

New Human-centered Production System -Building an Integrated Human Management System-

Hirohisa Sakai
Toyota Motor Corporation
Toyota, Japan
h_sakai@mail.toyota.co.jp

Abstract—Currently, Japanese companies are working to survive and develop "global production" to realize "the same quality and simultaneous start-up" in the world. From such background, the production operator is required to change from simple labor until now to intelligent production operator, and it is important not only to carry out the decided standard work, but also to train the operator who can conceive itself and self "kaizen" at an early stage. The author has defined them as intelligent operator and consider that "the evolution of technology and skill (man)" which makes "the advanced production system be used and guaranteed high quality in the manufacturing site" decides the success or failure of the global strategy. Therefore, the author has devised an integrated human management system "HI-POS (Human Intelligence-Production Operating System" aiming at strategic operation to "global production", and demonstrated the effectiveness of the proposed "HI-POS" at an advanced company, Toyota.

Keywords—global production, integrated human management systems, HI-POS

I. INTRODUCTION

Currently, Japanese companies are developing "global production" for realization of "same quality and simultaneous start-up" in the world in order to survive [1][2]. Against this background, the author has proposed an integrated human management system "HI-POS" aimed at strategic operation to "global production". Concretely, it is composed of the core of operator training based on "human".

The author has demonstrated the effectiveness of the proposed "HI-POS" in Toyota.

II. BACKGROUND-PAST AND CURRENT OF THE MECHANISM OF JAPANESE PRODUCTION

A. Production methods that have supported the automobile manufacturing industry

The following are examples of the automobile manufacturing industry, which has played a central role in manufacturing. Vehicles were invented at the end of the nineteenth century, and the manufacturing method of automobiles begins with hand making by skilled workers. Later, Henry Ford developed a mass production system by setting up standard components and using a conveyor system [3].

Toyota Motor Corporation (hereinafter referred to as "Toyota") inspected the Rouge Plant of Ford Co., Ltd. of the mass production method, and the current "Toyota Production System (TPS)" was developed and established over a long period of time, and this production method became the driving

force of the strength of the manufacturing of Japanese manufacturers [4][5][6].

Specifically, it is aimed at eliminating wastefulness through human ingenuity ("kaizen") and pursuing the standardized work of the production line. Nowadays, it is called "lean production system" and "JIT", and it is a typical Japanese production system [7][8].

Especially, regarding "human", the standardized work shows the procedures, etc. in which a worker handles multiple machines, and the standardized work is also a means for "kaizen" the present work, and the revision of the standardized work is always carried out by a person.

B. What are the management issues facing Japanese companies?

Implicit knowledge, including intuitive elements such as personal knowledge, perspectives, and values rooted in the experience of each individual, was the source of the competitiveness of Japanese corporations. Now, this is a major step in the transmission and development of technologies and skills to overseas countries.

It is important to place the highest priority on and localize a wide variety of culture in foreign countries.

C. What is required of the next-generation production system?

In order to provide customers with "high value-added products" that overcome "global quality competition", it is essential that production operators embodying unprecedented "high-performance, high-functionality" products are required to transform from simple labor orientation until now to intelligent production work, and not only implement the determined standardized work, but also develop operators who can "kaizen" themselves by conceiving their own wisdom at an early stage. The author has defined them as intelligent operators and consider that the "evolution of technology and skill (man)" that makes full use of production facilities and guarantees high quality at the manufacturing site determines the success or failure of the global strategy [9][10][11][12].

III. NEW HUMAN-CENTERED PRODUCTION FRAMEWORK: CREATION OF "HI-POS"

A. Aim of "HI-POS" Innovation

Figure 1 shows "HI-POS" (Human Intelligence-Production Operating System) of realizing an improvement in intelligent productivity by capturing the necessity of creating a new human-centered system for manufacturing that satisfies creative work [13].

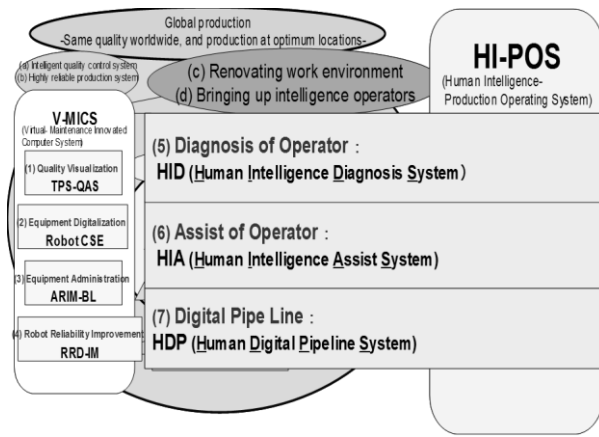


Fig. 1. Human Intelligence-Production Operating System

Concretely, (5) the training method according to the diagnostic result [14], (6) the mechanism for self-learning and the data-making of personal skill [15], and (7) the optimum human movement such as digital pipeline-process organization [16] are required as the promotion means of the assist-skill training of the operator, after the diagnosis of the operator-aptitude diagnosis of dexterity and dexterity.

