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論　文

The Division of Labor to Deal with "Changes and Problems" on Manufacturing Shopfloors

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Chapter 1 Division of labor to deal with unusual operations or "changes and problems" on manufacturing shopfloors

Introduction

Kazuo Koike's Theory of Intellectual Skills attracted widespread attention as a theory giving an explanation of high efficiency in manufacturing shopfloor work in Japan at a time when high industrial growth in Japan became an object of interest in the 1980s. What plays an important role in his theoretical structure is the concept that by implementing "unusual operations," in

other words, by performing "acts of dealing with changes and problems," workers acquire such a kind of intellectual skills that cannot be obtained in performing "usual operations." Furthermore, it is argued that the separation of thinking and working in a Taylor-based line organization, as well as the resulting low quality of labor, stems from that work organization where the work of workers is limited to "usual operations" and where "unusual operations" are put into the hands of engineers or technicians (this work organization being referred to as "the separate system"), and that the Japanese way of production system has an advantage, since the intellectual ability of workers is fully derived by using the same line organization and by adopting, at the same time, that work organization in which "unusual operations" are committed to the care of relevant workers (this work organization being referred to as "the integrated system").

The present writer has some reservation about Koike's Theory of Intellectual Skills but he believes that the attention to the above-mentioned "unusual operations" is an important contribution of Koike's. About thirty years ago, the present writer wrote *Philosophy of Factories* [12], in which a discussion was made about the tendency for labor to get simplified under new technologies. However, this discussion was based in large part on observations limited to manufacturing shopfloors of the 1960s in Japan. Since then the present writer has seen, even on simple labor manufacturing shopfloors, to what extent workers experience various changes and problems in their lifetimes and in what way they learn from such events. Moreover, the present writer has seen that in a period when new technologies play a key role in market competition between enterprises, rapid model changes are made on a steady basis, that the acts of dealing with "changes" based on technological progress constitute "usual operations" in manufacturing shopfloor organizations, and that just as Koike points out, a part of repair and maintenance works of equipments which are handled by mechanics or technicians in Europe and North America, constitute operators' work in Japan.

For a considerably long period of time, our joint team has been making comparative studies of work in Japan and Sweden. It can be said that those studies have been carried out with major interest focused on "usual operations" (operations contained in standard work sheets). There came a time when a suggestion was made that another step forward should be taken and attention should be paid to "unusual operations," that comparisons should be made as to how workers deal with changes and problems in the two contrasting work organizations, namely one in Sweden based on workstation operations and the other in Japan based on line operations, and that comparisons should be made as to how such acts would be reflected in the formation of workers' skills.

At this time, we were faced by the indescribable ambiguity and versatility of the concept of

"unusual operations," particularly by the somewhat panacean role of the concept of intellectual skills. This concept cannot serve as the guidelines on empirical comparative research. For the purpose of obtaining a more pragmatical clue to comparative research, it became necessary to make precise studies of the structure of Koike's argument, thereby establishing our group's common recognition regarding the acts of "dealing with changes and problems" that conform to the realities of production lines. Chapter 1 was prepared in such a way that notes submitted by the present writer for purposes of inter-group discussions of the above were rewritten for publication to the outside. In this regard, the present writer wishes to make it clear that the objects of major interest of our studies are assembly lines for automobiles and household electrical appliances, and that Koike's theory is studied here from the single viewpoint of whether the theory is in agreement with the realities of manufacturing shopfloors on production lines.

1 Review of Koike's theory: centering on dealing with problems

One of the problems with Koike's methods is as follows: unprecisely defined commonsensical terms such as usual operations and unusual operations, namely "dealing with changes and problems" are frequently used in the theory; several examples of observations are mentioned in which it is not expressly stated at what production sites, with respect to what "changes and problems," such acts are performed in substantiation stages; and on the basis of the above, arguments are regarded as substantiated.

In consequence, in Koike's arguments, recognition regarding various conditions that restrict workers' behavior on lines is extremely inaccurate, with the result that circumstances in which changes and problems on lines cannot help being resolved by division of labor with people outside of lines are overlooked. Furthermore, the fact that "changes and problems" are of various types and that at the same time, such types are limited by the characteristics of manufacturing shopfloors (such as product types, techniques, and manufacturing methods) is disregarded, and as a result, the following facts are overlooked: on manufacturing shopfloors, those types of changes and problems which are most liable to occur are grasped through long experiences; setups are prepared in which such changes and problems are dealt with by different kinds of division of labor depending on such types; and in such setups, engineers and specialized workers play important roles.

In Koike's arguments, acts of dealing with problems are given an important standing, particularly in terms of relationships with intellectual skills. Therefore, in the first place, let us take problems as an example, to make a study of how Koike's arguments are constructed. Koike [9], which attracted the greatest attention, contains the following paragraph.

"The second part of unusual operations concerns handling any problems that may arise. ….The ability to deal with problems efficiently is an essential part of the skills needed. Actions taken to cope with problems can be divided into three steps.

(1) Detect the smallest problem in goods or production equipment as soon as possible. This requires long experience to acquire knowledge of variety of patterns or symptoms in unusual operations.

(2) Diagnose the sources of the problem. This step is crucial to prevent the recurrence of problems.

(3) Rectify or mend the process to eliminate the problem. If the source of the problem lies in the machinery, then repairs are obviously called for. A complete overhaul of the equipment will normally outside the job definition of its operators, but some repair and maintenance can be entrusted to the workers.

Being able to diagnose and rectify such problems implies a knowledge of the structure, functions, and mechanisms of the equipment, the products, and the production process itself, since most problems are due to troubles in some part of the machinery or to a part of the production process. This ability can be called the intellectual skills." [9, p. 44].

The key lies in the wording, "Actions taken to cope with problems can be divided into three steps." Here, Koike appeals to an image of commonsensical "dealing with problems," which anyone can bring to mind even if he / she does not know manufacturing shopfloors. Namely, this image is such that if it is determined what the causes are, and if those causes are eliminated, then the abnormalities will be corrected This fact is the key that makes Koike's arguments understood easily by anyone. The assumption for Koike's theory is that an operator working "at the very place" where a machine is running and production is carried out detects a problem, and diagnoses the sources of the problem, thus resolving the relevant problem and defect by himself / herself. People are persuaded that the operator's "ability to cope with problems" which is enhanced through repetition of cycles consisting of detection, diagnosis, and resolution is what Koike calls "intellectual skills."

However, if a thought is given in the framework of actual manufacturing shopfloor conditions, at least in the framework of manufacturing shopfloor conditions on flow production lines, these matters are quite infeasible. In the first place, as long as a line is running, no relevant operator can leave the line unless a relief person is available. Furthermore, repair of any device or automatic machine installed in the line cannot be performed unless the line is stopped. When a line on which the average *tact time*[1] for a "usual operation" is one to two minutes is taken into account, even if an operator increases his / her speed by making an unusual effort, whatever time

to spare created may probably be only several seconds. Therefore, it is impossible to perform, within the above-mentioned *tact time,* the work of inferring the cause of any abnormality discovered by him / her, taking countermeasures, and returning the operation to normal while carrying out the "usual operation." If he / she did, operation delay would instantly occur, and the line would stop in great confusion.

In some special case, for instance, a paint shop in which hand guns are used, it is so arranged that the final operator of each step performs finish work by correcting coating errors of the previous operator. As regards assembly shops, there may be cases where a worker in a downstream process is entrusted with the work of discovering correctable errors of an operator in an upstream process and making corrections. However, such work is an operation incorporated in the relevant work standard and is not an act of dealing with a problem as an "unusual operation" discussed here. Therefore, for the purpose of taking countermeasures against problems while the relevant line is running, each operations team should have at least one person who can freely move separately from the line. The principle of problem countermeasures that a line operator can take is to raise his / her hand to call out to the above-mentioned person.

In continuation of the paragraph quoted previously, wrote Koike, "In an integrated system, there are workers on the spot, i.e. beside the machinery, to perform unusual operations; when there is any sign of unusual trouble, these workers can handle it immediately. Compare this with the scenario where production workers have to call technicians or engineers from their offices every time they feel that something unusual is occurring. It is very likely that more than a few defective parts might pass without detection unless the operators themselves are able to identify what is wrong. If on the other hand, engineers or technicians walk around production line enough to give a similar benefit, then the numbers of engineers tends to be quite large. This becomes extremely costly, particularly as engineers' salaries are relatively high." [9, p. 46].

This paragraph, which is evidently written with regard to a manufacturing shopfloor on a line, shows that Koike is not a careful observer of the manufacturing shopfloor. The present writer emphasizes that as far as a manufacturing shopfloor on a line is concerned, a person who discovers a problem and a person who deals with the problem cannot help being different from each other (there is no choice but to adopt the separate system). However, the present writer does not think that it is an engineer or a technician that the relevant operator should immediately call out to. In the past, it was customary in Japan to station a relief person as a specialist dealing with problems encountered on lines. Nowadays, however, team leaders double as relief persons on many manufacturing shopfloors on lines. It is his / her team leader that the relevant operator should immediately call out to. The team leader judges in an instant whether he / she can deal with the problem by himself / herself. If he / she cannot do that, he / she consults his / her group

leader, and calls out to a technician in an appropriate field. Therefore, even in the case of "the separate system," it is not likely that more than a few defective parts pass without detection.

The present writer does not deny that even on manufacturing shopfloors on lines, there are cases where workers carry out troubleshooting. However, not everyone can perform troubleshooting. Only the team leader and a few qualified members of the team can carry out troubleshooting of relatively simple tools and equipments. It will be necessary to see how such acts of dealing are carried out.

On automobile assembly lines of Company T, there is a system involving designated troubleshooters. In many cases, designated troubleshooters are assigned to repair failures and troubles of auxiliary implements for assembly works on manufacturing shopfloors. However, a designated troubleshooter is not permitted to deal with problems in general, but he is responsible to a few specific implements on which his name is labeled as the designated troubleshooter. It never happens that workers with a career of under six or seven years are permitted to perform troubleshooting. Operators having longer experiences are designated as such after receiving training on troubleshooting and repair of his responsible implements. A production manager of Company T told the present writer that the acquisition of this qualification serves as a good incentive for workers.

Company D also has almost the same system for qualifications, and the term "approved troubleshooter" is used. This system is similar to that of Company T in the following points as well: only designated workers can perform troubleshooting; and in order to become an approved troubleshooter, it is necessary to have work experience longer than 6 or so years and in addition to undergo training for troubleshooting with the relevant equipment (this practice is different from Koike's argument that production workers get skilled by dealing with problems on an on-the-job basis). Furthermore, even if a worker is a designated or approved person, in order for him / her to be able to actually carry out troubleshooting, it is necessary that either he / she should be in a job position free from line duties or someone else (his / her team leader, for example) should relieve him / her of his / her line duties.

In the document of Company D titled "For Those of You Who Are Not Permitted to Perform Troubleshooting," which was shown to the present writer, the following items were written as "Points to Note When Any Problem Occurs" :

1. "Stop." Stop the machine in the first place.
2. "Call." Contact the team leader at once.
3. "Wait." At a place a little apart from the machine in which the problem occurred, wait until the person who is called arrives.

This practice is in a form in which team leaders and forepersons make thoroughly sure that the

most important manufacturing shopfloor rules are hammered into operators, by repeating "Stop, call, and wait" when any problem occurs. It is shown that the dominant principle on manufacturing shopfloors is for any unapproved person never to attempt to repair any problem machine by himself / herself.

A section manager of Company T emphasized that none of the operators assigned to line operations are able to deal with any problem as a matter of fact, and that it never happens that any person with a career of less than five or six years becomes a designated troubleshooter, then it is concluded that ordinary rules for dealing with manufacturing shopfloor problems are such that persons permitted to perform troubleshooting are either relief person-like workers or supervisors ranking as team leaders or sub leaders and that none of the workers assigned to lines are permitted. It can be said that in Koike's paragraph quoted above, not only is an impossible situation assumed in which unqualified operators carry out troubleshooting on lines at their discretion, but also such an assumption is widely different from the situation where acts of dealing with a certain level of problems is actually performed by operations teams on manufacturing shopfloors in Japan.

2 Division of labor to deal with changes and problems on manufacturing shopfloors: problem of communication between sections in division of labor in particular

With regard to the system for designated troubleshooters, the production manager of Company T told the present writer as follows: countermeasures against any problem that ever occurs on a manufacturing shopfloor are standardized without fail, and if such countermeasures can be implemented on manufacturing shopfloors, then designated troubleshooters will be created. Namely, on any decent manufacturing shopfloor, whenever they experience a new type of problem for the first time, the countermeasures for it will be discussed afterwards by workers, team leaders, and production engineers. Thus how to cope with this sort of problem is prescribed in a form of work standard or a simple shopfloor rule like "Stop Call Wait". Therefore, when a problem of the same nature occurs again, workers as well as the team leader can cope with it easily according to the relevant rule or work standard. Any manufacturing shopfloor has a history of production experiences regarding specific products. In the course of the history, innumerable problems and errors are experienced, and workers achieve growth accumulating rules, systems, and know-how for addressing such problems and errors. Relative superiority of such systems constitutes a great factor that governs the production efficiency of any enterprise. In our comparative research, it is necessary for us to have a greater interest in these aspects.

