THE INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH

ISSN: 0020-7543 (Print) 1366-588X (Online) Journal homepage: https://www.tandfonline.com/loi/tprs20

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To cite this article: Y. SUGIMORI , K. KUSUNOKI , F. CHO & S. UCHIKAWA (1977) Toyota production system and Kanban system Materialization of just-in-time and respect-for-human system, THE INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH, 15:6, 553-564, DOI: 10.1080/00207547708943149

To link to this article: https://doi.org/10.1080/00207547708943149

Published online: 28 Mar 2007.

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INT. J. PROD. RES., 1977, VOL. 15, NO. 6, 553–564

Toyota production system and Kanban system Materialization of just-in-time and respect-for-human system

Y. SUGIMORI†, K. KUSUNOKI†, F. CHO† and S. UCHIKAWA†

The Toyota Production System and Kanban System introduced in this paper was developed by the Vice-President of Toyota Motor Company, Mr. Taiichi Ohno, and it was under his guidance that these unique production systems have become deeply rooted in Toyota Motor Company in the past 20 years. There are two major distinctive features in these systems. One of these is the ' just-in-time production ', a specially important factor in an assembly industry such as automotive manufacturing. In this type of production, " only the necessary products, at the necessary time, in necessary quantity " are manufactured, and in addition, the stock on hand is held down to a minimum. Second, the system is the ' respect-for-human ' system where the workers are allowed to display in full their capabilities through active participation in running and improving their own workshops.

Starting point of concept—making the most of Japanese characteristics

The starting point of the concept of the Toyota Production System was in the recognition of Japan's distinguishing features.

The most distinctive feature of Japan is the lack of natural resources, which makes it necessary to import vast amounts of materials including food. Japan is placed under a disadvantageous condition in terms of a cost of raw material when compared to the European and American countries. To overcome this handicap, it is essential for the Japanese industries to put forth their best efforts in order to produce better quality goods having higher added value and at an even lower production cost than those of the other countries. This was the first thing that Toyota recognized.

The second distinctive feature is that Japanese concept of work, such as consciousness and attitude, differed from that held by the European and American workers. The Japanese traits include: (1) group consciousness, sense of equality, desire to improve, and diligence born from a long history of a homogeneous race; (2) high degree of ability resulting from higher education brought by desire to improve; (3) centring their daily living around work.

Such Japanese traits have also been reflected in the enterprises. Customs such as (1) lifetime employment system, (2) labour unions by companies, (3) little discrimination between shop workers and white-collar staff, and (4) chances available to workers for promotion to managerial positions, have been of great service in promoting the feeling of unity between the company and workers. Also, unlike European countries, Japan does not have the problem of foreign workers.

Therefore from the standpoint of labour environment, Japan is much better off than the European and American countries. In order to make full use of the Japanese advantages, it is important that the

Presented at the 4th International Conference on Production Research (Tokyo) August 1977.

†Production Control Department, Toyota Motor Co., Ltd. 1 Toyota-cho Toyota-shi 471 Japan.

Published by Taylor & Francis Ltd, 10–14 Macklin Street, London WC2B 5NF.

industries have their workers display their capabilities to the utmost. This was the second thing that Toyota recognized.

Toyota production system and its basic concept

Upon recognition of the matters related above, Toyota is planning and running its production system on the following two basic concepts.

First of all, the thing that corresponds to the first recognition of putting forth all efforts to attain low cost production is " reduction of cost through elimination of waste ". This involves making up a system that will thoroughly eliminate waste by assuming that anything other than the minimum amount of equipment, materials, parts, and workers (working time) which are absolutely essential to production are merely surplus that only raises the cost.

The thing that corresponds to the second recognition of Japanese diligence, high degree of ability, and favoured labour environment is " to make full use of the workers' capabilities ". In short, treat the workers as human beings and with consideration. Build up a system that will allow the workers to display their full capabilities by themselves.

Cost cutting by thorough removal of waste

For materialization of this system, Toyota has attached special importance to ' just-in-time production ' and ' Jidoka '.

Distinguishing features of automotive industry: In order to have an efficient production system in the automotive industry, it is required that the following three distinguishing problems be solved.