In addition, it is important to create an environment with good workability based on the conventional "kaizen" and to arrange "persons" with different culture and habits all over the world in the right place for appropriate personnel, and to conduct training to give the specified skill uniformly.

B. Configuration of "HI-POS"

Features of "HI-POS" are composed of intelligent diagnostic method "HID" (Human Intelligence Diagnosis System) [14] which finds the factor which obstructs the high-quality, integrated assist system "HIA" (Human Integrated Assist System) [15] for the evolution and transmission of the technology of the human wisdom, and "HDP" (Human Digital Pipeline System) [16] which totally links the intelligent production information of them in the digital pipeline from design to manufacturing as the key technology of "HI-POS" which embody the intelligence of the production operator as three core-systems.

The features of "HID", "HIA" and "HDP" are described below.

"HID" has the following features. First, it is important to visualize the overall operation status of production equipment, such as equipment, operators, control equipment, and computers, focusing on the flow of items. In addition, regarding the production process, the "visualization of the production process" is embodied by converting information such as control equipment into "production technology information data". By this, the contents of tacit knowledge of production facilities and production processes which had been made black box are clarified [17].

Concretely, "HID" is proposed as a system which leads to analysis of problems and drafting of countermeasures, prior evaluation, execution of countermeasures, and evaluation as a production process [18].

Specifically, HID has been proposed as a system for analyzing problems, proposing countermeasures and making prior evaluations, implementing countermeasures, and

making final evaluations of integrated production processes. The system's structural elements are comprised of the seven steps shown in Figure 2 and outlined below.

(1) In the analysis plan proposal, the objectives and policies for analysis are clarified and related persons share relevant information. The following analyses and countermeasures are planned in agreement with related parties.

(2) A fact-finding survey is carried out, based on "genchi-genbutsu" and in line with the objectives and policies for analysis. This survey is divided into the survey and analysis of the overall outline, and a survey and analysis of the details. The former involves gaining an understanding of the outline of the entire process to be analyzed and defining any problem areas. The latter is based on these results and aims to make problem issues still clearer.

(3) Overall problem issues are defined in terms of the elements related to both the production process and the production line division (people, production-related items, money, information, time, etc.). The positives and negatives of each of these are analyzed from various perspectives in terms of integrated production processes. Furthermore, the authors have established and are applying a new modeling method, TLSC (Total Link System Chart), which facilitates the consideration of kaizen details and methods already implemented.

(4) When tracking down problem areas, TLSC should be utilized, thereby allowing latent problems to also be discovered.

(5) Problem areas should be organized by grouping using the KJ and other methods.

(6) The root causes of problems should be traced using further logical development and appropriate collection and organization of verifying information.

(7) In terms of the proposal and evaluation of countermeasures, the level to which each proposal will implement kaizen, as well as the cost of kaizen, should be considered.

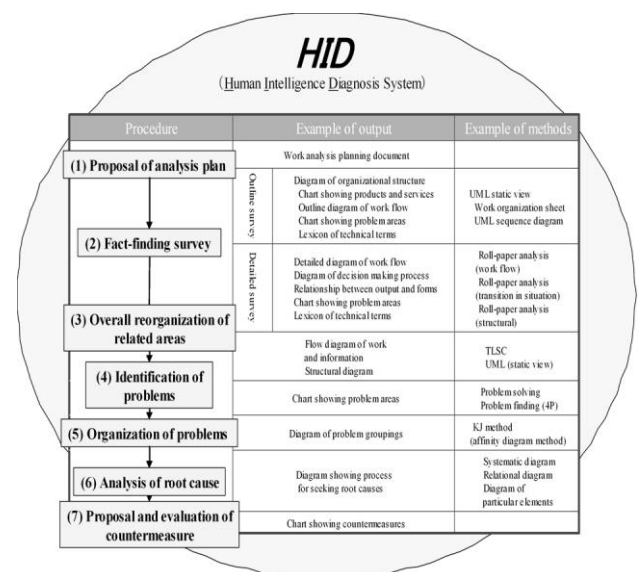


Fig. 2. Concept and structural elements of HID

It is necessary to utilize the previously mentioned "HID" to improve the performance of production operators. In addition to the ability of technology and skill, it is important to make them self-realize "challenge and creation" and give them the willingness, pride, ethics, etc.