Therefore, it is important to make distinction between problems that the shopfloor ever experienced and those it experiences for the first time. In order to cope with the former, there is

no need to "diagnose the sources of it" and countermeasures should be taken as quickly as possible according the shopfloor rule or the relevant work standard. It is only for the latter that it is necessary to "diagnose the sources of it." The present writer wishes to take a look, later, at how such diagnose is performed. It is emphasized that at present, in either case, the diagnose of the sources is not the role of the relevant operator, and that his / her role is to raise a hand to call out to the team leader, thereby informing him / her of the problem.

Koike argues that defects of product are an example of a problem. Just as with problems or failures of devices and tools, in the case of defects as well, confirmations are almost fully made, through long experiences on manufacturing shopfloors, with regard to defeats occurring frequently, locations of occurrences, and causes. Such defects are typical examples of problems already experienced on manufacturing shopfloors, and a category called "frequently occurring problem" may as well be established. The methods of dealing with such defects are specified. There are two methods of dealing with defects that come under the category of "frequently occurring problem." The first one is repair or correction. With regard to defects that can be corrected without stopping lines, it is decided in advance who is to perform correction in what way. Any line is divided into appropriate lengths so that the whole line does not need to be stopped when it is necessary to stop a certain portion of the line. There is a buffer zone at each dividing portion. In some cases this buffer zone is used as places for minor correction. The final portion of any line serves as a test line for completed automobiles. At this portion, there is certain to be a repair factory, where any rejected automobile, namely, any defective car, is repaired by multiskilled workers. That is, repairing is the job of specialized workers.

A more positive act of dealing with defects is to reduce the probability of occurrence of defects. The possibility for any line workers to diagnose the sources for the occurrence of any defect and to eliminate the source by himself / herself is not as high as considered by Koike. This is because, as is inevitable for line operations, it is always the case that any defect that occurs in an upstream manufacturing process is discovered in a downstream manufacturing process. For example, on a coating line, for the purpose of baking paint, a furnace is passed through each time that a series of coating processes are completed. Soot generated in furnaces can also be a cause for a coating defect. However, even if an operator discovers a defect caused by soot, he / she cannot eliminate the cause. The only thing that he / she can do is to call out to his / her team leader to tell that fact to the leader. The team leader gives that information to the team leader who is responsible to the relevant furnace. If reports on defects regarding soot come in from other teams five or six times per hour, then the team leader will be aware that a real problem is occurring in any of the furnaces and will probably take appropriate action to deal with the problem by holding communication with the maintenance team.

One of the sources of occurrence of coating defects is dust. Mere practice of diligently cleaning manufacturing shopfloors can reduce defects. This will be the task of all operations teams. There can be countermeasures in which a clean room is adopted as the relevant coating factory. This is a task of the Production Engineering Department. Furthermore, it is often the case that the task of reducing defects that occur frequently on manufacturing shopfloors is taken up as a suitable goal for QC circle activities. The effort of inducing and organizing such activities is also part of the work of the Quality Control Department. The task of reducing the occurrence of defects progresses by embroiling communication and cooperation of all organizations involved in division of labor on manufacturing shopfloors.

In Company T, an organization called the Engineers Office is attached to the Manufacturing Department. The present writer once asked the Manager of the Manufacturing Department what on earth the job of the members of this office was. The manager first said that their job is to play the role of technical staffer for the section managers and the department manager, and then made a mention of the following instance: in the installation process for instrument panels, there was a problem such that screws in a certain area tended to get loose; the pertinent worker complained that there might perhaps be a problem with design; then a technical staffer was assigned to this issue; both the technical staffer and the operator discussed the matter, and various cases were tried; experiments were performed to confirm that the operator's complaint was correct; design was requested to be revised; then a design change was made and the problem disappeared.

At production sites, this kind of troubleshooting problems occur frequently. The important role of technical staffers is to provide connections, in such a way, among production site entities, production engineering organizations, and design organizations. An explanation was given to the effect that another important job of Engineers Office is guidance on preparations for production. This point will be mentioned later under the section on preparations for production.

Here, a comment should be made on the issue of mutual understanding that occurs at points of contact in division of labor. This is an issue of communication that occurs at the point of contact between the Production Engineering Department and the Manufacturing Departments, which are two great organizations closely related to each other. Engineers engaged in design cannot understand the problems of workers engaged in manufacture at production sites. Even if workers manufacturing products feel that there might perhaps be a problem with design, such workers do not know the wording for conveying their feeling to designers. This situation exists against the background of defects that occur on a steady basis. Discommunication, which takes place at points of contact in division of labor, is splendidly eliminated by the presence of a single technical staffer who is always stationed at a production site to be in contact with workers on a daily basis.

The fact that Koike recognizes the presence of this issue is shown by the following paragraph. "It is critical to the level of efficiency that proper production procedures and the right jigs and tools are selected when new products are about to be produced. Naturally, there will be production engineers and designers in charge of designing these. However, engineers are not almighty. It is not that they can foresee everything. Unexpected problems may occur." [9, p. 43].

This is precisely commensurate with discommunication described above that occurs at points of contact in division of labor. However, Koike's argument does not progress toward analytically determining the nature of such discommunication and then searching for a possibility of overcoming it as an issue of what division of labor should be. Instead, almighty "intellectual skills" appears on the scene.

"But if there are also production workers who can point out some part of the process that should be modified according to their own experience, then efficiency can be greatly improved. In order to do this, such workers must know both the structure of the machines and the logic of the production process, and this is precisely the intellectual element of skill. When it comes to dealing with unplanned problems in production, it is then that intellectual skills become all the more necessary." [9, p. 44].

In fact, matters such as discrepancies between design and production site situations, mistakes in design, and operational inconvenience in new equipment, which occur at innumerable frequencies when a new production process is introduced, are well-known issues in any factory. What matters is how to eliminate such discrepancies starting in the design stage. The operation called "preparations for production," which was previously mentioned in connection with the roles of technical staffers, is as follows: beginning in the trial production stage, predictable discrepancies are identified and eliminated in advance, with cooperation received from the Manufacturing Department; and starting in a certain stage, a team participated in by all organizations concerned is formed, thereby eliminating all discrepancies before new lines start up. This is a scene where "changes and problems" are dealt with, by collective efforts based on division of labor.

The present writer does not deny that in a certain stage of such preparations for production, test operations by veteran workers play an important role. However, this is but one step of a large "production preparation" project carried out in close cooperation between the product development division, the production engineering division, and the manufacturing division. Systematic studies should be made regarding what step of production preparation and in what way, operations by veteran workers or those by operations teams are performed, as well as concerning what can be found there. It is not until such studies are made that the roles of team

leaders and veteran operators in the system, as well as the contents of "skills," can be grasped objectively.

The logic, frequently used by Koike, in which an exemplification as shown above is directly linked to workers' "intellectual skills," can be understood very easily by people who do not know production sites. This is the basis for the fact that Koike's argument has a widespread influence. However, the ease of understanding is achieved by omitting all operations of addressing problems up to the relevant stage, as well as all aspects of division of labor that is underway in parallel. In other words, intellectual operations which progressed to the relevant stage in all fields of division of labor and which are in progress are caused to sneak into what he calls operators' "intellectual skills." This is the reason why his "intellectual skills" is regarded as imaginatively enlarged.

Unfortunately, it is impossible to further deepen this argument in line with the actual progress of preparations for production. Introduction of new models and that of new production methods are top secrets of enterprises, and therefore, it is impossible for outsiders to have access to such matters. Consequently, the present writer cannot make arguments on the basis of observed facts. However, there are literary documents that give rough information on how such activities are performed. One such literary document will be taken up at the section 4 of this paper. Now the present writer would like to turn to the issue of seeking the course of action for comparative research by looking back on facts that have so far been clarified.

3 Skill formation through out-of-hours activities and troubleshooting by division of labor

What has so far been pointed out by reviewing Koike's writings comes down roughly to two points. One is the following issue: it is impossible for line workers to perform flexible troubleshooting by themselves while carrying out "usual operations," and therefore, there is no choice but to cope with the problem by division of labor, namely by "the separate system" in Koike's word; and division of labor by the operator discovering problem, the team leader, and designated troubleshooters is the basis of troubleshooting setups at production site. The other is the fact that in dealing with changes and problems by division of labor, the issue of communication or quick exchange of relevant information between members is essential to total work efficiency.

The first issue leads not only to the conclusion that for this reason, we should pay more attention to dealing with changes and problems due to division of labor but also to the conclusion that we should direct our eyes more attentively to the fact that the only time period when workers can act flexibly on their own will is the time period after they are liberated from lines. Attention may well be paid to the fact that many of the activities often mentioned as features of Japanese

way of work, such as suggestion activities and QC circles, are "out-of-hours" activities. In company D, part of the work of preventive maintenance, which is the job duty of the maintenance organization, is carried out by production site operators. This work is also performed before the start time, that is, when no machines are running.

The present writer has no experience in investigating such activities, but he happened to investigate a mini-truck assembly line of company D, where the *tact time* was extremely long (90 to 110 minutes at the time of investigation). He has an experience in being surprised to know, at this time, each of the workers interviewed for survey had many types of in-house qualifications. A worker with a career of 22 years, who was interviewed for survey at this time, not only had in-house qualifications for forklift operation, in-factory transportation vehicle operation, hoist operation, and slinging operation, but also was an approved troubleshooter. There was a worker whose career was shorter than the former worker and who had nearly 10 types of qualifications. The answer to the present writer's question as to how it was possible to obtain such qualifications was that it was feasible to gain them by a combination of correspondence education by the in-house skill training organization, schooling performed such as on holidays, and tests. On that manufacturing shopfloor, seven operators including the team leader were manufacturing about four mini trucks per day. The present writer had a good understanding of the following situation: the fact that everyone was able to perform slinging operation and the fact that there were multiple persons who were qualified to operate transportation vehicles extremely enhanced the flexibility of operations on the manufacturing shopfloor under such circumstances.

On this manufacturing shopfloor, the present writer was impressed also with QC circle activities. During his observation period, the QC circle on this manufacturing shopfloor was addressing a theme "Reduction of Walking Distances." The fact that operators' walking distances turn out to be long is a system defect specific to this type of assembly operations in which the *tact time* is long. He was surprised that the goal was set precisely at this point. If the *tact time* is increased, the number of parts installed per operating station increases proportionally, with the result that it becomes gradually difficult to secure space for placing parts at locations close to the operating station. Inevitably, there are increases in numbers of trips made to take parts from parts racks placed at distant places and to return to the operating station by holding such parts in hands. Also increased are distances of such return trips. Operation time loss and physical fatigue due to relevant walking become non-negligible.

That issue is a contradiction that similarly occurred in the long cycle time team work method in Sweden, which is the object of our comparative research. An issue that was dealt with by engineers in Sweden was coped with by a QC circle in Company D. This difference stems mainly from the difference in scale of factory. Therefore, it should be made clear that it is

dangerous to assign an excessive meaning. However, articles such as racks, hoisting accessories, tilting tables, and drawers, which Company D operators created one after another by exerting ingenious efforts and which were used to place required numbers of parts in limited space were far less sophisticated than those created by Swedish engineers. However, the present writer was led to be impressed in that such articles were created out of hours in such a way that those operators made full use of their abilities based on in-house qualifications for electric welding and gas welding.

Let us now turn to the second problem, that is, the issue of information transmission in division of labor. As has been emphasized so far, the operations of dealing with changes and problems on manufacturing shopfloors are basically carried out by division of labor. In order for such operations to be performed effectively, all organizations involved in division of labor should cooperate closely with one another. To put it in Koike's words, this system, which is the separate system, should function in overall terms as if it were an integrated system. What guarantees the relevant function is transmission of information among all organizations involved in division of labor. Namely, what matters is how fast necessary information is transmitted to organizations that need such information. Also, no discrepancy in mutual understanding should occur at points of contact between any two organizations that should cooperate closely with each other.

As regards the former issue, in work organizations in Japan, a hierarchy consisting of operators → team leader → foreperson → subsection chief plays a very important role. If troubleshooting is taken as an example, information on any problem is subjected to information processing called hierarchical judgment at each stage of the hierarchy, and is transmitted to appropriate organizations at full speed. A team leader is positioned between operators who can do nothing but raise their hand at the time of occurrence of any problem and their superiors in a management position.