(1) The automotive industry is a typical mass production assembly type where each vehicle is assembled from several thousand parts that have undergone numerous processes. Therefore, a trouble in any of the processes will have a large overall effect.

(2) There are very many different models with numerous variations and with large fluctuation in the demand of each variation.

(3) Every few years, the vehicles are completely remodelled and there are also often changes at a part level.

The ordinary production control system in such an industry consists of fulfilling the production schedules by holding work-in-process inventory over all processes as a means of absorbing troubles in the processes and changes in demand. However, such a system in practice often creates excessive unbalance of stock between the processes, which often leads to dead stock. On the other hand, it can easily fall into the condition of having excessive equipment and surplus of workers, which is not conformable to Toyotas' recognition.

Just in time production: In order to avoid such problems as inventory unbalance and surplus equipment and workers, we recognized necessity of schemes adjustable to conform with changes due to troubles and demand fluctuations. For this purpose, we put our efforts in development of a production system which is able to shorten the lead time from the entry of materials to the completion of vehicle.

The just-in-time production is a method whereby the production lead time is greatly shortened by maintaining the conformity to changes by having " all processes produce the necessary parts at the necessary time and have on hand only the minimum stock necessary to hold the processes together ". In addition, by checking the degree of inventory quantity and production lead time as policy variables, this production method discloses existence of surplus equipment and workers. This is the starting point to the second characteristic of Toyota Production System, that is, to make full use of the workers' capability.

(*a*) *Withdrawal by subsequent processes*: The first requirement of just-in-time production is to enable all processes to quickly gain accurat knowledge of ' timing and quantity required '.

In the general production system, this requirement is met as follows. The production schedule of the product (automobiles in the case of automotive plant) is projected on the various parts schedules and instructions issued to the various processes. These processes produce the parts in accordance with their schedules, employing the method of " the preceding process supplying the parts to its following process ". However, it can be seen that this kind of method will make it vastly difficult to attain production adaptable to changes.

In order to materialize the first requirement, Toyota adopted a reverse method of " the following process withdrawing the parts from the preceding process " instead of the " the preceding process supplying the parts to the following process ".

The reason for this is as follows: Just-in-time production is production of parts by the various processes in the necessary amounts at necessary timing for assembling a vehicle as a final product of the company. If such is the case, it can be said that only the final assembly line that performs the vehicle assembly is the process that can accurately know the necessary timing and quantity of the parts.

Therefore, the final assembly line goes to the preceding process to obtain the necessary parts at the necessary time for vehicle assembly. The preceding process then produces on the parts withdrawn by the following process. For the production of these parts, the preceding process obtains the necessary parts from the process further preceding it. By connecting up all of the process in chain fashion in this way, it will be possible for the entire company to engage in just-in-time production without the necessity of issuing lengthy production orders to each process.

(*b*) *One piece production and conveyance*: The second requirement of just-in-time production is that all processes approach the condition where each process can produce only one piece, can convey it one at a time, and in addition, have only one piece in stock both between the equipment and the processes.

This means that no process for any reason is allowed to produce extra amount and have surplus stock between the processes. Therefore, each process must approach the condition where it produces and conveys only

one piece corresponding to the single unit that is coming off the final assembly line. In short, all the shops are withheld from lot production and lot conveyance.

Toyota has succeeded in reducing the lot size through greatly shortening the setup time, improving production methods including the elimination of in-process inventory within the process resulting from ordering of multi-purpose machining equipment in accordance with the processing requirements for a product line, and improving conveyance resulting from repetitive mixed loading. All of these have been carried out, including large numbers of subcontractors.

(c) *Levelling of production*: Provided that all processes perform small lot production and conveyance, if the quantity to be withdrawn by the subsequent process varies considerably, the processes within the company as well as the subcontractors will maintain peak capacity or holding excessive inventory at all times.

Therefore, in order to make a just-in-time production possible, the prerequisite will be to level the production at the final assembly line (the most important line that gives out the production instructions to all processes). A degree of this levelling is determined by top managers.

(1) Final assembly lines of Toyota are mixed product lines. The production per day is averaged by taking the number of vehicles in the monthly production schedule classified by specifications, and dividing by the number of working days.