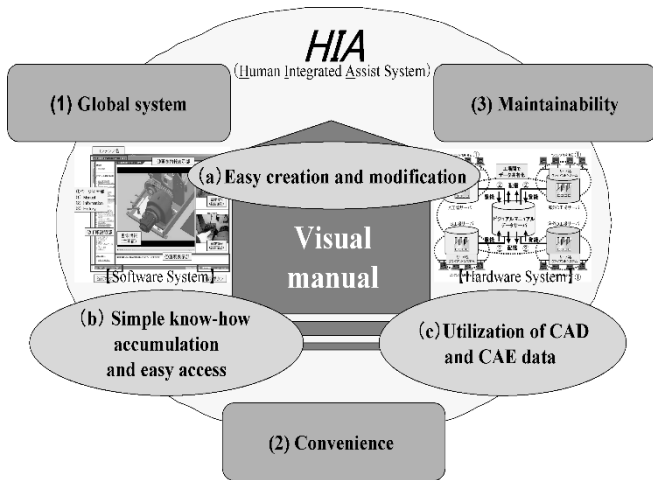


Fig. 3. Concept and structural elements of HIA

Therefore, "HIA" is a new system to assist them in voluntarily advancing "kaizen" by self-answering about their own work involved.

This system comprises the following elements as a means of developing the techniques (knack and key points) of production operators engaged in standardized tasks, as shown in Figure 3:

- (1) Global implementation of same standards,
- (2) convenience, and
- (3) maintenance/maintainability of intelligent systems.

By this, it is considered that the creative contrivance for the skill improvement of the production operator voluntarily and willingly advances.

The level of performance of production operators should be evaluated using HID, as explained above. In addition to engineering and technical skills, it is important that operators possess a spirit of challenge and creativity, enabling them to realize their own targets, and work with commitment, pride and logic.

"HDP" is a system that allows domestic and overseas production operators to totally link the intelligent production information on accumulated technology and skill in a digital pipeline from design to manufacturing in order to solidify the simultaneous start-up of the world. By this, it is possible to realize intelligent education and training in which intelligent productivity is raised.

The main structural elements of this system are shown in Figure 4. They include:

(1) the use of design data (even in cases where there is no prototype) relating to a new product, from its design to the production engineering stage, as well as the individual operations used by production operators on the assembly line; all of which are included in a work instruction sheet, which is created in advance.

(2) Facilitating image training in the proscribed order of assembly, even when there is no actual process available to

refer to, so that the necessary technical and engineering processes are understood and operators are trained in them from the production engineering process stage.

These elements work to reduce the disparity level between individual production operators, and allow the bottom-up communication of skills to those unfamiliar with them in a short time [19][20][21].

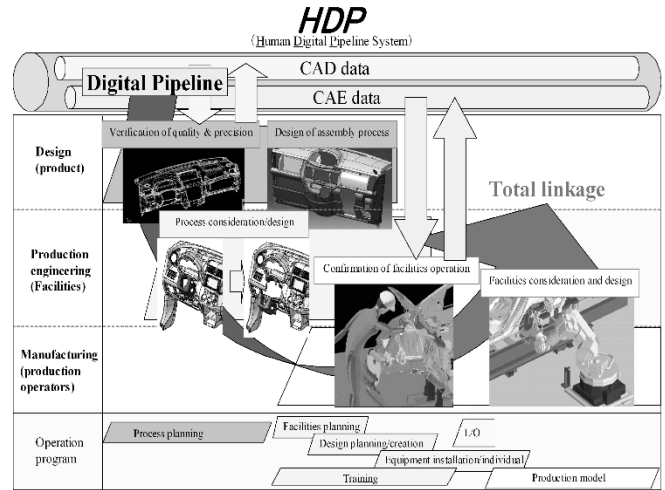


Fig. 4. Concept and structural elements of HDP

C. "HI-POS" hardware system software system

"HI-POS" consists of HID, HIA, HDP, and V-MICS hardware and software.

The first HID which composes the main system of "HI-POS" has a software system which explicitly indicates the concrete output and method of the production process, and a hardware system which enables management and operation of them on a computer. Then, the second HIA has a friendly software system which can be used universally and a hardware system which shares those information. In addition, the third HDP has a software and hardware system capable of extracting and generating the necessary data from the digital pipeline. By utilizing these systems in an integrated manner, the development of intelligence operators is properly realized in a short period of time.

In addition, the fourth V-MICS which supports "HI-POS" has a software system representing how the components constituting the robot are disassembled and reassembled by CGs and a hardware system sharing those informations.

IV. CASE STUDY OF "HI-POS"

In this chapter, the author has illustrated "HID"; operator diagnoses, "HIA"; operator assistance, "HDP"; digital pipeline as a case study of the "HI-POS" the author can propose.

A. HID

This paper presents an example of applying "HID" to a new person at the start-up of a line in a new overseas factory. Here, the example of visualization of work training process and skill learning step is taken up, and the effect is described.