When any worker raises his / her hand, the team leader immediately hurries to the spot, grasps the situation, and passes judgment in an instant as to 1) whether the problem should be corrected by the team leader or by a designated troubleshooter, 2) whether there is any problem with any upstream manufacturing process, and 3) whether a higher ranking person should be requested for judgment of the problem. In the case of item 1) above, judgment is further passed as to whether the relevant line should be stopped. In the case of item 2) above, the team leader identifies the manufacturing process in which the problem lies, and informs the team leader for this line accordingly. If this manufacturing process cannot be identified, or if item 3) above is the case, the team leader immediately informs the group leader accordingly. In this case also, it is necessary to pass judgment as to whether reporting should be performed with the line running or after it is stopped. The key to troubleshooting is that such a series of judgment should be passed

promptly and correctly by the team leader.

In order for such judgment to be passed, it is necessary to presume the cause. However, in order for judgment to be passed in an instant, action will not be completed in time if the cause is "inferred." In order to be useful in instantaneous judgment, it is only the following type of cause presumption that serves as the basis for prompt judgment: as soon as the situation of the problem is watched, it occurs reflexively to the mind that the relevant cause is XXX and that the occurrence location is ZZZ. Here, experience has a great meaning. Any problem that was experienced recently remains in the memory. Therefore, if this problem occurs again, it can be identified instantly. If the same problem occurs a couple of times, a memory is formed, which is never erased in the lifetime. For this reason, it is important not to fail to standardize the dealing method with regard to any problem that ever occurs on any manufacturing shopfloor. It turns out that workers will create, in their memories, a stock of combinations of types of indications of problems and methods of dealing with such problems.

As stated by Koike, various changes and problems occur on manufacturing shopfloors, and therefore, the amount of such empirical knowledge accumulated while workers are working is surprisingly large. Furthermore, thinking done by workers when they act in accordance with such empirical knowledge is also intellectual and inference-oriented. However, such inference is not of a type conceived by Koike, which is done by retroacting to "the structures of devices and products, and further to the mechanism of production." This type of inference is a job to be performed by engineers. Such inference involves an element consisting of time to think, and therefore, it is inevitable for delays to occur in dealing with problems. In addressing any problem occurring at any production site, it is necessary for the cause to be determined at once and for countermeasures to be taken immediately thereafter. What can meet such requirements is empirical knowledge in which indications of problems are reflexively linked to dealing methods.

In this regard, the amount of empirical knowledge is proportional to the length of experience of the worker. In the case of a team leader, it often happens that even problems which were experienced in the past by the relevant manufacturing shopfloor are not within the scope of his / her empirical knowledge. In such a case, it is necessary to immediately take action in item 3) above. If judgment competence is transferred to higher ranks in the relevant hierarchy, that is, from a team leader to a foreperson and then to a subsection chief, it is possible for a person having rich empirical knowledge to judge appropriately, with the result that judgment as to which indirect organization is to be requested for cooperation can be passed most quickly. At least as far as problems that were experienced in the past by manufacturing shopfloors are concerned, it will be possible, in this way, to sufficiently deal with problems

Then what will be case with a problem of a type experienced for the first time by a

manufacturing shopfloor? What can be said with certainty is that it is not until a problem of this type occurs that engineer-specific inference becomes effective in cause determination. Empirical knowledge does not contain a stock of information for combining indications of problems with relevant countermeasures. Therefore, it becomes necessary to infer the cause from the indications of the problem in such a way that the relevant system structure and theoretical knowledge are used as a clue. In terms of hierarchical ranking, it is by all means necessary to have the relevant section chief (engineer) pass judgment. However, it is highly likely that at some stage before the section chief is involved, an appropriate technical staffer is called in for consultation. There is a high possibility that experience-dependent thinking and the relevant system mechanism function with each other complementarily to lead to the effective solution of the problem or that it can be appropriately decided which organization is able to solve this problem.

However, in the case of problems of a type experienced for the first time, it is certain that not many of them appear all of a sudden out of a fog of utter uncertainty. Through long experience of shop floor work, it is identified that problems experienced for the first time occur frequently when a large scale of change is introduced into the line. And setups for dealing with such problems are prepared. Typical of such occasions is the time when a new production method or a new model product (including a model change of product) is introduced into a line. On such occasions, various problems occur frequently. Those problems are of types that are experienced for the first time by manufacturing shopfloors. The setup for "preparations for production" is a special setup established for the purpose of eliminating such problems as far as possible and minimizing problems in advance to the startup of operation. Such activities constitute operations performed by collective efforts by manufacturing shopfloors for the purpose of dealing with "changes and problems." On those occasions, it is easy to observe processes where problems having the possibility of occurring in the wake of changes are detected and eliminated in early stages through cooperation based on division of labor between indirect organizations and direct organizations.

As already stated, it is practically impossible for outsiders to have a chance of observing such processes. However, when the present writer made an observation of the assembly line for the M II mini-truck of Company D, as stated above, he was given a pamphlet titled "Why does M-Atelier attract public attention now?" This document gives a history of MII from its planning to the initiation of production. And some paragraphs are paid for the stage of preparations for production of MII. In addition, the present writer's interview notes contain dispersed writings of information obtained from operators who experienced preparations for production. With the above as a guide, the present writer wishes to reconstruct the scene as mush as possible.

4. Introduction of new models and preparations for production

The headperson responsible for all work of the M II Production Preparation Group is the Manager of the Second Manufacturing Department of Company D. The First Manufacturing Department is an organization engaged mainly in pressing and forging, with body parts as principal products. The Second Manufacturing Department centers on the assembly factory. It can be seen, therefore, that preparations for production is a project where main roles are played by manufacturing organizations, which have assembly lines. The above manager writes that when he became the "Responsible Leader" of the project, the factory superintendent said: "It is really difficult to tell how many of these cars will be sold. Anyway, these cars will be made by hand by utilizing the skills of highly skilled workers. It suffices if this M II production factory can be utilized as a place for revitalizing old people and for fostering young people." This fact shows that before preparations for production were started, matters such as forms of manufacturing processes and basic policies on relevant operations had been decided in a considerably specific way.

The flow of decision making on the manufacture of this mini truck seems to have been as follows: in about the middle of the 1990s, a decision was first made on a positive new model strategy in which Company D would go as far as to create one new model every six months starting at the relevant point in time. What surfaced as the first suggestion was an idea of putting on the market an ultra small truck suggestive of the light tricycle truck M, which was a hit model that triggered the development of Company D in Post-World War II days. In accordance with that idea, a light truck was designed which was small in size, whose turning radius was extremely small, and which was aimed at a niche market in that this truck was intended to be used for delivery purposes in apartment complexes, where many cars were parked on roads, and in towns, where many narrow roads existed. Demand forecasting was performed on the basis of the relevant design. The results were such that predicted numbers of automobiles produced per month varied greatly between the maximum figure of 2,000 and the minimum figure of 200. On the basis of this demand forecasting, monthly production of 400 automobiles was taken as the profitable line of business. Studies were made by the Production Engineering Department regarding the production method whereby it would be possible to manufacture as many as 2,000 automobiles per month and even if the number of automobiles produced per month became 200, no great loss would be incurred.

Theoretically it suffices to build a production line where the fixed cost is zero and the variable cost is 100 percent in order to meet the following conditions: the production cost will not be greatly affected even if the production volume varies excessively; and particularly, when the production volume falls greatly below the profitable line for business, the production cost per

vehicle will not be greatly raised for that reason. In actuality, that is impossible.

It seems that at least the following points were worked out by way of policies between the Executive Office and the Production Engineering Department: capital investment would be reduced to the bare minimum; human manual operation would be increased as mush as possible; conveyors would be dispensed with, and movement between work stations would be carried out by manually pushing vehicles placed on carriers; great variations in production volume would be flexibly dealt with, for example, by disassembling manufacturing processes to increase numbers of work stations, thereby shortening *tact time*, or by integrating manufacturing process to decrease numbers of work stations, thereby lengthening *tact time*; and advantage would be taken of the trend of the times where manual production is attracting a growing interest, in such a way that publicity would be given to the point that those mini trucks are handmade with no conveyors used.

Then at a stage for deciding at what factory this truck is to be manufactured, the Head Office Factory volunteered to do the job, and it was decided that the line be built in the Head Office Factory. Thereafter, negotiations started between the Production Engineering Department and the Manufacturing Department of the Head Office Factory. Probably, it was the top echelon of the Head Office Factory that established the policy for aged technicians and young beginners to pair up together and take charge of relevant manufacturing processes and attached a meaning to that policy by means of philosophy of transfer of skills from the aged to the young. Therefore, before the Production Preparation Group was launched, policies had been established to a significantly detailed extent among the following entities: the Manufacturing Department; the top echelon of the Manufacturing Engineering Department; and the Production Engineering Department. To what extent such policies had been established is important in getting to know the scope of activities of the Production Preparation Group.

It is a matter of course that items such as the detailed specifications, design, parts to be used, and suppliers of such parts had already been decided. All of the following matters had been decided in terms of proposed plans: the location and scale of the factory; and the arrangement where only body production and final assembly would be performed in the new factory and where coating and inspection would be carried out in the form of interflow production in such a way that part of manufacturing processes for existing models would be modified. The Production Engineering Department submitted those matters in the form of the "Concept of Production Engineering Department" as shown in Table 1. The tasks of the Production Preparation Group are stated with this table as a basis for discussion.

Under circumstances where it was extremely difficult to make sales forecasts, the Production Engineering Department made studies, as a first step, on the factory that would be capable of

Table 1 Concept of Production Engineering Department

M II is a model which is manufactured in small lots and for which numbers of automobiles produced is not predictable. Therefore, a production method different from conventional ones is proposed.

Basic concept	Method of taking action
(1) Initial investment will be reduced as much as possible for the purpose of curbing investment risks to a low level (for both in-house production and outsourcing).	* The second floor of the parts kit shop will be utilized in body production and final assembly. * Unautomated manufacturing processes will be used. Equipment like hand bogies will be used, with no conveyor employed. * Only coating and inspection will be caused to interflow into existing lines. (In the case of body production and final assembly, interflow is disadvantageous.) * In the case of settings for in-house production and outsourcing, attention will be paid to reducing press die costs.
(2) Thoroughly low cost manufacturing methods * Settings for in-house production and outsourcing different from those for mass-produced vehicles * Utilization of highly skilled workers	* Class A and B pressed parts and bumpers are usually produced in-house. However, if any of those articles can be produced less expensively by being outsourced, then any such article will be outsourced. * Nonaffiliated manufacturers may be utilized. * Studies were made of overseas procurement but it turned out that this method does not lead to lower costs. * Production will be carried out by utilizing people such as skilled workers.
(3) Dealing with changes in monthly production volumes	* The current plan can deal with change in production volumes of up to 1,400 vehicles per month by increasing / decreasing operations and personnel. * Further production increase will be dealt with economically by means of follow-up investment up to a production volume of 3,000 vehicles per month.

Source: In-house information material of Company D

flexibly dealing with change in production volumes which fluctuate between 200 and 1,400 vehicles per month. Table 1 shows considerably definitely what the production line would inevitably be like. However, nothing whatever was decided with regard to matters such as specific manufacturing processes, types of devices, or method of performing work. Namely, the task of production preparation was to decide specific forms of manufacturing shopfloors in

continuation of the above.

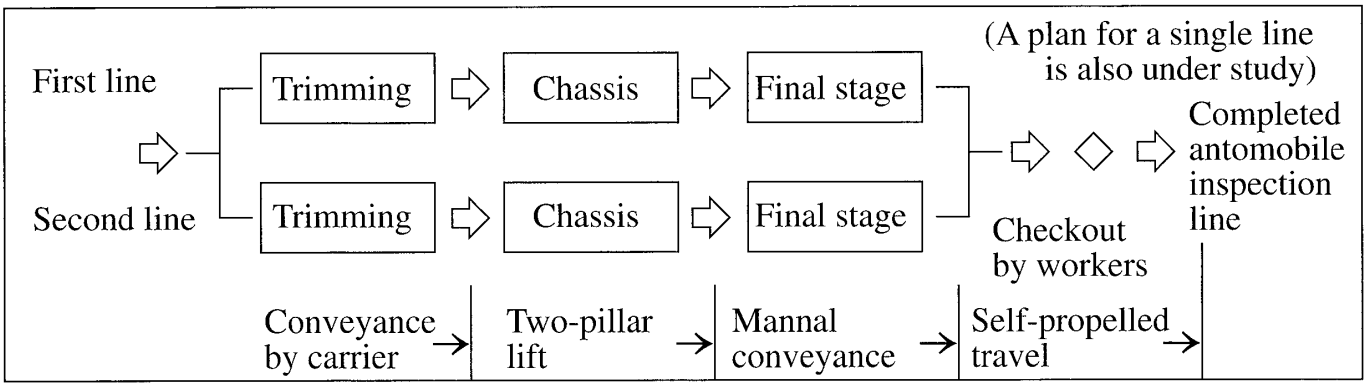
The Production Preparation Group consisted of the following members: staffers selected from the Manufacturing Engineering Department; a couple of workers, mostly veterans, selected from each group of the section in charge of manufacturing, which was the Third Section of the Manufacturing Department in this case. In this connection, the present writer has so far failed to confirm whether Company D has a system involving technical staffers. During his investigation, he did not meet anyone with the title of Engineers Office. It was after the investigation at Company D was over that he knew that Company T has the Engineers Office in its Manufacturing Department. Instead, Company T does not have a department called the Manufacturing Engineering Department, which Company D does have. There is a possibility that at Company D, this organization called the Manufacturing Engineering Department plays roles corresponding to those of the Engineers Office of Company T.