(2) In regard to the production sequence during each day, the cycle time of each different specification vehicle is calculated, and in order to have all specification vehicles appear at their own cycle time, different specification vehicles are ordered to follow each other.

If the final assembly line levels the production as related above, the production of all processes practising subsequent process withdrawal and one piece production and conveyance are also levelled.

The second significant point in levelled production is to observe the basic rule of just-in-time; to produce only as much as possibly sold, on the one hand adjusting its production level according to the change in market, on the other hand producing as smoothly as possible within a certain range. Even after the monthly production schedule has been decided, Toyota will still make changes among the different specification vehicles on the basis of daily orders, and even when it comes to the total number, if there is necessity to meet the changes in market conditions, Toyota will make revisions in the monthly schedule so as to reduce the shock of market fluctuation as much as possible.

When the production system related above is compared with the generally adopted scheduled production system, the former system can operate with smaller production changes than the latter system. Consequently, it will be possible to do with the less equipment capacity and more stable number of workers. (This is specially important to Japanese companies that have lifetime employment system.)

A production control system which has been developed to practise the above three general rules is Kanban System.

(*d*) *Elimination of waste from over-producing*: The underlying concept in just-in-time production systems is that thevalue of existence of inventory is disavowed.

In the conventional production control system, existence of inventory is appreciated as a means to absorb troubles and fluctuations in demand and to smooth fluctuations in load of processes.

In contrast to this, Toyota sees the stock on hand as being only a collection of troubles and bad causes. We consider that virtually most of the stock on hand is the result of ' over-producing ' more than the amount required, and is the worst waste that can raise the production cost.

The reason why we consider inventory resulting from over-producing is the worst waste is that it hides the causes of waste that should be remedied such as unbalance between the workers and between the processes, troubles in various processes, workers' idle time, surplus workers, excessive equipment capacity and insufficient preventive maintenance.

Such latency of waste makes it difficult for workers to display their capability and it even becomes obstructive of an ever-lasting evolution of a company.

Jidoka: The term ' Jidoka ' as used at Toyota means ' to make the equipment or operation stop whenever an abnormal or defective condition arises '. In short, its distinctive feature lies in the fact that when an equipment trouble or machining defect happens, the equipment or entire line stops, and any line with workers can be stopped by them.

The reasons for ' Jidoka ' being so important are as follows:

(1) To prevent making too much. If the equipment is made to stop when the required amount is produced, making too much cannot arise. Consequently, the just-in-time production can be accurately carried out.

(2) Control of abnormality becomes easy. It will only be necessary to make improvements by directing attention to the stopped equipment and the worker who did the stopping. This is an important requirement when making up the system of ' full utilization of workers' capabilities ' related next.

Toyota has made countless number of improvements to realize ' Jidoka '.

Full utilization of workers' capabilities

This is Toyota's second basic concept of making the best use of Japan's favoured labour environment and excellent workers. It has built up a system of respect for human, putting emphasis on the points as follows: (1) elimination of waste movements by workers; (2) consideration for workers' safety; and (3) self-display of workers' capabilities by entrusting them with greater responsibility and authority.

Elimination of waste movement by workers: Workers may realize their work worthy only if the labour of diligent workers is exclusively used to raise added value of products.

Then what are the waste movements that lower added value and which we must eliminate? The first of these is workers' movements accompanying the waste of making too much. The movements of material handling operations between the equipment and between the processes due to large inventory are all waste movements. It has become possible for Toyota to effect large reductions of this waste by making up a system that allows thorough just-in-time production.

However, even though the waste of making too much is reduced, it will be of no avail if the waste of worker's waiting time is created as a result. In the just-in-time production, even when there is surplus capacity in the equipment, only as much as the subsequent process has withdrawn is produced. Thus, if the equipment and workers are tied together, workers are subject to idleness. To prevent such waste of waiting time being created, various improvements have been made such as: (1) separating the workers from the equipment by assigning a worker to multiple equipments; (2) concentration of workers' zones at the automatic lines; and (3) making up lines that do not require supervisory operation.