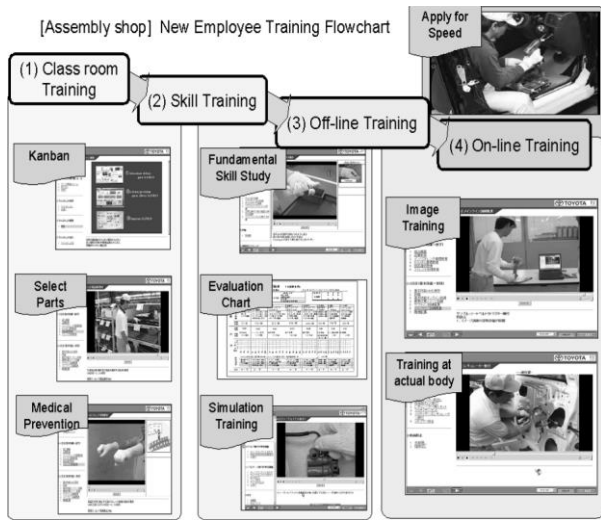


Fig. 5. Training process for assembly shop

Figure 5 shows an example of visualization of the work training process, "Training Process for Assembly Shop". (1) Class room Training, (2) Skill training, (3) OFF-line training, and (4) ON-line training are organized in this order, and each operation method can be extracted from the system and found in real time, and systematic practical skill training is carried out by these.

As a consequence, the author was able to achieve the "HID" at the same time and at the same time the target operating rate was achieved from the start of production at new overseas plants in Toyota, making it the foundation for the "global production" strategy [22].

Next, the author has outlined the visualization of skill mastery steps. When a new person and veteran were compared on the "fundamental skill" training, it was found that the dispersion of the work using the tool was big in comparison with that of the manual work. It is presumed that the accumulation of failures in the setting of parts to the tool is varying.

In addition, it is classified into four classes according to the level of skill learning from the results of work training (Class A: early learning time in dynamic training in dexterity, Class B: slow learning time in dynamic training, Class C: relatively early learning in dead but dynamic training, Class D: slow learning time in dynamic training in dead dexterity).

When the transition from the level of mastering in the "fundamental skill" training such as bolt tightening to the dynamic training was analyzed using the three factors of tool work mentioned above-manual work, stability over the failure frequency-instability, and the learning time (time base) is quick-slow, as shown in Figure 6, it can be confirmed that the transition from Class A to Class D is stepwise since the four classes overlap according to the time base in the whole as shown in Figure 6.

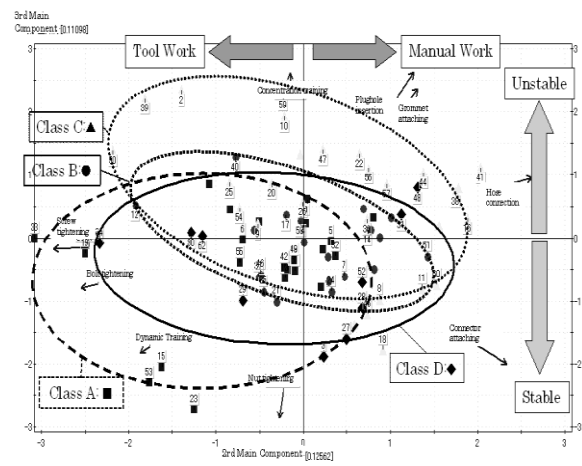


Fig. 6. Steps in skill acquisition

Once the trainees complete the class room training on quality, safety, etc., they are ready to acquire the skills required for their actual work. Skill training breaks down the fundamental skills into eight categories: (1) Tightening, (2) Screws and grommets, (3) Attaching, (4) Connectors, (5) Hoses, (6) Hole plugs, (7) Flare nuts and (8) Inserting.

The training also identifies techniques (knack and key points), which are taught in appropriate sequence. The training is repeated until the trainees reach the goals indicated on the evaluation sheet. For off-line training, an actual vehicle will be used and the trainees receive on the job training (OJT) in parts assembly on a stationary vehicle, followed, finally, by the on-line training where they are placed on real assembly lines. The on-line training gives the trainees another OJT opportunity and is conducted at actual line speed.

Figure 7 shows the assembly work training curriculum and traditional and HID training results. The traditional one-to-one method that focused on OJT relying on the individual capabilities of highly-skilled trainers with years of experience in Japan resulted in inconsistency among plants (plants A through D) in terms of training hours required and contents of class room training, skill training, off-line training, and on-line training. Some trainers skipped the off-line training and took the trainees directly to the on-line training stage for exposure to the speed of the actual production line.

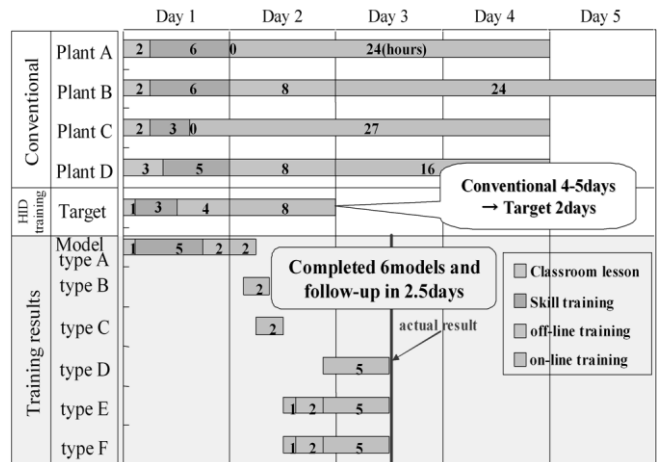


Fig. 7. Training curriculum for assembly works and current status using HID

In contrast, the HID training cut the target completion of the course by more than half, to 2.5 days. It also set the training hours for each segment; class room training: 1 hour; skill training: 3 hours; off-line training: 4 hours; and on-line training: 8 hours. When training was carried out, off-line training took one day and on-line training 1.5 days. The training finished in 2.5 days. The on-line training in this particular case study had to deal with many different model types (model types A to F), which caused some problems. However, it encouraged the authors and led to the conclusion that training could be completed in two days, under normal circumstances.