It seems that Production Preparation Group was run as follows: at the beginning, task was started by a relatively small number of members consisting mainly of staffers of the Manufacturing Engineering Department, as well as of veterans and persons like subsection chiefs and group leaders of the Manufacturing Department; members were gradually increased with the progress of task; and finally, some of the junior workers scheduled to work on the new line were caused to participate in this group. Two of the workers interviewed for survey at the M II Atelier participated from the production preparation stage (at the end of this stage, to be precise). Both of them said that they enjoyed themselves most at that time.

The tasks progressed in dialogue form between the Production Engineering Department and the Production Preparation Group. The Production Engineering Department presented preliminary drafts, and the Production Preparation Group studied them, and presented points to be revised, or made counterproposals. If agreements were reached, implementation was undertaken. The very first issue was the layout of the assembly line. The Production Engineering Department proposed the plan as shown in Figure 1. It seems that the Production Engineering Department proposed this plan by interpreting the parallel method at Uddevalla in this way. In response to the above, the Production Preparation Group pointed out that if each manufacturing process was assigned with excessive workloads, there would be a problem with operator education, and that parts storage place would be so large as to cause problems to parts transportation. Then this group proposed a linear or U-shape line which is divided into a bit smaller sections and which were capable of being integrated when the *tact time* was lengthened. Finally the line as shown in Figure 2 was agreed to.

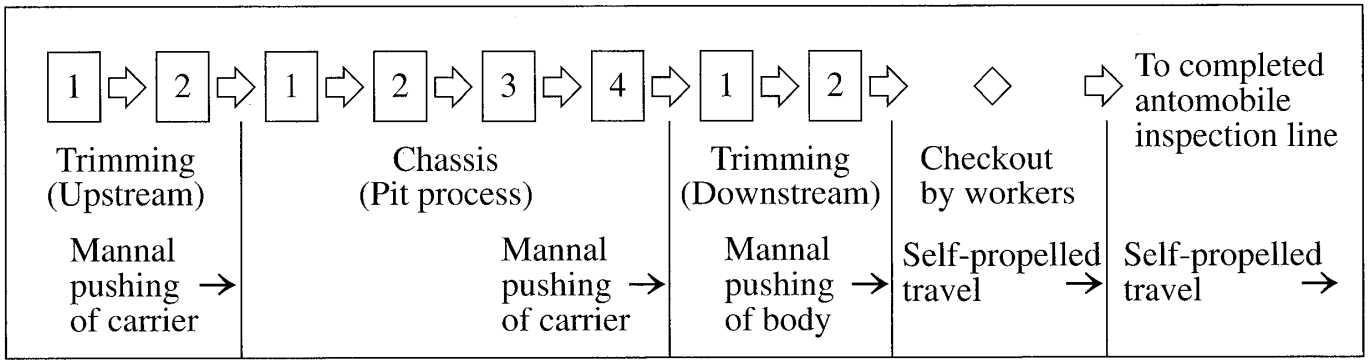
Let us take the body welding line as an example of a little more detailed manufacturing process. In accordance with the policy of curbing capital investment to the minimum, the

Figure 1



Source: In-house information material of Company D

Figure 2



Source: In-house information material of Company D

following arrangement was agreed to: no welding robot would be used; mainly, manual welding would be performed; and as regards spot welding handguns, the whole factory would be searched to obtain usable idle articles, and only substitutes for shortfalls would be newly purchased. As a result, with respect to a total of 72 handguns, the ratio of use of idle devices amounted to 70 percent. The body line looked like a forest of handgun hoisting accessories. Operators exerted ingenious efforts to modify the line into an easy-to-use one. In this manufacturing process, about 100 places per person were to be spot welded, and therefore, it became necessary to take measures against looking over of the places to be welded. For example, welding locations were marked on welding jigs, and as regards locations apart from jigs, ingenious efforts were made to fabricate simple gauges marked with welding locations.

What cannot be overlooked is the fact that "Voluntary Study Meetings for Production Preparations" were held a total of three times; namely, once in the basic planning stage, once in the manufacturing process planning stage (the stage where the manufacturing process layout was decided), and once in the final manufacturing process planning (the stage where the work up to the detailed layout was finalized). Each of these meetings was held for a full day jointly by members selected from the Improvement (Kaizen) Department, the Production Engineering

Department, the Manufacturing Engineering Department, and the Maintenance &Repair Department, as well as with members of the Production Preparation Group. Such a meeting was run as follows:

- Participants were divided into four groups, each in charge of one of the relevant manufacturing processes (body production, coating, assembly, and parts supply).
- In each of the four groups, a member of the Production Preparation Group gave an explanation with regard to a draft manufacturing process plan of the relevant shop, and studies and discussions were made.
- At the end of the meeting, all members gathered, and each group gave a report of the results of studies and discussions. Furthermore, all members held discussions, and then final decisions were made.
- On the basis of such resolutions, the manufacturing process plan was reviewed and refined.

A manufacturing process plan formulated through meticulous dialogues and studies by the Production Engineering Department and the Production Preparation Group was further refined by being subjected to discussions by all related organizations. It seems that these operations had the following dual objectives: overlooked problems would be discovered by exposing the plan to observation from different points of view; and organizations that were to support the new line through division of labor would be familiarized with the new line. The production preparation effort for M II was the first project where such a voluntary study meeting was tried by Company D in imitation of the method of Company T. The explanatory document says, "It was really good that this was done."

After the final manufacturing plan was established, construction of the new line was started. In the case of the line for M II, it was decided that a large number of pieces of equipment be manufactured in-house or fabricated by operators themselves (under the guidance of skilled workers, as a matter of course), in accordance with the policy for reducing capital investment as much as possible. When the line took form, articles such as for Production Test 1 and Production Test 2 were run on the line to actually carry out manufacture. The results were fed back precisely for purposes of improvement of manufacturing processes.

This kind of feedback of opinions of production site people was started in the stage where trial production of the new model was performed. A group consisting of members selected from the production site made observations of the first, second, and third trial production, recorded operation procedures of each step of whole assembly processes, picked out latent defects, and fed them back. It is considered as a matter of fact that this group developed into the Production Preparation Group. However, no confirmation has been made about this point.

This was the case with production tests as well. At this time, detection and correction of defects of equipment and tools were also important work. A Production Preparation Team was organized in the Manufacturing Engineering Department, in such a way that members consisted of managers in the department, skilled workers remaining after the mandatory retirement age, and skilled workers in the department. Defects of equipment, tools, and jigs were repaired one by one, except that those for which manufacturers were responsible were caused to be repaired by relevant vendors. The Production Engineering Department also concerned deeply in production test. Experiences in assembly operations were also fed back to this department and, if necessary improvement of design was carried out. The leaders of all groups for the new line prepared work standards for each step of manufacturing processes of which such leaders are in charge, in accordance with the record of operating procedures for individual manufacturing processes that were formulated by being repeatedly revised since the first trial production.

The foregoing paragraphs were written on the basis of "Why does M-Atelier attract public attention now?" with supplementary information added by means of the present writer's notes. While he was making observations of operations at the M II factory, he realized for the first time that experiences in production preparations played an important role in forming workers' skills. In subsequent survey interviews with workers, he made it a rule to add that point to his questions. Such questions were put to all persons who claimed to have participated in production preparations, as well as to M II line workers. The information capable of being obtained by interviewing was fragmentary, but all interviewees said that what was learned in the course of production preparations was extremely great and useful. On the part of the enterprise, participation in production preparations is regarded as an important opportunity for fostering skills. There are many instances where workers experience production preparations before being promoted to team leaders.

As seen above, when the production line for a new model is to be introduced, a scene is encountered where innumerable troubles (problems) occur, for example, through discrepancies between the intention of the organization that designed the production line and the usability on the part of the organization using the line to perform production, or through discrepancies between suppliers that delivered equipment and conditions of production sites where such equipment is used. In this regard, "Production Preparation" is a systematic operation in which problems are found and abnormalities are eliminated as far as possible before the new line start. It starts with the first trial production of the new model, as dialogues between the design organization and experienced workers of the Manufacturing Department who observe trial production and, at a certain stage, switches to consultation with the Production Preparation Team consisting mainly of members of the Production Engineering Department, the Manufacturing

Department, and the Manufacturing Engineering Department. In the final stage it involves the Improvement (Kaizen) Department and the Maintenance and Repair Department. The purpose of all its activities is to find and eliminate discrepancies before they evolve so abnormally as to evolve into troubles. The first half of such operation centers on design and layout. After the construction of the new line is started, operations will be such that troubles (problems) in terms of manipulation and operation will be eliminated through trial production and trial operation. Superficially, those are operations aimed at eliminating all defects before the operation of the new line is started. However, it can be seen that such operations provide a learning process where all organizations concerned with the relevant operations get familiar with the features of, and problems with, the new line.

The role of organically organizing all of these processes and leading them is played by the Manufacturing Engineering Department in the case of Company D. The present writer knows nothing at all about production preparations in Company T. However, he presumes that the same role is played by the Engineers Office of the Manufacturing Department.

5 Research methods[2]

We highly appreciate the fact that Koike was the first to point out that "unusual operations" or dealing with changes and problems play a great role in forming the skills of workers on manufacturing shopfloors, and we intend to conduct a joint research, by obtaining suggestions from the above, as to what skills are acquired by manufacturing line shop workers through dealing with changes and problems.

However, in the course of studying Koike's theory for preparation purposes, we found the following fact: in his system of explanation of the concept of intellectual skills, he excessively appealed to commonsensical understanding of "changes" and "problems" for the probable purpose of making his argument understood easily by everyone, with the result that matter-of-course restrictions imposed on manufacturing shopfloors on lines are neglected.

On any manufacturing shopfloor on a line, any operator's acts of dealing with changes and problems are restricted by the condition under which he / she has to perform such acts while carrying out standard operations packed to the limit of the *tact time*. Furthermore, on ordinary manufacturing shopfloors, it is prohibited, probably on the basis of many years of experience, for any operator with short years of experience to perform troubleshooting. Koike assumes the presence of operators who discover problems at the very place where such problems occur, who infer causes by themselves, and who eliminate such causes by themselves. However, as far as importance is attached to various conditions that impose restrictions on labor on actual manufacturing shopfloors, such an assumption is infeasible at least with regard to operators

working on manufacturing shopfloors on lines. We consider, therefore, that it is detrimental to empirical research to depend on such an assumption.

Therefore, it is necessary to take the standpoint that acts of dealing with changes and problems are performed basically by division of labor, namely by "the separate system" in Koike's term. We should aim to conduct research of a type such as follows:

a) The starting point is the division of labor of the most basic form involving operators, team leaders, and approved troubleshooters: it is important to clarify what sort of coping with problems they can carry out by the judgment of the team leader.

b) The following points to be clarified is the role of hierarchical circumferential judgment involving team leaders, forepersons (group leaders), subsection chiefs, and section managers (usually an engineer in Japan). It is expected that the hierarchy of judgments reflects the degree of seriousness or complexity of the relevant change (unusual event).

c) The third point is to clarify in accordance to the above hierarchical judgment on types and seriousness of changes and problems: what sort of organizations are embroiled; what roles are fulfilled, under these circumstances, by each of the organizations involved in division of labor; and what is gained by operators through the acquisition of experiences in such activities.

However, in view of the situation of manufacturing shopfloor research in present-day Japan, it will be considerably difficult to find manufacturing shopfloors where such a type of research is accepted.