The second waste is to have the workers perform operations that are by nature not suitable for men. Operations involving danger, operations injurious to health, operations requiring hard physical labour, and monotonous repetitive operations have been mechanized, automated and unmanned.

The third waste is workers' movements as a result of troubles of defects. Thorough ' Jidoka ' by Toyota has greatly reduced this kind of waste.

Considerations to workers' safety: Workers of Toyota are diligent and enthusiastic about attaining production. Thus, he may not stop operation if the trouble is not of a serious nature and will take non-standard methods just to keep the line running. If waiting time occurs, he will become impatient and eventually start doing something extra. However, such kinds of unusual operation or extra work are often accompanied by accidents, troubles, or defects.

The ' Jidoka ' and elimination of waiting time now being advanced by Toyota is not only for reducing the production cost, but also effective as a measure for safety.

The results have been reflected in the fact that from an international standpoint the frequency rate of injury at Toyota is low.

Note: Comparison with the frequency rate of injury in American automotive industry shows that against the 1·5 shown in the United States (ILO 1974 statistics), Toyota had 0·8 or about one-half lower.

Self-display of workers' ability: Nowadays, it has become an international interest to respect humanity of workers in production shops. Toyota firmly believes that making up a system where the capable Japanese workers can actively participate in running and improving their workshops and be able to fully display their capabilities would be foundation of human respect environment of the highest order.

As the first step in this method, all workers at Toyota have a right to stop the line on which they are working.

Even in a long line like the final assembly line, if any abnormality comes up such as the worker finding himself unable to keep up or discovering an incorrect or defective part, he can stop the entire line by pressing the stop button near at hand. It is not a conveyer that operates men, while it is men that operate a conveyer, which is the first step to respect for human independence.

As the second step, at all shops in Toyota, the workers are informed of the priority order of the parts to be processed and the state of production advancement. Therefore, the actual authority for decisions of job dispatching and overtime is delegated to the foreman, and this allows each shop to conduct production activities without orders from the control department.

As the third step, Toyota has a system whereby workers can take part in making improvements. Any employee at Toyota has a right to make an improvement on the waste he has found.

In the just-in-time production, all processes and all shops are kept in the state where they have no surplus so that if trouble is left unattended, the line will immediately stop running and will affect the entire plant. The necessity for improvement can be easily understood by anyone.

Therefore, Toyota is endeavouring to make up a working place where not only the managers and foremen but also all workers can detect trouble. This is called ' visible control '.

Through visible control, all workers are taking positive steps to improve a lot of waste they have found. And the authority and responsibility for running and improving the workshop have been delegated to the workers themselves, which is the most distinctive feature of Toyota's respect for human system.

Kanban system

Aim of Kanban System

A production control system for just-in-time production and making full use of workers' capabilities is the Kanban System. Utilizing Kanban System, workshops of Toyota have no longer relied upon an electronic computer. It is shown in Fig. 1.

The reasons to have employed Kanban System instead of computerized system are as follows:

(1) Reduction of cost processing information. It calls for huge cost to implement a system that provides production schedule to all the processes and suppliers as well as its alterations and adjustments by real time control.

(2) Rapid and precise aquisition of facts. Using Kanban itself, managers of workshops may perceive such continuously changing facts as production capacity, operating rate, and man power without help of a computer. Hence, data of schedules corresponding to the change are accurate, which urge workshops to found responsibility systems and to promote activities for spontaneous improvements.

(3) Limiting surplus capacity of preceding shops. Since an automotive industry consists of multistage processes, generally the demand for the item (the part) becomes progressively more erratic the further the process point