The trainees traditionally needed four weeks to develop their skills to a level that satisfied the time and accuracy requirements. Under the HID operator training processes, all the trainees were able to acquire the skills in about half that time. An analysis of the result shows the following:

- (1) The classroom training allowed the trainees to develop more accurate images of their work. The skills training broke down the skills into more detailed elements such as tightening. It clarified the skill level of each individual in specific elements. The training focused on his/her low skill level elements, resulting in quick improvement in the trainee's skills.
- (2) The teaching processes and the sequence were clearly identified. It eliminated variation of training by trainers and achieved teaching content and method consistency. Consequently, the training was efficient and resulted in even acquisition of the skills by the trainee.

This case study has proven the effectiveness of the HID operator training processes in faster skills acquisition through breaking down the skills, visualizing the skill level of each individual, focusing on select skills, and repeating training on these specific skills.

A supplementary benefit of these processes was noticed with disabled operators. The operator training for disabled trainees has typically been a special session. The HID operator training processes, however, made it possible to train these operators along with other trainees. It eliminated the need for a special session, contributed to faster skills acquisition, and improved training efficiency. Despite these benefits, the HID operator training processes proved to be slightly less effective than the conventional one-to-one method in some specific work items where operators need to improve their skills to an even higher level. This issue should be studied in the future.

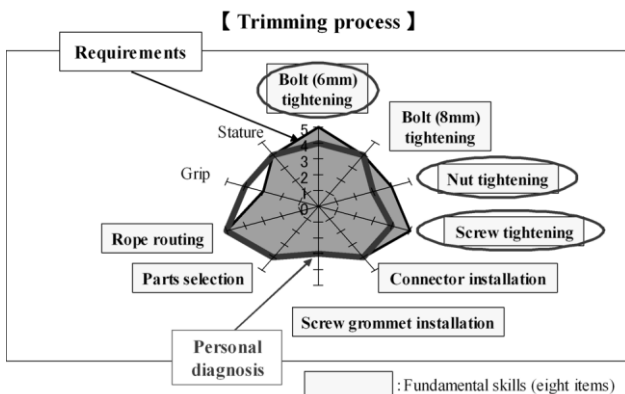


Fig. 8. Example of skill levels between requirements and personal diagnosis

The analysis was then carried out with only two components: tool work-manual work, quick-slow, and it was found that there exists an extremely independent class: D. Further analysis of this class on a stable-unstable axis did not fail, but because the time was slow, it was found that the finger did not move and the learning level did not improve.

By these, the step of the skill learning became to move the finger first, and then the manual work became possible, and the tool work became possible last, and the number of failures decreased by repeating the number of training afterwards, and the stable work became possible [14].

B. HIA

An example of applying "HIA" to production operators in overseas factories is introduced. Here, the example of the intelligent IT system which utilized the video is taken up, and the effect is described.

To be more precise, an example from the trimming process is shown in Figure 8. Fundamental skills are stratified into eight items: (1) bolt (6 mm) tightening, (2) bolt (8 mm) tightening, (3) nut tightening, (4) screw tightening, (5) connector installation, (6) screw grommet installation, (7) parts selection and (8) rope routing.

The training is conducted with stress placed on bolt (6 mm) tightening and nut/screw tightening, which involves significant differences between requirements and personal diagnosis, making each person aware of, and able to overcome their weak points through training. The training is conducted repeatedly until attainment of the target level by evaluation using the specified evaluation sheet.

While conventional training is aimed at mere satisfaction of the target time specified, the new method uses a visual manual aimed at ensuring each trainee acquires the required skills for specified quality assurance through repeated teaching according to his or her progress for the procedure, broken down into techniques (knack and key points).

Figure 9 shows an example of the visual manual concerning the bolt feeding operation. Accurate motions are visually indicated clearly using still pictures, moving images and animation. The explanatory text under each image describes why the posture is needed, what role it plays in quality assurance or other information from the intelligence operator so as to share the best practices in the world.