Accordingly, under the assumption that persistent efforts will be made, on one hand, to realize the aforementioned type of research, the present writer would like to propose, as a complementary approach to the above, a research method which is expected to be a more plausible approach such that what is known at present will be started from. Within the scope of Chapter 1, it is shown that there are interesting systems and job types on manufacturing shopfloors with regard to dealing with changes and problems. Such examples include, among others, designated troubleshooters (approved persons), the Engineers Office, and the Production Preparation Group. It was confirmed that in company D, important roles were played by an organization called the Kaizen-gumi (Improvement Team) which was not mentioned in this Chapter. This organization is one that creates changes proposed by workers (Teian) rather than deals with change as unusual event.

These are systems and job types found in enterprises where we performed fieldwork. From the fact that such items exist, it follows that manufacturing shopfloor entities are supposed to have objective evidence based on long experiences in dealing with changes and problems. It is expected, therefore, that by starting with a simple question as to why such systems and job types

exist and by perseveringly asking that question, there will come to light experiences in changes and problems on manufacturing shopfloors, as well as what is learned by enterprises from such experiences. For example, the present writer asked considerably frequently why operators with short years of experience were not permitted to perform troubleshooting. Answers referred to "safety" without exception. If the present writer had asked that question in a more adroit way, it would have been possible to extract information on instances of accidents caused by inexperienced workers' troubleshooting. This approach will be as follows: every time that each of our group conducts manufacturing shopfloor investigation in the future, such questions will be asked; the results will be brought to the relevant study meeting; and through discussions and analysis, it will be found out what types of changes and problems are present on manufacturing shopfloors and by what type of division of labor, such items are dealt with. At first glance, this approach may appear roundabout. However, it is usually the case that if many persons share the same question, and if the results are checked with one another, then unexpectedly large numbers of things will be found out.

However, it has not been confirmed whether such job types and systems exist in other companies. It is also an important task to check whether those items are unique to the enterprises where we carried out fieldwork or are universal existences that are present in all enterprises. Here, such a question as follows can constitute an adequate entrance to research: "Company T has a system called 'Engineers Office' in the Manufacturing Department. Does such a system exist in your company as well?" It is expected that if questions like the following are pursued, then approach types common to enterprises during dealing with changes and problems, as well as differences due to job types, histories, and cultures of enterprises, will make their appearance: "If any such system exists, then what necessity caused the said system to exist, and what role is played by the said system?" ; and "If no such system exists, then as an alternative, does there exist any organization that play similar roles?" It is expected that if the same approach is applied to Sweden, then more interesting issues will come forward.

Chapter 2 Division of labor in automobile and electrical machinery industries in Japan: through comparison with experiences in Sweden

1. Framework for analyzing structures of division of labor on assembly shopfloors

The concept of intellectual skills associated with "unusual operations," that is, "dealing with changes and problems," plays a decisive role in Koike's theory. However, as pointed out in Chapter 1, this concept is extremely ambiguous. Therefore, it is impossible for the concept as is to serve as an analytical tool for empirical research. In Koike et al.[10], Koike himself not only divides problems (troubles) on production sites into two categories of quality troubles and

equipment troubles but also classifies different levels of dealing with problems into categories such as detection of troubles (or returning equipments to original positions) as well as inference of causes and implementation of countermeasures (see Table 2A). It can be said that such categorization means that Koike himself has virtually admitted the ambiguity of the concept of intellectual skills. Nevertheless, in Koike et al.[10], a judgment is made to the effect that possessors of intellectual skills on automobile assembly shopfloors "generally account for about 50 to 60 percent" (p. 7). As shown by this judgment, the consequence is that an exaggerated image of intellectual skills still continues to be provided. This is because, as emphasized in the preceding Chapter, there are two major defects in the way Koike's argument is constructed.

In the first place, the viewpoint of standardization of operations (dealing with troubles) is extremely weak. As a consequence, differences in levels of dealing with problems (troubles) on manufacturing shopfloors are rendered ambiguous in the long run. Namely, in Koike's theory, it is assumed that standardized items are "usual operations" and that "unusual operations" are not standardized [10, p. 10]. However, changes and problems that occur on any manufacturing shopfloor are of two types: one that has not been experienced so far on the manufacturing shopfloor; and one that has already been experienced on the manufacturing shopfloor. It is necessary to distinguish between those two types. If any change or problem occurs which has not been experienced so far on the relevant manufacturing shopfloor, it is a matter of course that no countermeasure method is established. However, in the case of any change or problem that has already been experienced, it is possible for the relevant countermeasure method to have been established, and as a matter of fact, rules including procedures have been established. For example, at manufacturing sites of Company M, dealing with troubles for which procedures are established are called "non-routine operations." which are distinguished from operations for which no procedures are established. In another respect, in Company W, there are "routine operations" (operation of machines, inspection / maintenance of equipments, and changes to setup) and "non-routine operations" (troubleshooting), by way of "categories" (operation names) in evaluation tables for multi-skilled operators at manufacturing sites. It has not been confirmed whether "non-routine operations" in Company W come under the category of troubleshooting for which "procedures are specified" as in the case of Company M. However, operations called "troubleshooting actions" are included in multiskilled worker training programs, and therefore, it is considered that relevant handling methods are standardized although such operations are called "non-routine operations."

The second defect of Koike's theory is that no importance is attached to the fact that dealing with changes and problems that occur on manufacturing shopfloors are usually carried out as cooperation based on the division of labor. For example, in dealing with quality deficiencies that

occur subsequent to the initiation of mass production, a series of operations ranging from the detection of deficiencies to the cause analysis and countermeasures are carried out not only by assembly operators but also frequently by a number of people including supervisors and engineers. However, in the case of Koike's theory, importance is attached only to the viewpoint regarding to what extent assembly operators are involved in dealing with quality deficiencies, with the result that his argument is developed in such a way that the relationships of the division of labor with other workers are left unclear.

It is necessary to consider a framework in which awareness is paid at least to the above points in order to clarify the characteristics of, and the problems with, the structures of division of labor in Japan in such a way that the following items are taken into account: Koike's argument in which studies are made of the development of skills on manufacturing shopfloors by paying attention to "dealing with changes and problems" ; and Nomura's criticism of it [17]. Tables 2 and 3 are attempts at the above. Explanations will be given below one after the other.

Table 2 was prepared for the purpose of distinguishing qualitative differences in operations carried out by assembly operators. Table 2A is based on Koike's theory, and Table 2B is based on our hypothesis.

If seen from the viewpoint of standardization of operations, it can be said that procedures and the like are standardized, not only for standardized operations contained in standard operation sheets (hereinafter referred to as "routine operations") but also for dealing with changes and problems experienced in the past on manufacturing shopfloors, although there may be differences in degrees of standardization. The reason why standardization is carried out is that if dealing with changes or problems experienced on shopfloors were not to be standardized at all, no prompt countermeasures would be taken when similar changes or problems occur, resulting in reduced efficiency. On any "decent" shopfloor (see p. 7 of Chapter 1), where efficiency is pursued all the time, the method / rules for dealing with any change or problem experienced will be specified each time that such a change or problem is experienced for the first time.

Thus dealing with changes and problems experienced on manufacturing shopfloors can usually be classified as "standardized operations." Let us call such operations "non-routine operations" as distinct from routine operations. These non-routine operations can be divided into operations handled by qualified operators ("operations requiring qualifications") and operations that can be handled even by unqualified operators ("operations not requiring qualifications"). Operations requiring qualifications are, for example, operations performed by operators who are capable of taking measures against troubles with equipments, such as qualified troubleshooters. Individual operations at the time of equipment deficiencies (acts in which assembly operators press buttons in operation panels to return equipments to original positions;

Table 2 Classification of Operations of Operators on Assembly Shopfloors

<table>
<tr><th colspan="4">A: Koike's theory</th></tr>
<tr><td>Usual operations</td><td colspan="3">This term refers to simple repetitive operations, although no clear definition is given.</td></tr>
<tr><td rowspan="2">Unusual operations =dealing with changes and problems</td><td>Dealing with problems (troubles)</td><td colspan="2">①Detection of quality deficiencies
②Inference of causes of quality deficiencies and implementation of relevant countermeasures
③Individual operations at the time of equipment deficiencies (returning equipments to original positions)
④Inference of causes of equipment deficiencies and implementation of relevant countermeasures</td></tr>
<tr><td>Dealing with changes</td><td colspan="2">⑤Dealing with consequences of changes in personnel structures (replacement of absentees, as well as education of inexperienced people)
⑥Dealing with changes in production volumes (a practice whereby a single operator carries out many jobs on his / her manufacturing shopfloors, as well as an arrangement whereby operations are redistributed)
⑦Production preparations for new products (such as distribution of operations, preparations of operating procedures, and attendance at trial production)</td></tr>
</table>

<table>
<tr><th colspan="5">B: Our hypothesis</th></tr>
<tr><td rowspan="2">Standardized operations</td><td colspan="2">Operations contained in standard operation sheets</td><td colspan="2">Routine operations</td></tr>
<tr><td rowspan="3">Dealing with changes and problems</td><td rowspan="2">Dealing with events experienced in the past on manufacturing shopfloors: countermeasure methods are standardized.</td><td rowspan="2">Non-routine operations</td><td>Operations requiring no qualifications</td></tr>
<tr><td rowspan="2">Operations requiring qualifications</td></tr>
<tr><td>Non-standardized operations</td><td>Dealing with events experienced for the first time on manufacturing shopfloors:
no countermeasure methods are standardized.</td><td colspan="2">Unprecedented operations</td></tr>
</table>

Notes: 1) The table for "Koike's theory" was prepared on the basis of Chapter 2 of Koike et al. [10].
2) An example of an "operation requiring qualifications" is one handled by a person having a specific qualification, such as a qualified troubleshooter for specific equipments.

namely, returning equipments to original positions) are typical operations not requiring qualifications.

On the other hand, it is impossible to standardize, beforehand, dealing with any change or problem experienced for the first time on any manufacturing shopfloor. Therefore, operations carried out by operators on assembly shopfloors, including dealing with changes and problems, can be broadly divided into two categories of "standardized operation" and "non-standardized operation." Let us call this "non-standardized operation" an "unprecedented operation." Incidentally, if any manufacturing shopfloor ever experiences such an unprecedented operation, then standardization is usually carried out in such a way that some sort of procedures or methods are specified as a provision for cases where similar changes or problems occur. Namely, unprecedented operations are transformed into non-routine operations, although there may be differences in degrees of standardization.

Thus operations involving operators on assembly shopfloors are first divided into the following categories: routine operation; and operation other than a routine operation. Furthermore, the latter is divided into three categories of operation not requiring qualifications (non-routine operation), operation requiring qualifications (non-routine operation), and unprecedented operation. These operations are each carried out through cooperation based on the division of labor on assembly shopfloors. We consider it necessary to analyze the structures of division of labor on manufacturing shopfloors by paying attention to what type of division of labor such cooperation is based upon. Table 3 was prepared by taking the following points into account to some extent. Typical operations in which assembly operators are expected to be somewhat involved in production processes ranging from product design to mass production are taken up in the table portion of Table 3. This table is intended to show by what persons those operations are handled. Relationships with Table 2 lie in the following points: ①operations other than standard operations (those other than routine operations) are "preparation / change of drawings," "prearrangement of equipments and establishment of layouts / standard operations," "dealing with troubles," and "improvements" ; ②dealing with troubles in mass production stages are classified into non-routine operations and unprecedented operations.

In contrast to the above, the table head consists of the following two items: ① types of production systems; and ② characteristics of standard operations. Production systems in item ① above refer to systems that have been realized (or had been realized) in the four enterprises / plants of Ford, Toyota, Company N, and Volvo Uddevalla. Each of the production systems shows a characteristic type in terms of the contents of standard operations and product flow patterns. The characteristics of standard operations will be described later. An explanation will first be made of the reason why attention is paid to product flow patterns.

Notes:

1) Here, assembly shopfloors are assumed to be those where automation rates are low, such as final automobile assembly lines. Namely, labor-intensive manufacturing shopfloors are assumed here.

2) The criteria for distinguishing a "traditional system" and a "nontraditional system" from each other depend on whether or not any standard operation is functionally complete.

3) Lengths of cycle times differ, even on a single assembly line, depending on items such as types of products assembled, as well as production volumes. Here, a "slightly long cycle time" refers to a case where the cycle time is slightly longer than prior to the adoption of assembly cells (namely, than during conveyor system).

4) A "partial operation that is functionally complete" refers to a case where any standard operation handled by any individual assembly operator or by any operation group consists of a partially "united piece of work" (such as the mounting of an instrument panel). An "overall operation that is functionally complete" refers to work in which any individual assembly operator or any operation group assembles an entire complete article.

5) Any of those acts of dealing with troubles in mass production stages which come under the category of "non-routine operation" is an act in which a "trouble experienced in the past (on the relevant manufacturing shopfloor)" is dealt with, and for which the countermeasure method and the procedures are usually specified (or standardized). An "unprecedented operation" refers to an act in which a "trouble not ever experienced (on the relevant manufacturing shopfloor)" is dealt with, and for which the method or the procedures are not specified (or standardized).

