackling these six themes separately is not effective because they are strongly interrelated. As specialized investigations are necessary, a project team called *AWD6P/J* [10,16] (Aging and Work Development 6 Programs Project) was formed within Toyota as shown in Fig. 5 and it shows the project themes of *AWD6P/J*. The relation diagram in Fig. 5 shows the inter-relationship of each theme. This diagram was created to emphasize team unity during the project. *AWD6P/J* team structure is also shown in Fig. 6. A division specializing in a theme acted as the leader and members including the Assembly Division and related divisions acted as a total task management team. The project was mainly promoted by the Vehicle Production Engineering Division, Safety and Health Promotion Division, and the Human Resources Development Division. The TQM Promotion Division coordinated the overall project. Also, by having directors (vice president, senior managing director and managing director) as project advisors, systematic implementation throughout the organization became possible [17].

4.2. Total task management team activity by practical application of Science SQC

Each team activity took the form of *total task management* [3]. By applying Science SQC, team activities by managers and staff members ensured the rotation of the PDCA cycle (plan, do, check and action). The relation diagram in Fig. 5 and the mountain climbing chart for problem solving in Fig. 7 were made for the management of the overall activity so that all teams share the same milestones and steps for attaining goals and recognize the inter-relationship between individual teams and the direction of each activity. As the main players in the assembly line are workers, a worker-oriented approach is the key to problem solving in each project team. Fig. 8 shows the steps for making implicit knowledge explicit via the practical application of *Science SQC*. First, implicit knowledge (ambiguous, subjective information) such as opinions, intuition and worker sense should be quantified with objective and subjective indicators. These quantitative data can then be scientifically analyzed to identify causal relationships within the given phenomena. These indicators make possible objective, universal evaluation and make implicit knowledge explicit. The next section presents examples of *AWD6P/J* activities.

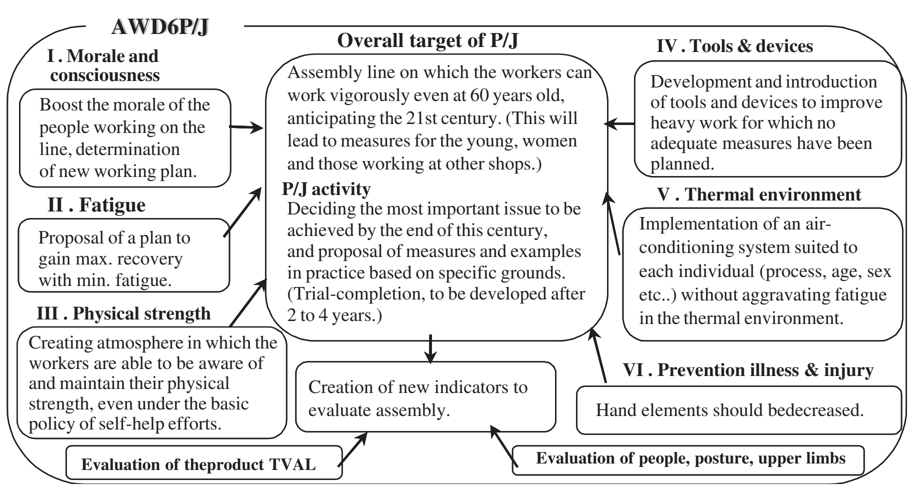

Fig. 5. Relation diagram of overall objectives of projects and objectives of respective teams.

5. Activity examples

5.1. Project II "Study work standards to reduce fatigue"

The objective of this project was to achieve work standards that minimize fatigue and maximize its recovery. The following three actions were taken: (1) establishing technologies for evaluating the fatigue of assembly line workers, (2) identifying the types of fatigue experienced by aging workers, and (3) setting and testing methods for reducing fatigue.