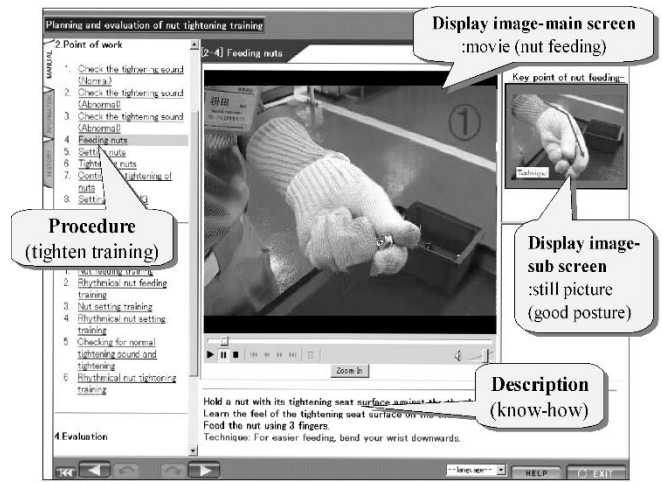


Fig. 9. Example of visual manual concerning bolt feeding operation using HIA

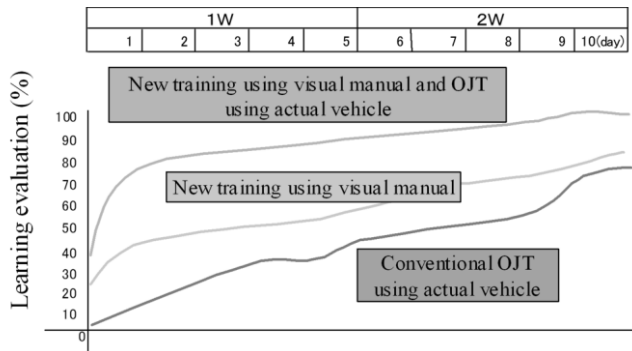


Fig. 10. Learning evaluation for new employees assigned to trimming process

Figure 10 shows the learning evaluation conducted for new employees assigned to the trimming process. The learning curve for conventional training consists mainly of OJT using the actual vehicle is compared with the new training using the visual manual. The degrees of learning indicated in time series for the assigned trimming process job according to the individual evaluation sheet (details are omitted) show that it took four weeks until satisfaction of the specified level of accuracy within the specified work time in the case of conventional training, but this was reduced to one half with the new method. The analytical results are as follows:

- (1) Training with the visual manual of primarily individual weak points based on personal diagnosis has improved the image of the assigned job, and achieved faster learning compared to the conventional method.
- (2) When training with the visual manual is combined with OJT on the actual vehicle, etc., it has been confirmed that the learning speed can be increased through repetition of training that places an emphasis on personal weak points.
- (3) Efficient training was attained without dispersion in the degree of learning by teaching the same contents in the same manner according to the clarified teaching process and procedures not dependent on differences between trainers.

Furthermore, "HIA-Intelligent IT System (HIA-IITS)" which makes the person understand and convince by the video which was studied voluntarily using the video on the know-how such as the working posture which was conventionally communicated verbally was devised, and the training is carried out repeatedly until the person understands and convinces the person. Specifically, after image training is loaded, a series of operations with "Highly skilled trainer" is recorded with moving images as shown in Figure 11, and the newly employed operator is similarly captured with the movement of the operation as data so that both images can be viewed synchronously side by side in the PC [15].

By this, the newly employed operator can understand its weak point objectively, and it became possible to reach to the predetermined skill level in a short period by repeatedly practicing it again. In addition, a system in which video of a series of work by a highly skilled trainer is contracted with a production operator as an employment condition was also introduced in overseas production plants.



Fig. 11. Image comparisons of a highly skilled trainer and a newly employed operator

C. HDP

An example of applying "HIA" to production operators in overseas factories is introduced. Here, the example of the intelligent IT system which utilized the video is taken up, and the effect is described. An example of applying "HDP" to the simultaneous world start-up of new products is introduced. This paper outlines the process composition simulation ((a) operator interference simulation, and (b) process interference simulation) which derives the optimum combination of works based on the work procedure manual, and describes the effect.

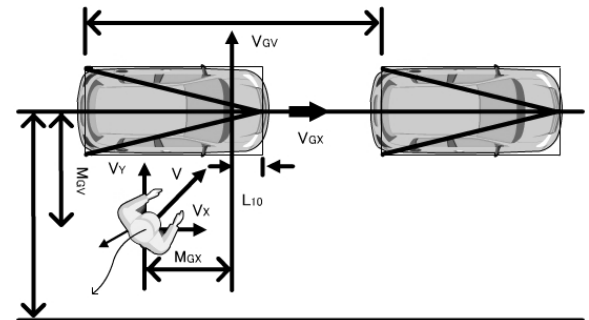


Fig. 12. Calculation of coordinate locations

V; Walking speed

VG; Tact Speed

MG; Distance from start position

VX; X-coordinate of V's working position

VY; Y-coordinate of V's working position

MGX; Max Move Time per Hour for X-Coordinates

MGY; Y-coordinate maximum travel time per hour

T; Walking time

"Walking time calculation formula":

$$T = (-b + \sqrt{b^2 - ac}) / a \tag{1}$$

$$a = V^2 - V_{GX}^2 - V_{GY}^2$$

$$b = -M_{GX} \times V_{GX} - M_{GY} \times V_{GY}$$

$$c = -M_{GX}^2 - M_{GY}^2$$

When moving from the operator's current work position to the next work position, considering the speed of the conveyor, Figure 12 shows the concept of coordinate calculation so that the operator can move in a straight line. The walking time of the worker is generally expressed as shown in Equation (1). In addition, considering the matching with actual work, the following three requirements are complemented and the next coordinate position is calculated.