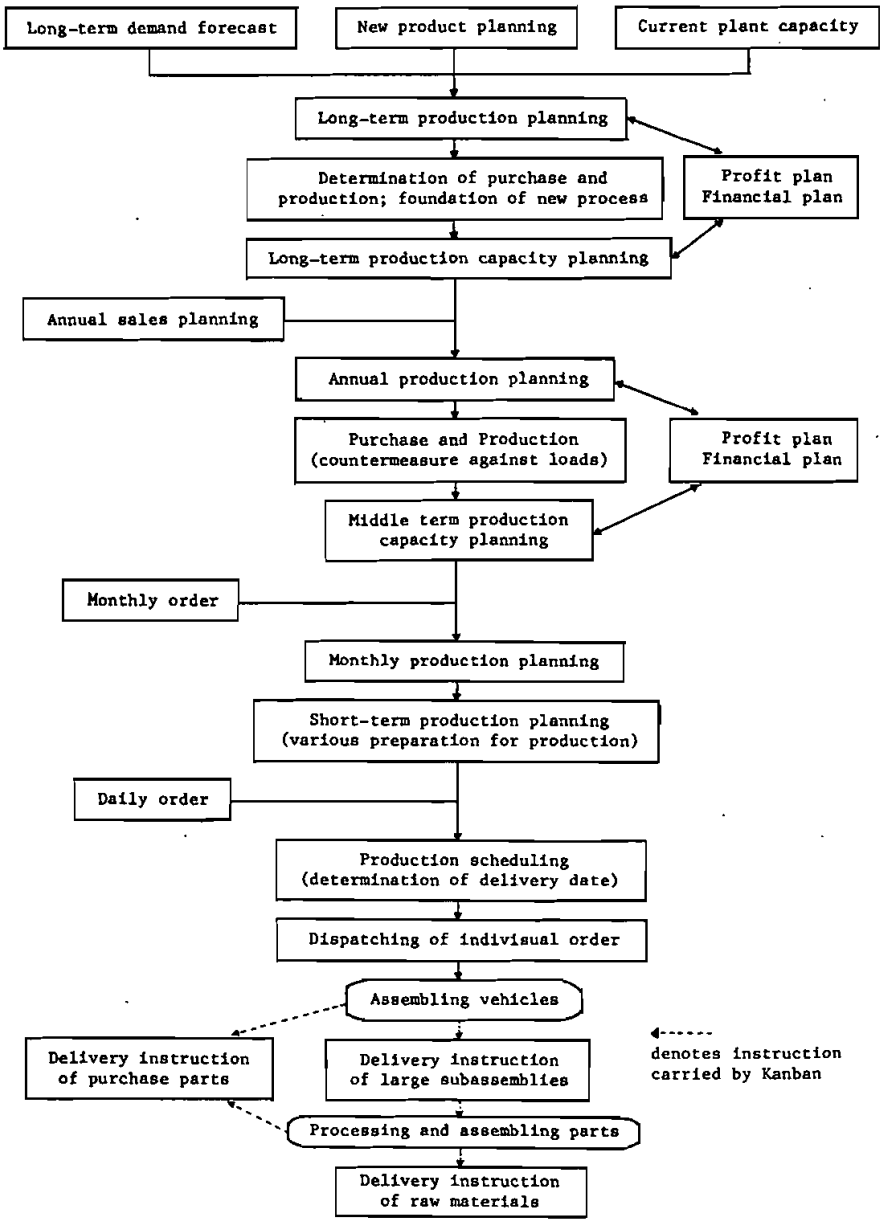


Figure 1. Structure of production planning.

is removed from the point of the original demand for finished goods. Preceding processes become required to have surplus capacity, and it is more liable to have waste of over-producing.

3.2 *Description of Kanban system*

(1) In the Kanban System, a form of order card called Kanban is used. These come in two kinds, one of which is called ' conveyance Kanban ' that is carried when going from one process to the preceding process. The other is called

' production Kanban ' and is used to order production of the portion withdrawn by the subsequent process.

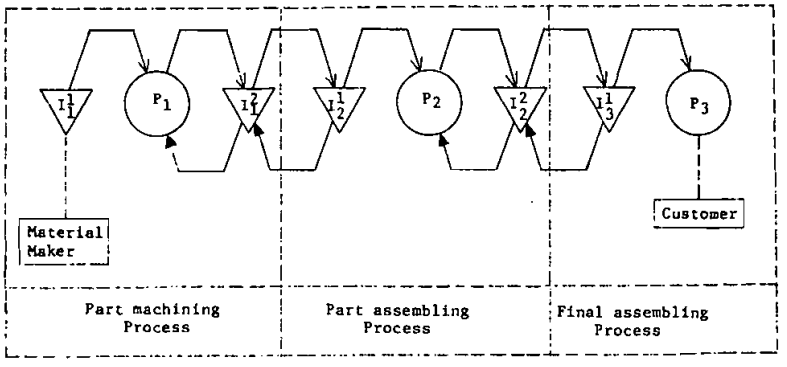
These two kinds of Kanban are always attached to the containers holding parts.