6) It is often the case that team leaders and cell leaders are engaged in assembly operations. Therefore, such persons are not included in supervisors but are classified as assembly operators.

7) The symbol "×" denotes that the relevant person handles the relevant operation. The symbol "N/A" signifies that relevant person is does not handle the relevant operation. The symbol "△" means that the relevant person only handles part of the relevant operation, or that only some of the relevant members handle the relevant operation. The symbol "?" denotes "Unknown." The symbol "—" signifies that there exists no relevant person in charge (the managerial organization of Volvo Uddevalla consists of the three echelons of the plant manager, assembly shop leaders, and team leaders; and there exist no supervisors that correspond to forepersons in Japan).

8) Company N and Volvo Uddevalla are manufacturing subsidiaries. Therefore, neither of these entities has any product design department, and consequently neither of them has any product design engineer. In this respect, engineers in this table are to be construed as including product design engineers of the head offices.

9) A "worker with10 or more years of service (Grade A)" is expected to acquire Grade A (advanced grade) as a skill level under the Specialized Skills Mastering System of Toyota Motor Corporation [16, pp.186-187].

Table 3 Structures of Division of Labor at Assembly Shopfloors (Tentative draft)

Production process	Operation	Person in charge	Prot Ford	Toyota (Prior to introduction of autonomous complete processes)	Toyota (Autonomous complete processes)	Electrical / electronic machinery assembly cells (Company N): Mini-assembly lines without conveyor	Electrical / electronic machinery assembly cells (Company N): Single-operator assembly cells	Volvo Uddevalla (1989－1992)
		Type of production system	Traditional systems		Nontraditional systems			
			Serial product flow patterns				Parallel product flow patterns	
		Characteristics of standard operation	Short cycle times			Slightly long cycle times	Long cycle times	
			Partial operations that are functionally incomplete (in terms of both individuals and groups)		Partial operations that are functionally complete (in terms of groups)	Overall operations that are functionally complete (in terms of groups)	Overall operations that are functionally complete (in terms of individuals)	Partial operations that are functionally complete (in terms of individuals) and overall operations that are functionally complete (in terms of groups)
Product design	Preparation / change of drawings	Engineer	×	×	×	×	×	×
		Supervisor (Foreperson / subsection chief)	N/A	△ (Only points out problems)	△ (Only points out problems)	?	?	—
		Maintenance worker	N/A	?	×	?	?	?
		Assembly operator	N/A	△ (Only points out problems)	△ (Only points out problems)	△ (Only points out problems)	△ (Only points out problems)	△ (Only points out problems)
Preparations for production	Prearrangement of equipments, Establishment of layouts/ standard operations	Engineer	×	×	×	×	×	×
		Supervisor (Foreperson / subsection chief)	N/A	×	×	×	×	—
		Maintenance worker	N/A	×	×	×	×	?
		Assembly operator	N/A	△ Team leader / veteran, in the main	△ Team leader / veteran, in the main	△ (Such as assembly of work table)	△ (Such as assembly of work table)	?
Mass production	Standard operation	Assembly operator	×	×	×	×	×	×
	dealing with troubles (Non-routine operation and unprecedented operation)	Engineer	×	×	×	×	×	×
		Supervisor (Foreperson / subsection chief)	×	×	×	×	×	—
		Maintenance worker	×	×	×	×	×	×
		Assembly operator	N/A	△ Team leader / veteran, qualified troubleshooter	△ Team leader / worker with 10 or more years of service (Grade A) / qualified troubleshooter	△ Cell leader / veteran, rework worker	×	×
	Improvement (Kaizen)	Engineer	×	×	×	×	×	×
		Supervisor (Foreperson / subsection chief)	×	×	×	×	×	—
		Maintenance worker	×	×	×	×	×	×
		Assembly operator	N/A	△ (Minor improvement / one-second improvement)	△ (Minor improvement / one-second improvement)	△ (Improvement of work table / layout)	△ (Improvement of work table / layout)	×

Product flow patterns include serial product flow (so-called line production) and parallel product flow. In the case of serial product flow, not only does the production process handled by any assembly operator constitute only part of the whole, but also the assembly operation of any individual operator and any operation group is always affected by assembly operations of other operators and other operation groups. Namely, there is no technical autonomy in terms of fulfillment of operations for any individual operator or any individual operation group. In contrast to the above, in the case of parallel product flow, in which any operation group or any individual operator assembles the whole of the relevant product, no influence is exerted by any other assembly group (or by any other assembly operator), since the relevant individual operation group (or the relevant individual assembly operator) handles the whole of the relevant production process. Namely, there is technical autonomy in terms of fulfillment of operations. In a case where such technical autonomy is secured, it becomes extremely easy for any assembly operation group or any assembly operator to carry out part of operations other than standard operations, for example to deal with quality deficiencies detected during operations (namely, doing rework). In this regard, even in the case of line production, if a line is divided into a number of mini-lines, then certain technical autonomy is secured in terms of mini-lines, with the result that room for rework on the relevant line expands [10, pp.37-38].

Characterization of standard operation in item ② above is based on two criteria. One is the length of the cycle time, which is the time interval at which any assembly operator repeats a standard operation, and the other is qualitative differences in the contents of any standard operation handled by any individual operator and any operation group. An explanation will be made first of the latter. Qualitative differences in the contents of any standard operation are judged from the viewpoint of the following: a) whether or not functional completeness (unity) of the operation exists; and b) whether the range of the operation covers part or the whole of the relevant product (whether or not totality exists). To the greater degree the functional completeness and the totality are comprised in the contents of any standard operation carried out by the relevant individual assembly operator or the relevant assembly operation group, then the more easily the individual assembly operator or the assembly operation group can understand the meaning of the standard operation handled and the meaningful relations among work elements. Moreover, the deepening of the relevant understanding is supposed to broaden the possibility of expanding the range of operations other than standard operations that the individual assembly operator or the assembly operation group can handle (operations ranging from preparation / change of drawings to improvements). Furthermore, the contents of such standard operations depend greatly on lengths of cycle times. Namely, the longer are cycle times, to the greater extent the completeness and totality of standard operations tend to increase.

As is evident from explanations of the table portion and the table head, Table 3 is formulated in such a way that the further rightward a type of production system is located as seen from the extreme left of the table head, that is, as viewed from "Prot Ford" toward "Single-operator assembly cells" (or toward "Volvo Uddevalla"), then the more greatly the completeness and totality of standard operations increase. On the basis of the above, we would like to assert the following hypothesis. Namely, as production systems change, or in other words, as the completeness and totality of standard operations increase, there probably occurs a tendency that the range of operations which are other than standard operations and which can be handled by assembly operators or assembly operation groups (operations ranging from preparation / change of drawings to improvements) will expand, and therefore, that the state of cooperation based on the division of labor[3] on manufacturing shopfloors will also change.

In the following section, we would like to try to analyze, as much as possible, structures of division of labor on five assembly shopfloors having a different production systems. In this connection, of the five production systems, the following three systems will be taken up as case studies: parallel product flow assembly system in Volvo Uddevalla; autonomous complete processes in Toyota, cell production in Company N. With regard to the structure of division of labor in Prot Ford and the corresponding structure in Toyota as it was prior to the introduction of autonomous complete processes, we would like to limit our mention to the minimum required for comparison with other types of production systems.

2. Three case studies

2-1 Parallel product flow system in Swedish automobile assembly shop: Volvo Uddevalla

The subject in this sub-section is to pay attention to the contents of standard operations, as well as the operational structures, in the Uddevalla Plant of Volvo, thereby making studies of the characteristics of the division of labor in this plant. Major issues of interest are as follows: how the contents of standard operations changed in both quantitative and qualitative terms due to the fact that the line configuration, which constituted the technical pivot of the operations and the relevant production system, was switched to the parallel product flow system; and how this change caused changes in the domain of indirect operations accompanying standard operations. Studies will be promoted in accordance with Table 3, centering on direct operations, indirect operations, and improvement activities. The Uddevalla Plant, which is the subject of studies, started operation in 1989 as the third automobile assembly plant of AB Volvo after the Torslanda Head Office Plant and the Kalmar Plant.

2-1-1 Indirect operation domain: dramatic improvement of completeness in assembly operations

(1) Differences between Ford and Uddevalla: conditions for technical systems

The nature of direct operations ("usual operations" = standard operations) undergo changes depending on conditions for technical systems including product flow patterns in plants where assembly is performed. This is because technical systems have decisive impacts on work patterns and work contents organized under such systems. The technical system of the Uddevalla Plant was greatly different from the Ford type technical system, which was a major production system in conventional assembly of automobiles.

Namely, in the case of the Ford type technical system, where operations are performed in the form of "serial product flow," including the complete process introduced in Toyota, assembly operation spots are located along assembly lines, and all such operation spots are mutually connected together. Automobile bodies automatically move on lines by means of belt conveyors, and parts to be installed on automobile bodies are placed beside lines and are mounted on automobile bodies. Movement of automobiles is synchronized on any single line. Therefore, operators' operations are specified according to line speeds. Line lengths extend to several kilometers. Thus a single automobile is to be completed by being handled by at least several hundred operators.

That is to say, the Ford type technical system is greatly featured by the fact that serial lines utilizing conveyor systems constitute the technical basis for assembly. On any serial line, operators are stationed along the line. Therefore, the premise for operation formation is that each of the operators is to take charge of a certain portion of all operations. Consequently, an important concept of the operation design of Ford type technical system is the subdivision of operations. Judging from the relevant technical formation, there is not created an idea that a single person takes charge of a set of assembly operations from the start to completion. Operators are regarded strictly as entities taking charge of partial operations. Besides, subdivided work contents are fragmented by the use of conveyor systems. The reason is as follows: automobile body movement speeds become constant, and thus it becomes possible for assembly to progress synchronously; consequently the securing of line balance becomes an absolute must; then priority is given to performing operations in as uniform *tact times* as possible; therefore, mutual relations which pertain to contents and which operations are essentially equipped with are cut off; and as a result, operation assignment is decided on the basis of time.

In contrast to the above, assembly in the Uddevalla Plant was greatly featured by the fact that assembly layout was adopted in which all assembly spots were located in parallel, and completion was achieved with automobile bodies placed at fixed locations. Namely, prior to the

initiation of assembly, each automobile body was placed on a carrier and was transported to the spot where the relevant operation body was to perform assembly operations. Then an operation body of 10 persons or less carried out assembly operations in such a way as to surround the automobile. At the same time, parts were transported by AGVs (Automated Guided Vehicles) to the spot beside each automobile body in which such parts were to be installed. Technical conditions where operation synchronization occurs among operation bodies disappeared.

Such fixation of operation spots caused great changes to the aspect of operation organizations. One of such changes is increases in degrees of freedom that operation bodies can exhibit in terms of operations. In contrast to the Ford type, in which compulsory progress of operation was technically structured, in the case of the Uddevalla Plant, it was possible for operators themselves to establish operational paces, thereby taking the initiative in assembly operations. Another change is the improvement of cooperation among operators in work groups. Namely, due to the fixation of operation spots, operators' spatial movements during the progress of operations were caused to concentrate basically on areas around automobile bodies. This fact greatly increased the density of operational cooperation in work groups due to the following reasons, among others, thus leading to increased operational efficiency: communication between operators usually working in pairs and communication in work groups were improved; thus it became possible to allocate work depending on situations. Furthermore, such concentration of operation spaces led to a physical basis that enabled the realization of the "complete automobile assembly" method, whereby a single work group takes charge of assembly including the complete automobile stage. Actually, a work group combined four operating cycles each of which was handled by an operator and of which the longest cycle time was 120 minutes, thereby completing an automobile in eight hours. Therefore, it can be said that in the Uddevalla Plant, the principle of the division of labor pertaining to operational subdivision on which the Ford type technical system is premised was switched over to operation integration.

(2) Operation formation by "functional completion" : qualitative switchover of standard operations

Then what were standard operations ("usual operations") were like in the Uddevalla Plant, where the new principle of the division of labor as mentioned above was introduced (for details, see [6] and Chapter 5 of [19])? What attracts attention is the fact that standard operations in the Uddevalla Plant were designed in such a way as to become an "operation series" in which "functions are completed" and which constitutes a united combination. The term "operation series" here refers to operations where functionally combined units (groups) are installed with consideration given to relationships between the automobile to be equipped with the said units

and the attributes with which individual parts are uniquely equipped, such as the following: ① structures with which the relevant automobile itself is equipped; ②functional attributes created by parts; and ③areas where parts are installed. Actual operations not only refers to units which are functional combinations founded on the above-mentioned product structures but also are formed as an "work module," which is a combined operation unit with consideration given to items such as specific operational situation involving, among others, stains on operators' hands during installation and actual installation procedures. Standard operations in Uddevalla refer to this "work module," which is composed in such a way as to contain about 15 minutes of work. This is the minimum unit of operations that an operator takes charge of. This "work module" is composed centering on the functional combinations with which automobile structures and parts are equipped, and the contents are functionally complete.