a) In order to simulate the route to circumvent by avoiding the contact between the worker and the body (Vehicle), it is set beforehand which avoidance point is taken in the case of which working position from which working position. (When working inside an actual vehicle, the avoidance point is set to a total of four points by considering the front of the vehicle (Engine Compartment), the rear (Luggage) or the whole as one square, respectively, and the avoidance point is set to two points on the right and left (Center Pillar), and the process operator is programmed to avoid interference with the vehicle: Figure 13)

b) In order to obtain the shortest route and the shortest distance, the following working positions to be moved are calculated using the Dijkstra's algorithm [23][24] (shortest route calculation method). (Provide a pattern in which a process worker can move by line segment as shown in the following figure for each vehicle model, and calculate which route is shortest when passing through it using the Dijkstra algorithm.)

c) As various conditions, the next movement coordinate is calculated for each increment time (initial setting is 1 second). The shorter the increment time, the more precise the simulation can be performed (however, the load on the PC increases because the computational complexity increases).

Through these efforts, they were successively deployed at the time of new car switch of overseas business entities, and the effects of early adoption were obtained, such as reaching the target level at the assembly trial stage before the start of mass production, as the initial aim of both productivity and quality. In addition, falls at changing points such as cycle time changes due to increased production capacity after the start-up are also avoided [16].

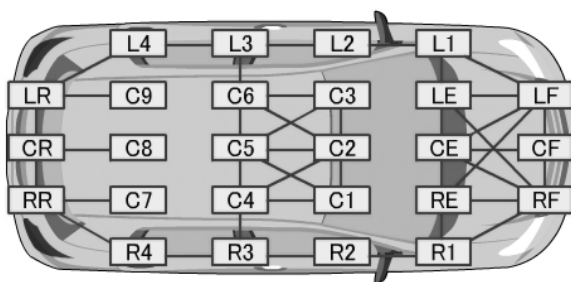


Fig. 13. Advance setting for avoidance points

D. Effectiveness of HI-POS application

As shown in Figure 14, the target of both productivity and quality was achieved at the stage of trial assembly before the start of mass production, demonstrating the accelerating effect. Also, the drop at transitional points, such as the cycle time change for increasing production capability was avoided. The proposed system made a contribution to the global production strategy of Toyota; which requires achieving worldwide uniform quality and simultaneous new model

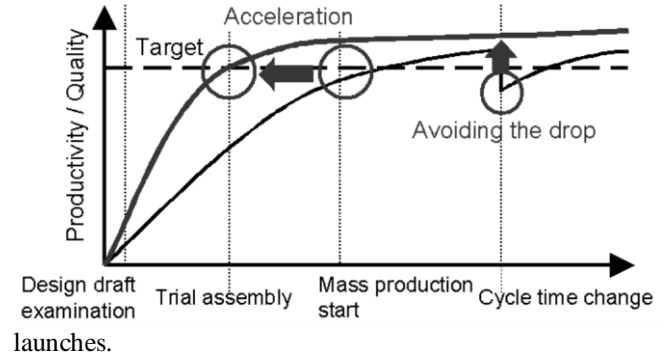


Fig. 14. Productivity / Quality Evaluation

V. CONCLUSION

The author has proposed an integrated human management system "HI-POS" aiming at strategic operation to "global production" in order to realize "simultaneous start-up and same quality" in the world, and demonstrated its effectiveness through demonstration examples of Toyota.