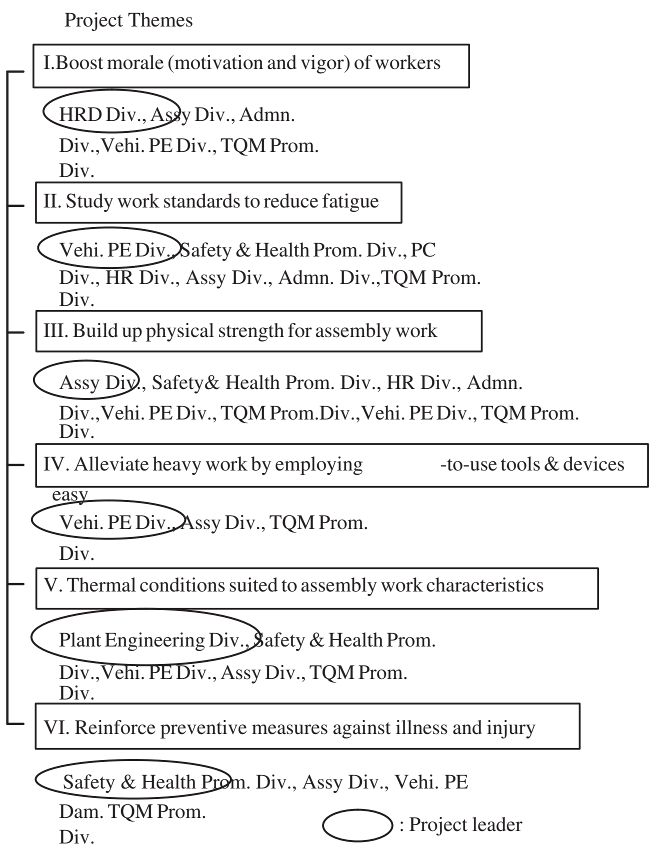

Fig. 6. *AWD6P/J* structures.

5.1.1. Fatigue evaluation and types of fatigue experienced by aging workers

Continuous assembly work results in fatigue. Fatigued workers have the desire to rest. In other words, fatigue involves changes in physical and mental state. These changes first appear as symptoms such as declining productivity and health and increased operational errors as physical function decreases. Fatigue evaluation, therefore, requires the analysis of these changes. Effective indicators in analyzing the fatigue of workers have been confirmed in both subjective and objective terms. Through evaluation, it was concluded that aging workers experience chronic fatigue rather than acute fatigue.

5.1.2. Experiment by changing the rest pattern and testing the obtained knowledge on model lines

As a way to minimize fatigue, rest patterns were studied. Two rest patterns (varying the time of continuous work and breaks) were tested experimentally to analyze differences in fatigue level. As shown in Fig. 9, fatigue during operations gradually increases with time and decreases after each break. It was confirmed that fatigue increases as

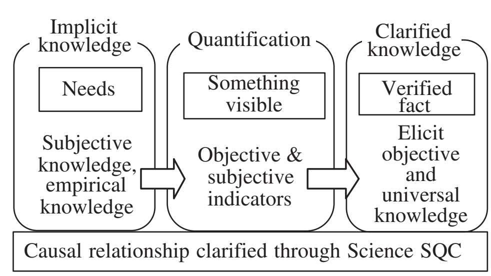

Fig. 8. Science SQC approach.

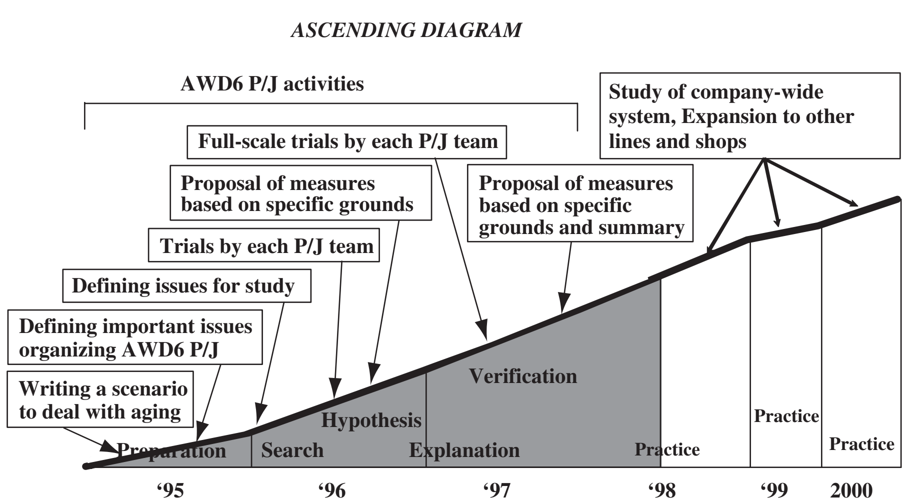

Fig. 7. Diagram of climbing mountain of problem-solving for all projects.

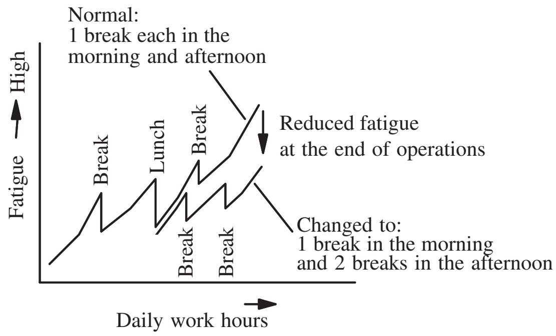

Fig. 9. Changed break time and effect.