(2) When content of a container begins to be used, conveyance Kanban is removed from the container. A worker takes this conveyance Kanban and goes to the stock point of the preceding process to pick up this part. He then attaches this conveyance Kanban to the container holding this part.

(3) Then, the ' production Kanban ' attached to the container is removed and becomes a dispatching information for the process. They produce the part to replenish it withdrawn as early as possible.

(4) Thus, the production activities of the final assembly line are connected in a manner like a chain to the preceding processes or to the subcontractors and materialize the just-in-time production of the entire processes.

The flow of parts and Kanban are as shown in Fig. 2.



Pi; Operation of process i

I_i^1; Part inventory for process i

I_i^2; Finished good inventory for process i

⟶ ; Flow of Kanban

⟶ ; Flow of parts

Figure 2. Flow of parts and Kanban.

The equation for calculating the number of Kanban that play the most important part in this system is as follows:

Let,

y = Number of Kanban.

D = Demand per unit time.

T_w = Waiting time of Kanban.

T_p = Processing time.

a = Container capacity (not more than 10% of daily requirement).

α = Policy variable (not over 10%).

Then,

$$y = \frac{D(Tw + Tp)(1+\alpha)}{a}.$$

Notable points of operations of Kanban System—meaning of the equation computing number of Kanban

In order to materialize Toyota Production System through Kanban System, we do not accept each factor as a given condition, but we attach importance to modify each by means of positive improvements.

(1) α is a policy variable which is determined according to workshop's capability to manage external interference.

(2) D is determined with a smoothed demand.

(3) Value of y is rather fixed despite variation of D. Therefore, when D increases, it is required to reduce the value of $(Tp+Tw)$, that is, a lead time. At a workshop with insufficient capability of improvement, they cannot avoid overtime for a while. They might even cause line-stops. However, the ultimate objective of Toyota Production System is to visualize such wastes as overtime and line-stop, and to urge each workshop to become capable in improvement. Incapable shops might have to cope with the situation by means of increasing α, that is, number of Kanban for the time being. Hence, the top managers consider the value of α as an indicator of shop capability in improvement.

(4) In the case that demands decreases, the lead time becomes relatively larger. Consequently waste of increasing idleness becomes visible, which is an object of improvement called ' Syojinka '—to decrease the number of workers as demand (production) decreases.

(5) Work-in-process inventory could become much less by conducting an improvement to reduce the value of a, α, and $(Tp+Tw)$.

What Toyota considers as a goal through Kanban System related above is total conveyor line production system connecting all the external and internal processes with invisible conveyor lines. Because, a set of values of α, a, and Tw is 0, 1, and 0, respectively, which means nothing but attributes of a conveyor line. All the parts that constitute a vehicle are processed and assembled on a conveyor line, raising its added value. Finally they come out as a completed vehicle one by one. On occurrence of troubles, the whole line may stop, but it begins to move again immediately. Toyota Production System is a scheme seeking realization of such an ideal conveyor line system, and Kanban is a conveyer connecting all the processes.

Expansion of just-in-time production by reduction of set-up times of pressing dies

In applying the concept of just-in-time production for reduction of lead times and work-in-process inventory, we faced difficulty in press shops practising lot production. After discussing a solution of this difficulty in lot production, we concluded that lead time was proportional to set-up times, using the following illustration.

Let,

T = Operation time a day or 480 minutes.

S = Total set-up time for all products, assuming that S is independent of sequence of products.

t_{mi} = Unit processing time for the ith product.

d_i = Demand for the ith product per day.

x = Lead time for all products (in number of days).

Q_i = Lot size for the ith product.

Then, $T \cdot x = S + \sum_i t_{mi} \cdot d_i \cdot x$.