REFERENCES

- [1] A. Gabor, "The man who discovered quality: How Deming W. E.", Brought the Quality Revolution to America, Random House Inc., 1990.
- [2] R. Chawla, "An automated 3D facilities planning and operations model generator for synthesizing generic manufacturing operations in virtual reality", Journal of Advanced Manufacturing Systems, Vol.1, No.1, pp. 5-17, 2002.
- [3] J. P. Womack, D. Roos, and D. T. Jones, "The Machine That Changed The World", New York: Maxwell Macmillan International, 1990.
- [4] T. Ohno, "Toyota Production System", Diamond, Inc., 1978.
- [5] J. Richard Schoenberger, "Japanese Manufacturing Techniques", New York: The Free Press, 1982.
- [6] K. Liker Jefferey, "The Toyota Way: 14 management principles from the world's greatest manufacturer", The Toyota way fieldbook: A practical guide for implementing Toyota's 4Ps, Nikkei BP, 2004.
- [7] M. Imai, "Kaizen", New York: Random House Business Division, 1998.
- [8] E. Robert Callahan, "Quality circle: A program for productivity improvement through human resource development", New York: Praeger Publishers, 1982.
- [9] K. Amasaka, "New JIT, a new management technology principle at Toyota", International Journal of Production Economics, Vol.80, pp. 135-144, 2002.
- [10] K. Amasaka, "New Japan Production Model, an Advanced Production Management Principle: Key to Strategic Implementation of New JIT", The International Business & Economics Research Journal, Vol.6, No. 7, pp.67-79, 2007.
- [11] K. Amasaka (editor), "New Japan Model- Science TQM: Theory and Practice of Strategic Quality Management", The Concept of Quality Management in the Manufacturing Industry, Academic Study Group Edition, Maruzen, 2007.
- [12] K. Amasaka and H. Sakai, "TPS-QAS, New Production Quality Management Model: Key to New JIT-Toyota's Global Production Strategy", International Journal of Manufacturing Technology and Management, Vol.18, No.4, pp.409-426, 2009.

- [13] H. Sakai, and K. Amasaka, "Strategic HI-POS, intelligence production operating system", WSEAS TRANSACTIONS on ADVANCES in ENGINEERING EDUCATION, Vol. 3, No.3, pp.223-230, 2006.
- [14] H. Sakai, and K. Amasaka, "Human Intelligence Diagnosis Method Utilizing Advanced TPS", Journal of Advanced Manufacturing Systems, Vol. 6, No.1, pp.77-95, 2007.
- [15] H. Sakai, and K. Amasaka, "Human-Integrated Assist Systems for Intelligence Operators", Encyclopedia of Networked and Virtual Organizations, Vol. II G-Pr, pp. 678-687, Information Science Reference, Hershey, New York, 2008.
- [16] H. Sakai, and K. Amasaka, "Human Digital Pipeline Method using Total Linkage through Design to Manufacturing", Journal of Advanced Manufacturing Systems, Vol. 6, No.2, pp.101-113, 2007.
- [17] A. Kelly, "Maintenance Strategy", Butter worth Heinemann, 1997.
- [18] J. S. Peter, and K. W., "Data visualization in manufacturing decision making", Journal of Advanced Manufacturing Systems, Vol.2, No.2, pp.163-185, 2003.
- [19] K. Amasaka, "Highly Reliable CAE Model, The Key To Strategic Development Of Advanced TDS", Journal of Advanced Manufacturing Systems, Vol.6, No.2, pp.159-176, 2007.
- [20] H. Sakai, and K. Amasaka, "TPS-LAS Model Using Process Layout CAE System at TOYOTA", Journal of Advanced Manufacturing Systems, Vol.5, No.2, pp.127-140, 2006.
- [21] M. Yamaji, H. Sakai, and K. Amasaka, "Evolution of Technology and Skills in Production Workplaces Utilizing Advanced Tips", International Journal of Business & Economics Research, Vol.5, No.6, pp.61-68, 2007.
- [22] K. Ebioka, M. Yamaji, H. Sakai, and K. Amasaka, "A New Global Partnering Production Model "NGP-PM" Utilizing "Advanced TPS"", International Journal of Business & Economics Research, Vol. 5, No.9, pp.1-8, 2007.
- [23] E. W. Dijkstra, "A note on two problems in connexion with graphs", Numerische Mathematik, 1, pp.269-271, 1959.
- [24] B. Korte, and J. Vygen, "Combinational Optimization: Theory and Algorithms", Springer Science and Business Media, 2, pp.184-185, 2009.
- [25] H. Sakai, and K. Amasaka, "V-MICS, Advanced TPS for strategic production administration", Journal of Advanced Manufacturing Systems, Vol.4, No.6, pp.5-20, 2005.
- [26] H. Sakai and K. Amasaka, "Proposal and Demonstration of V-MICS-EM through the Development of Intelligence Operators: Development of Advanced TPS for Global Production Strategy", International Journal of Manufacturing Technology and Management, Vol.18, No.4, pp.344-355, 2009.
- [27] H. Sakai, and K. Amasaka, "Development of a Robot Control Method for Curved Seal Extrusion for High Productivity in an Advanced Toyota Production System", International Journal of Computer Integrated Manufacturing, Vol.20, No.5, pp.486-496, 2007.
- [28] K. Amasaka, and H. Sakai, "Availability and reliability information administration system ARIM-BL by methodology in inline-online SQC", International Journal of Reliability, Quality and Safety Engineering, Vol.5, No. 1, pp.55-63, 1998.
- [29] K. Amasaka, and H. Sakai, "Improving the Reliability of Body Assembly Line Equipment", International Journal of Reliability, Quality and Safety Engineering, Vol.3, No. 1, pp.1124, 1996.
- [30] H. Sakai, and K. Amasaka, "The robot reliability design and improvement method and the advanced Toyota production system", International Journal of Industrial and Service Robotics, Vol.34, No. 4, pp.310-316, 2007.