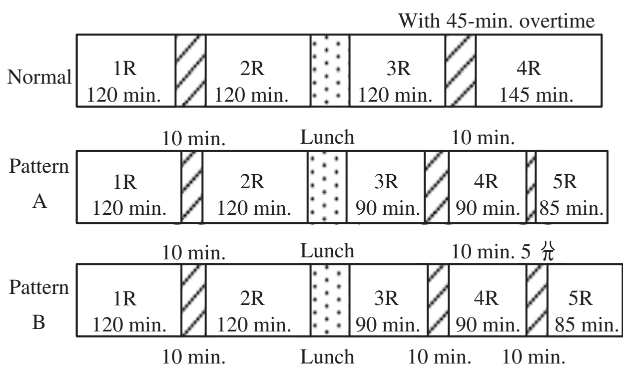

Fig. 10. Break pattern comparison (normal and trial patterns).

a whole with ups and downs. When the number of breaks was increased and the length of continuous working time was reduced in the afternoon (when fatigue tends to increase), the fatigue level at the end of the operation became lower, according to both subjective and objective indicators (e.g. physiological data).

To verify the above-mentioned finding, two assembly lines at the Motomachi Plant, where the *CROWN* and *IPSUM* car model are manufactured, were selected as experimental lines for a two-month trial. Two patterns shown in Fig. 10 were set for the trial, with continuous 90-min operation as the base. Pattern A adopts 5 min for the second break in the afternoon while pattern B adopts 10 min. Pattern A follows pattern B on the No. 1 line and pattern B follows pattern A on the No. 2 line. The trial was conducted with about 500 workers on the No. 1 and No. 2 lines. The effect perceived by workers and their opinions were used as subjective indicators, while the effects on productivity were used as objective indicators to provide the major basis for evaluation.

5.1.3. Perceived effect and free opinions (subjective indicators)

For both patterns A and B, most workers found that fatigue was reduced at the end of daily operations. It was also confirmed that pattern B produced a greater effect than pattern A. A possible reason for this result is that workers felt psychological stress from a 5-min break, because they were used to 10-min breaks. Furthermore, answers to questions about expected retirement age based on confidence in physical strength showed a rise, indicating a reduced physical load. Free opinions on changes in physical, mental and operating conditions during the trial were collected, classified and summarized. About 70% responded that breaks were "good for health" and that they felt "less load to parts of the body" in terms of physical condition. As for the mental aspect, about 60% said that they "felt more relaxed with work time reduced to 90 minutes" and were able to "concentrate more on the operation." Lastly, regarding operations, about 50% declared that such changes resulted in "less operational delay" and "fewer errors." These responses indicated improved operational quality resulting from the synergy of physical and mental effects.

5.1.4. Effect on productivity (objective indicators)

The line stop time data between 12:25 and 13:25 when delay is most likely to occur was sampled, as it was assumed that line stop time is closely related to delays in operation on the No. 2 assembly line. As shown in Fig. 11, the line stop time decreased by about 2 min on average and productivity increased by about 3% during the trial period of December and January compared to November. Free opinions were collected from foremen who constantly watch assembly lines to check operation rates and product quality. About 50% of foremen said that there were fewer operational delays. With regard to product quality, about a 40% declared improvement. These results demonstrate the effectiveness of the rest pattern change in decreasing worker fatigue and improving productivity.

5.2. Project V "Temperature conditions suited to assembly work characteristics"

The project team aimed to realize an air conditioning system that considers individual differences in temperature preferences so that temperature conditions do not adversely affect fatigue levels. The focus of their activities were as follows: (1) clarifying the relationships between temperature and fatigue (2) analyzing problems of current air conditioning for assembly lines, and (3) development of an air conditioning system suitable for assembly processes.

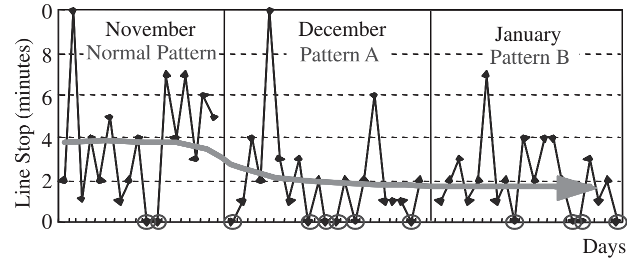

Fig. 11. Line stop time between 12:25 and 13:25 that causes work delays.

5.2.1. Suitable temperature conditions for minimizing fatigue

Activities revealed that a temperature of 28–31 °C and airflow of 1 m/s is desirable for suppressing fatigue [16]. When this environment was created using line-flow air conditioning and synchronous fans, suppression of fatigue was observed from both subjective indicators and physiological data. In addition, it was also found that non-breathable, sweaty work clothes have an adverse affect on body heat control. Therefore, development of comfortable work clothes with excellent moisture absorption and drying properties was promoted.