Hence,

$$x = \frac{S}{T - \sum_i t_{mi} \cdot d_i}$$

	Toyota	A (U.S.A.)	B (Sweden)	C (W. Germany)
Set-up time (hour)	0·2	6	4	4
Number of set-ups a day	3	1	–	0·5
Lot size	1 day-use †	10 days-use	1 month-use	—
Strokes per hour	500–550	300	–	—

† For less demanded products (below 1000 units per month), as large as 7 days-use.

Table 1. Press plant productivity characteristics (hood and fender).

	Takaoka plant of Toyota	A (U.S.A.)	B (Sweden)	C (W. Germany)
Number of employees	4300	3800	4700	9200
Number of outputs a day	2700	1000	1000	3400
Man-hours for completion of vehicle	1·6	3·8	4·7	2·7

Table 2. Man-hours for completion of a vehicle in automotive assembly plants of major counties.

	Toyota	A (Japan)	B (U.S.A.)	C (U.S.A.)
1960	41	13	7	8
1965	66	13	5	5
1970	63	13	6	6

Table 3. Turnover ratio of working assets in automotive companies of major countries.

Year	Total number of proposals	Number of proposals per capita	Acceptance
1965	9000	1·0	39%
1970	40000	2·5	70
1973	247000	12·2	76
1976	380000	15·3	83

Table 4. Transition of number of annual proposals per capita and acceptance rate.

Lead time is proportional to set-up times for a given set of t_{mi} and d_i for all $i=1, 2, \ldots, n$. And lot size for each product Q_i is;

$$Q_i = d_i \cdot x \quad \text{for all } i=1, 2 \ \ldots, n.$$

Improvements in production engineering have been made so as to reduce set-up times since 1971. We have succeeded in reducing set-up time down to 10 min at 800 ton-line pressing hood, fender and others, while it used to take 1 hour. (Under the present condition of western countries, 4 to 6 hours as shown in Table 1.)

The result = the present condition of Toyota

As related above, Toyota has built up a unique production system through its history of more than 20 years. The results are as follows:

(1) Labour productivity is the highest among automotive industries of major countries. (Table 2.)

(2) Turnover rate of working asset is also extremely high. (Table 3.)

(3) Number of proposals and rate of acceptance in a proposal system shows the condition that workers positively participate in improvement (Table 4.)

Le système de production Toyota et le système Kanban présentés dans cet article ont été mis au point par le Vice-Président de la Toyota Motor Company, M. Taiichi Ohno et c'est sous sa direction que ces systèmes de production uniques se sont implantés si profondément au sein de la Toyota Motor Company au cours des 20 dernières années. Ces systèmes comportent deux caractéristiques distinctives principales: l'une d'elles est la 'production au moment opportun', un facteur spécialement important dans une industrie d'assemblage telle que la fabrication de voitures. Dans ce type de production, " seuls les produits nécessaires, au moment nécessaire et en quantités nécessaires ", sont fabriqués. En plus, les stocks sont maintenus au minimum. La seconde est 'le respect de l'être humain'. Dans ce systéme, on permet aux ouvriers de révéler toutes leurs capabilités par une participation active à l'exploitation et à l'amélioration de leurs propres ateliers.

Das Toyota Produktionssystem und das Kanban System, welche in dieser Arbeit vorgestellt werden, wurden vom Vize-Präsidenten der Toyota Motor Company, Herrn Taiichi Ohno, entwickelt; und unter seiner Leitung wurden diese einmaligen Produktionssystem in den letzten 20 Jahren zu einem fest verankerten Bestandteil der Toyota Motor Company. Diese Systeme haben vor allem zwei hervorstechende Merkmale. Eines davon ist die 'gerade-zur-rechten-Zeit'-Produktion, ein besonders wichtiger Faktor in der Montageindustrie, wie z.B. der Kraftfahrzeugindustrie. Bei dieser Art der Produktion werden "nur die notwendigen Produkte, zur notwendigen Zeit, in der notwendigen Menge" hergestellt, und die Vorräte werden auf ein Minimum Beschränkt. Zweitens handelt es sich bei dem System um ein 'Respektierung des Menschen'-System, in denen den Arbeitern die Möglich keit gegeben wird, ihre Fähigkeiten voll zu entfalten, indem sie sich aktiv an der Organisation und der Verbesserung ihrer Werkstätten beteiligen.

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