In the next place, how is the "work module," which is thus functionally complete, arranged? And how does the relevant operator carry out the long operation cycle? In the Uddevalla Plant, the "function-wise assembly" method was adopted. This method is such that operation categories are established according to four functional domains ("electrical equipment, air conditioner, and water system," "joining and decor," "drive system," and "interior furnishings") that an automobile has, and each automobile is manufactured in such a way that one quarter is assembled at a time. Now it is repeated that operators took charge of assembly operations in pairs, that each operator performed, at the respective operation location, assembly based on the work module which was composed centering on an operation unit containing about 15 minutes of work, and that each pair took charge of the assembly of at least one quarter of the relevant automobile. According to a rough calculation, each operator are supposed to have handled six work modules in the case of an operation cycle of 90 minutes or eight work modules in the case of an operation cycle of 120 minutes. In the Uddevalla Plant, by thus establishing each operational structure on the basis of standard operations, namely, <operation unit → work module>, which was arranged on the basis of the one-quarter functional category of each automobile, it became possible for a single operator to even assemble a complete automobile.

From the above, it follows that in the Uddevalla Plant, changes were made to the technical structure of the assembly line that governs operation formation, with the result that the nature of standard operations were switched in that the contents of such operations were changed to unities having functionality. Namely, each work module is formed not according to temporal division but according to content-based division. Furthermore, the assembly category for each quarter was composed centering on functional unities, namely, completeness, with which each automobile was equipped. As a result, the content-based organic nature of operations, which had been lost in Ford type line system, was recovered. Furthermore, attention should also be paid to

the fact that the range of unities of operations expanded greatly. A comparison of this "range" is made with that of Toyota, and it is evaluated that the completeness of assembly operations in Toyota at the level of "group" organizations was recovered at the level of partial operations, but the recovery was insufficient at the level of individual operators (see pp. 52-53 and [1]). In contrast to the above, in the Uddevalla Plant, operations of each operator are formed in such a way that at least one quarter of an automobile can be assembled on the basis of an work module having unities each comprising about 15 minutes of work, thereby ensuring functional completeness at the level of individual operators (achievement of "functionally complete partial operations"). Furthermore, each work group constitutes an independent production unit for the assembly of complete automobiles (achievement of "functionally complete overall operations"). As stated above, it can be said that in the Uddevalla Plant, functionally complete operations were realized both at the level of individual operators and at the level of work groups. Moreover, since the functional completeness of standard operations was enhanced, it is considered that an environment was created where operators' operation awareness expanded and where the ability to "deal with changes and problems" was enhanced.

2-1-2 Improvement of ability to "deal with changes and problems" by fostering ability in non-direct operation domain

In the next place, let us take a look at a "dealing with changes and problems" due to non-routine operations, which is another constituent component of work turned into standard operations. Regrettably enough, the following discussion will be premised on the fact that the studies made so far on this point cannot be said to be sufficient. However, the following matters may possibly be pointed out. When consideration is to be given to dealing with changes and problems in the Uddevalla Plant, it will be necessary to pay attention to the fact that great efforts were made to foster operators' abilities in the indirect operation domain that is adjacent to the direct operation domain. Namely, as stated earlier, in the Uddevalla Plant, assembly operations were formed on the basis of "long-cycle work." In parallel with the above, the domains of education, maintenance, production engineering, and quality were established as "specialized ability" fields. Many workers received special training regarding these fields, and each operator took charge of his / her respective domain in the relevant work group. In the past, such "specialized ability" overlapped with domains handled by engineers, and it is pointed out that before the Uddevalla Plant was started, operations requiring such ability "were carried out exclusively by white-collar employees" [4, p. 21].

Why were such fields established as "specialized ability" fields? The following fact can be mentioned as the major reason: the range of operations handled by each work group in the

Uddevalla Plant expanded to all assembly processes ranging from the assembly of doors to the assembly of complete automobiles. Namely, in the Uddevalla Plant, each single work group became a unit for assembling complete automobiles, and therefore, operations that were adjacent and ancillary to direct assembly operations could not help being created. For example, in the quality control field, the following items, among others, became quality verification items for important operations: adjustment of troubles in the course of assembly; correction of incorrect installation, and final check [5, pp. 194-195]. If such quality-related check operations fail be carried out properly by each pair handling one-quarter automobile assembly that takes a maximum of 120 minutes, then quality troubles will be caused to occur resulting in rework being required in the next production process. In order to correctly promote operations during long cycle times, the following turned out to be an important task: individual operators should improve knowledge not only on direct operations but also on quality control as a whole. Furthermore, in order for work groups to assume the responsibility for the assembly of complete automobiles, the following turned out to be indispensable to work groups: not only should work groups improve their basic operation levels, but also cooperation should be carried out between operation pair members and among work group members, thereby making it possible to deal with various operational troubles.

As a matter of fact, in the case of the Uddevalla Plant, troubles related to parts and transportation thereof were liable to occur in respect of the plant layout as well. Moreover, there were many cases where troubles occurring in assembling operations were caused by various composite factors. Consequently, importance was attached to increases in the knowledge of various fields adjacent to direct operations in that such increases led to the improvement of productivity of the whole plant. Furthermore, the fact that operators improved educational ability led to the maintenance and enhancement of operational levels of work groups. Therefore, it is considered that the above-mentioned fact was useful for improving the ability to deal with troubles although direct effects on troubles were low.

2-1-3 Introduction of original learning theory that enabled "long-cycle work"

As mentioned above, it can be pointed out "long-cycle work" as one of the features of direct operations introduced in the Uddevalla Plant. Even in Sweden, where many experiments on operation redesign was promoted on a historical basis, it was a general understanding, prior to the construction of the Uddevalla Plant, that the upper limit of operation cycle times was about 20 minutes. However, in the case of the Uddevalla Plant, the cycle time greatly exceeded 20 minutes. The "one-quarter" automobile assembly, which constituted the basic unit of assembly, was performed on a cycle of 120 minutes at a maximum [4, p. 11].

As a factor that enables such a long-cycle work, there exists an original learning theory called "holistic learning theory." Holistic learning refers to a "learning strategy" whereby on the part of operators, the following three sets of knowledge are accumulated with regard to operations, thereby causing operators to acquire planning functions, implementation functions, and functions of control including adjustment: ①total knowledge; ②knowledge on mutual relations among parts constituting the whole; and ③detailed knowledge on all parts [14, pp. 71-72][4].

By using this learning theory, conditions were formed where, in promoting operations, operation implementors were able to carry out control to cause operations to progress correctly, in such a way that the said implementors' awareness and the reality of operations performed under the said awareness are confirmed by the said implementors through inner dialogs involving the said implementors themselves. Furthermore, it can be said that not only did cycle times expand, but also at the same time, the breadth of operation awareness of operators expanded tremendously centering on direct operations, due to the fact that knowledge was acquired through "holistic learning."

2-1-4 Improvements: efficiency of functionally complete operations as seen from human viewpoint

(1) Improvement in "problem solution"

Finally, let us take a look at improvement. Improvement comprises two functions. The first one is an aspect showing employees' involvement and participation in enterprise activities, including the following various items performed by employees, for example, through QC circle activities (small group activities), such as contrivance suggestions related to operations and manufacturing shopfloors. The second one is a function where standard operations are established, and such operations are changed and revised, starting with operation improvement followed by equipments improvement; namely, an essential aspect of improvement. In what follows, studies will be made of "improvement for problem solution" and "change of standard operations" in that order.

In the first place, the former aspect "improvement for problem solution" will be taken up. A specific example will be cited. In Uddevalla Plant, mass production of Volvo 740 was stated in 1991. An assembly worker noticed that one of the fuel pipes was in contact with the plastic fuel tank. He thought that when the relevant automobile ran, there would be a possibility that vibrations or the like would cause the tank to get damaged due to friction between the tank and the pipe. Therefore, he reported his findings to the plant. In response to this report, a process engineer analyzed this problem, and temporary countermeasures were taken. Subsequently, a suggestion was made to the design organization of the Torslanda Plant in Göteborg. However, in

the Head Office in Göteborg, Neither assembly workers nor even engineers were able to promptly recognize the importance of the problem pointed out [2, pp. 127-128].

This problem found by the worker in the Uddevalla Plant was solved in the end in such a way that design changes were made to the pipe in the next model in 1992. In this instance, attention should be paid to the contents of the impact exerted on operation recognition of operators by differences in production processes and operation formation for pipes and fuel tanks between the Uddevalla Plant and the Torslanda Plant.

Namely, in the Uddevalla Plant, relevant operations consisted of a flow of united operation series as follows: a preassembled fuel tank was mounted on the relevant automobile; then the fuel pipes were installed on the body; and thereafter the pipe connected to the tank and the pipe installed on the automobile proper were connected together and tightened. This series of operation was handled by a single operator. In contrast to the above, in the Torslanda Plant, similar production processes were regarded as three separate operations, and production processes were as follows: an operator connected a pipe to the fuel tank; the next operator installed a fuel pipe on the automobile; and the final operator installed the fuel tank on the automobile, and connected the pipe to the tank. Furthermore, these operations were performed at separate operation stations on the line. Therefore, the process formation was such that it was difficult to for the relations between the fuel tank and the pipes to be understood as a whole. Besides, no operators had received training to the effect that individual operators would check operations performed at other operation stations [2, p. 128].

Namely, the problem suggested by this instance is as follows: there are differences in technical and social conditions surrounding operators between the Uddevalla Plant, where operations were designed on the basis of operations whose functional completeness were enhanced, and the Torslanda Plant, where the traditional technical system based on Ford type belt conveyors was applied; and thus it is presumed that such differences probably caused the state of operators' awareness to change, leading to great differences in the matter of problem solution (improvement) between the two plants. That is to say, the following was the case in the Uddevalla Plant: certain related operations were combined together; work whose functional completeness was enhanced was regarded as the basis of operation design; thus operators' operation awareness extended to the whole of production processes handled by such operators (A bird's-eye view was commanded); and operation design was formed in such a way as to draw operators' attention to mutual relations among articles to be assembled. As a result, in the case of the Uddevalla Plant, demonstration of the following factors, among others, with which operators were equipped was promoted: eagerness; senses; intentions; analytical ability; and inference ability. In contrast to the above, to put it briefly, the following was the case in the Torslanda

Plant: operators' awareness was caused to focus only on job portion in charge due to subdivision / fragmentation of operations brought about by the technical structure using conveyor lines; thus relations with other operations were cut off; consequently, relations between product quality and operational connectivity among production processes, to which importance should be attached in assembly processes, were removed from operators' awareness; and as result, it is considered that most probably it was difficult for operators to point out structural problems with products in terms of structures. Thus it is considered that in the Uddevalla Plant, the following took place by enhancing functional completeness of production processes and operations: operators' operational awareness was expanded further; and thereby contribution to production efficiency was realized.

(2) Improvement in "standard operations"

Standard operations in the Uddevalla Plant are shown by two-stage "work instruction" [6]. In the first stage, the following items are shown, among others: operation sequences; tolerances in terms of quality, such as those on torques; and tools used. In descriptive statements in the second stage, details of operations are described to a further extent. Namely, the contents and sequences of operating procedures, as well as specific areas of operations, are shown. Also contained are part numbers and quantities of parts used, among others. Operations are to be performed in accordance with such work instruction system.

As stated earlier under direct operation domains, unlike in the case of Ford type plants, assembly operations in the Uddevalla Plant were performed by the stationary method. Therefore, unlike in the case of the conveyor system of Ford type plants, it never happened that production facilities governed the sequences and contents of operations. Therefore, it is true that sequences of assembly operations were roughly decided, but multiple possibilities existed with regard to detailed sequences of operations, except for technically impossible cases. Consequently, when standard operations were to be decided, discussions were held between operators and engineers responsible for the preparation of work instructions. Then standard operations were decided in such a way that on the basis of the results of those discussions, engineers "recommended" some sort of methods of promoting operations.

Thus the Uddevalla Plant was governed by the technical structure contained in the production system supporting production activities in this plant, and it turned out that communications between establishers of standard operations and executors of such operations played important roles in the establishment and improvement of standard operations in this plant. Moreover, when attention is paid to the contents of communications, it turned out that in terms of relations between engineers and actual executors, there was much room where both parties were able to

behave as equal negotiators in such a way that each of those parties assumed their respective responsibilities in their respective jobs.