5.2.2. Development of comfortable work clothes and test on model lines

The present punch-knit work clothes made of 100% cotton offer good moisture (sweat) absorption performance but poor heat radiation, ventilation and drying, resulting in sticking. As a result of a technical survey and development efforts, stitch-knit work clothes made of a special fiber (porous hollow-section polyester) and cotton were made as prototype comfortable work clothes with 2.6 times the ventilation and drying capability of present work clothes, and similar moisture absorption properties. An awareness survey of actual workers on model lines (Motomachi Plant assembly lines Nos. 1 and 2) was conducted to test the following: (1) any difference in the feeling of workers with and without synchronous fans (with new wide-area exposure function) and (2) differences between comfortable work clothes and conventional work clothes.

Since the fatigue reduction effect of line-flow air conditioning had been made clear through past activities, we assumed line-flow air conditioning for the model lines. Since the temperature was felt to be 1–2 °C lower when wearing comfortable work clothes, the air conditioner outlet temperature was raised by 1 °C from that at the time of the last evaluation. Fig. 12 shows the scattered diagram obtained by principal component analysis of the survey results regarding the awareness of model line workers. The results show that workers felt that comfortable work clothes were better than conventional work clothes. Also, the installation of a synchronous fan was evaluated highly in terms of both air conditioning and work clothes. As the result of checking actual opinions, many workers commented that the comfortable work clothes were less stuffy and sticky and allowed for easy work movement. Comfortable work clothes were also evaluated favorably by workers involved in processes that have insufficient exposure to airflow. While the initial prototype clothes (100% special fiber) were favored for processes exposed to airflow at 1 m/s or more, they were unpopular for processes exposed to less airflow because they allowed for little heat radiation (due to the heat insulation effect of the pores in the special fiber). This problem was solved by mixing the special fiber with cotton. Stitch knitting may have reduced stickiness to the skin (contributing to easy motion) thanks to the added surface roughness. In the actual application test, evaluation was made by raising the air conditioner outlet temperature by 1 °C from that of the previous evaluation, resulting in reduced steam consumption by the condenser of about 13%. This yielded energy savings in addition to improving the work environment.

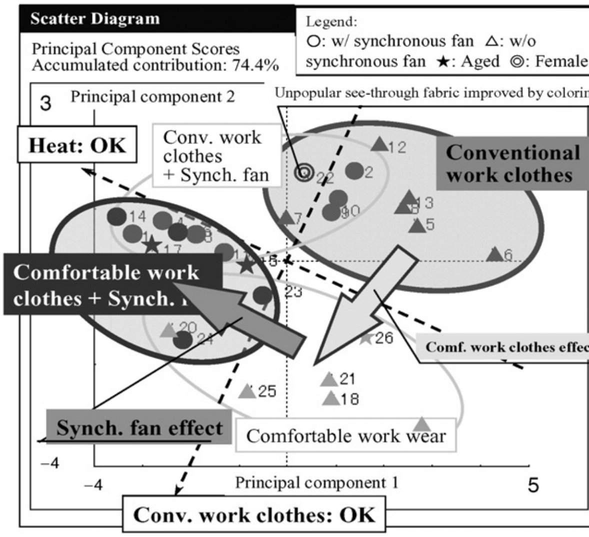

Fig. 12. Principal component analysis (correlation matrix) of awareness survey results.

5.3. Outline of other projects

(1) Project I: Implemented a new system for line workers (New Life Action Program) and promoted work development for skilled workers.
(2) Project III: Verified the effectiveness of stretch exercise in fatigue recovery at a model workshop successfully promoted stretch exercises and achieved fatigue reduction.
(3) Project IV: Improved high load work by providing easy to use tools and devices.
(4) Project VI: Developed methods to evaluate load to fingers for disease prevention and successfully conducted disease prevention activities at a model workplace.

5.4. Summary and future activities

This study reported on the process of problem analysis for coping with an aging workforce in the assembly process and its results. Actual examples of activities for solving problems were also introduced. The results obtained through these project activities are being verified in model lines for further expansion in application. Automation in vehicle assembly lines has been reviewed recently, as greater emphasis has been put on workers. In the 21st century, as in the past, workers are indispensable to vehicle production. Worker-oriented approaches will be a key point in future production. While worker requirements change with age, a production line should be friendly not only to older workers but also to young and female workers by responding to changes in the environment. A future study will focus on establishing a production system that enables all workers to work productively by making use of the knowledge obtained through this study.

6. Conclusion

From the viewpoint of "Global Production," this paper has proved the effectiveness of the strategic application of *New JIT* in AWD6P/J—a strategic management technology activity for realizing epoch-making innovation in the work environment at Toyota. This study, as a prerequisite of TPS, focused on innovation in automotive final assembly lines that have depended on young male workers, such that these workplaces will be able to cope with an aging workforce and obtain successful results that help realize a comfortable workplace for older workers through objective analysis from behavior science perspectives. This study is greatly contributing to global production strategies of Toyota Motor Corporation.

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