Now comparison is made with the situation in Japan. In this country, it is considered a general trend that heads of work groups (forepersons) play important roles in deciding standard operations, and at the same time, forepersons are incorporated, in terms of positions, into control setups on the part of the management. In contrast to the above, in the case of the Uddevalla Plant, it is true that there are differences among operators in terms of assembly skills in work groups, and those group leaders have skills high enough to assemble complete automobiles, but it is never the case that group leaders decide standard operations as persons holding managerial posts. Such leaders' positions do not point to authoritative posts like those in Japan. The major role of each leader is to act as an advisor as a member of the relevant work group. Furthermore, the number of automobiles to be assembled by each work group is decided by negotiations with the management. Therefore, it is impossible for the management to directly apply pressure with regard to the progress of operations.

2-1-5 Sub-summary

As stated above, direct operations (= standard operations) in the Uddevalla Plant are featured by high completeness both at the level of individual operators and at the level of whole groups. Namely, the composition of standard operation is as follows: functionality of automobiles and parts, as well as the flow of actual assembly operations, are incorporated into united "work modules" ; and individual work modules are mutually related to one another and are structured in such a way as to be linked to still larger one-quarter operational units. This fact may show qualitative conversion of the state of operation design and standard operations. In like manner, as mentioned when the learning theory was explained, the nature of operators' operational awareness underwent changes so that original recognition methods like "inner dialogs" are utilized, thereby making it possible to command a bird's-eye view. Thus a great switch was made not only at the level of standard operations but also at the level of operators' awareness.

What follows is not mentioned here, but the system of job structure in the Uddevalla Plant was of the stack-up type whereby skills were learned gradually. Namely, it was said that in the first place, operators learned how to assemble doors, then they learned how to perform assembly in domains such as of interior furnishings and drive system, and finally they mastered entire assembly domains. Besides, not only knowledge on direct operations but also knowledge adjacent to direct operations was set as "specialized ability." Furthermore, opportunities for learning items in "specialized ability" fields were given if operators so desired. It is considered that by acquiring advanced functional completeness and "specialized ability" in standard

operations, assembly operators achieved greater improvements than before in the ability to carry out "dealing with changes and problems," such as troubleshooting and improvements. Such job structures were closely related to wage raises, but were separated from the raising of ranks (promotion)[5] . Thus acquisition and expansion of skills purely showed "work development" of individual operators.

On the basis of the above, it is considered that in the Uddevalla Plant, support was provided by work development type job structures, and the nature of the standard operation structure was greatly changed to that of a functional entity having a relationship, thereby causing the structures of the direct operation domain, the indirect operation domain, and the operator awareness domain to be switched to structures where greater importance was attached to internal meaningful relations of human ability.

2-2 Complete process in Japanese automobile assembly shop: Toyota

2-2-1 Restriction of issues

In this sub-section, taking up the so-called "autonomous complete process" or "complete process" in the assembly lines of Toyota Motor Corporation, our studies will focus on the division of labor on assembly shopfloors. However, our surveys are insufficient in many respects, and therefore, it is impossible, at this time, to set forth the division of labor on manufacturing shopfloors on an overall basis. Here, "usual operations" in Koike's theory will be construed as "operations contained in standard work sheets." Those operations will be called "routine operations" in accordance with Table 2. Studies will be made regarding such routine operations. If Koike's terms "usual operations" and "unusual operations" are borrowed, then in this sub-section, we would like to firstly assert the analytical viewpoint that qualitative differences in "usual operations" have close relations with the structures of division of labor on manufacturing shopfloors; and secondly assert that the importance of this analytical viewpoint is shown by the realization of "complete process" in assembly lines that was carried out by Toyota in the 1990s.

In the case of "usual operations" which is standardized, variations can occur in degrees and quality of standardization as long as products with predetermined specifications are produced by predetermined manufacturing methods. It is true that operations in Volvo's Uddevalla Plant, are also standardized operations, but, quality of work standardization in Uddevalla is different from in traditional serial product flow assembly system with short-cycle work. If "usual operations" are subdivided / fragmented repetitive operations with short cycle times and high densities, then in physical terms involving operation times and, at the same time, in terms of capability, it will be difficult for production workers engaged mainly in "usual operations" to also handle

"unusual operations" while being engaged in "usual operations." Furthermore, is it the case that "unusual operations" will be experienced by assembly operators as operations which are outside the scope of proper operations and which belong to categories different from "usual operations" ? If consideration is given to a structure of division of labor on a manufacturing shopfloor such that assembly operators take charge of "unusual operations" to some extent simultaneously with "usual operations," and if this structure of division of labor is to function stably, then is it indispensable to form "usual operations" in such a way that meaningful functional relations among various work elements regarding assembly, or in other words, aspects of product building logic or "product's inherent production logic," [3] are repeated and reflected in operators' minds?

In arguments made in the past with regard to relations between "usual operations" and "unusual operations," those relations were studied in such a way that contents of "usual operations" were parenthesized and withdrawn from consideration. However, if there exists a structure of division of labor on manufacturing shopfloors where assembly operators themselves take charge of both "usual operations" and "unusual operations," or in other words, if there exists the so-called "integrated system" [8, pp. 66-68], it is necessary to study the qualitative contents of "usual operations" and then to analyze structures of division of labor on manufacturing shopfloors in relation to those qualitative contents. If such a hypothesis is set up, then in order that the "integrated system" involving "usual operations" and "unusual operations" should be promoted to some extent, it is necessary to change subdivided / fragmented "usual operations" into functionally complete ones. Toyota's implementation of "complete process" in assembly work that was promoted in the 1990s can be characterized as having such orientation. In an argument where the "integrated system" at production sites in Japan is asserted without caring about the qualitative contents of "usual operations," it will be impossible to properly position the significance involved in such changes in "usual operations" in the 1990s.

2-2-2 Assembly operations in Taylorism and "traditional system" : subdivision / fragmentation of operations and deprivation of functional relations among work elements

"Usual operations" in assembly operations have evolved through three historical stages. Then we would like to give consideration to the respective characteristics of the three historical stages on the basis of joint results of our survey group ([1], [15], etc.). Namely, in the first stage, standardized operations on manufacturing shopfloors were based on Taylorism prior to the introduction of belt conveyors. Secondly, "usual operations" consisted of routine operations in

the "traditional system" where belt conveyors were adopted and standardized operations were repeated within short cycle times. In the third stage, routine operations in assembly are organized on the principle of "complete process" in Toyota. The above-mentioned three types of routine operations are qualitatively different. In sub-section 2-2-2, explanations will be made on routine operations under Taylorism and the traditional system. In sub-section 2-2-3, studies will be made of routine operations on assembly shopfloors after the introduction of "complete process."

Standardized work based on Taylorism has been regarded as the basic principle of division of labor that runs on the foundation of modern mass production plants. However, what Taylor conceived was a production system comprising assembly on stationary work-tables and un-mechanized lines, as well as a production system for solving manufacture-related problems typical for small and medium scale production. Thus large scale mass production was not intended to be an indispensable premise. Taylor made it a task to eradicate "soldiering." He considered it necessary that engineers should perform motion analyses and operation time studies, and should conceive the combination of the most excellent tool and the most optimum operational method as the one best way, and should give the fixed work method to operators in the form of work instructions documents. Here, production site operations are subdivided into various work elements. Furthermore, work elements are broken down into basic motions. Then times required for those basic motions are measured. Thereafter, engineers eliminate "unnecessary movements," and decide the "fastest" and "best" movements, then form those movements into a standard operation series. The establishment of such standard operating procedures brings about the subdivision of work elements but does not inevitably impair functional relations in the relevant various work elements series. It is true that standard operations as an operation series for a single operator are an aggregate of subdivided various work elements. But it is never the case that such standard operations cannot be organized unless logical relations among various elements are cut off. In this sense, in the case of Taylorism, there exists no internal motive whereby operations are "fragmented."

However, in the case of "traditional systems " (in Proto-Ford and in Toyota prior to the 1990s) as referred to in Table 3, in order to avoid time losses that are caused in short cycle times for the assembly to complete automobiles as a result of the introduction of serial product flow system based on belt conveyors, it was so arranged that the "product's inherent production logic" was cut off, and subdivided work elements were combined together, regardless of meaningful functional relations among various work elements, thereby creating routine operations for individual operators, as a result assembly work was fragmented.

If the question of whether assembly operations are physically feasible is set aside, then the principle of combining various work elements and forming them into standard operations is

constituted by line balancing in the case of traditional system. Line balancing refers to an arrangement where in serial product flow assembly system, operational loads are distributed as evenly as possible to all workers engaged in operations on the relevant line. On any serial product flow line with belt conveyors, line balancing is pursued by means of the following: short cycle time is decided in the first place; and subdivided work elements are distributed, in keeping with short cycle time, to all of the numerous operators standing along the line, in such a way that no idle time will occur. Work elements should be distributed in such a way as to be in keeping with short cycle time. However, if distribution is performed in such a way that operations for each assemblers are completed within cycle times, then waiting times, namely time losses will occur. In order that various work elements will be distributed to all operators in keeping with short cycle times to prevent time losses, standard operations are to be established as follows so that time losses will be reduced to as minimum levels as possible: work elements should be further divided into smaller pieces; and subdivided various work elements should be distributed to different operators in disregard of functional relations among operations.

If the installation of a rear power seat is taken as an example, work elements are as follows: ① the seat frame is brought in to the interior of automobile body from the line side; ②bolts are tightened to install the seat frame; ③the connectors attached to the seat frame are connected to the wire harness wired on the floor; ④the seat is placed over the frame; and ⑤the connectors attached to the seat are connected to the corresponding connectors attached to the frame. Work elements in items ① to ⑤ above constitute a functionally complete element operation group having organic relations for the purpose of realizing the functions of the power seat. When these installation operations are subdivided and fragmented to thoroughly pursue line balancing involving no time loss, the following situation occurs: the bringing-in in item ① above is incorporated into the operations of worker "a" of operation group "A" (or "work group *'kumi'* A"); the tightening in item ② above is handled by worker "b" of operation group "A" (or "work group *'kumi'* A"); the connection of the connectors in item ③ above becomes a job of worker "c" of another operation group "B" (or "work group *'kumi'* B"); the installation of the seat in item ④ above is handled by worker "d" of another operation group "C" (or "work group *'kumi'* C"); and the connection of the connectors in item ⑤ above is incorporated into the standard operations of worker "e" of operation group "C" (or "work group *'kumi'* C") [1, pp. 140-142].

As can be seen in this example, on production shopfloors under traditional systems, operation subdivision, which is common to Taylorism, is further promoted. Besides, there occurs a tendency that operations are deprived of meaningful functional relations among various work elements and work elements are subdivided in order to achieve line balancing. The tendency to

deprive operations of functional completeness, as well as not only to subdivide but also to fragment operations, was a feature common to Ford production system in the past and in Toyota production system up to the 1980s, although there was a difference in the degree of such a tendency. Nevertheless, to what level it is possible to promote the subdivision and fragmentation of operations differ variously, in actuality, depending on the extent to which mechanisms for pursuing the elimination of time losses are established, on the levels of ability of enterprises to analyze manufacturing operations, and on the extent of labor unions' and workers' resistance to operation subdivision.

Problems with conventional assembly processes have been summarized starting at the stage where Toyota arrived at the formation of new assembly lines based on "complete process" in the course of the introduction of "complete process" in the 1990s [1, pp. 88-93]. According to this summary by persons concerned, the findings are as follows: on conventional assembly lines, "there was no philosophy" in the principle to make production processes; pursuit was made of "production process formation with importance attached to line balancing" where operations were to be fragmented as far as possible; as a result, individual operators' work tended to be "collections of diverse operations" without organic relations among work elements; "the roles or positioning of operators' work was unclear" ; and "it was impossible to understand the purposes or functions of work" allocated to operators; furthermore, all work performed was to assemble parts in unrelated areas; there was no opportunity to carry out quality checks or improvements with regard to intermediate products having certain complete functions, and it was difficult to form skills and abilities; "only installation was performed, with other operations left to other people," and "it was impossible to know the results" of the assembly operations performed by operators themselves; "no matter how long operators were stationed at production sites, it was impossible to understand the whole of 'automobiles' " and "it was difficult to develop specialized skills and knowledge" ; unless operators participated in preparatory work for startup of new automobiles, "there occurred no increase in knowledge" on production processes "even if experiences were accumulated."

In conventional assembly plants, if seen from the viewpoint of "complete process," operations contained on standard operation sheets, namely, routine operations are not only subdivided but also fragmented, as seen from the expression "collections of diverse operations." Under circumstances where "the installation of a single part is dispersed to multiple work groups and persons," functional relations among various work elements do not come to operators' minds during assembly operations, and therefore, it is impossible to understand the positioning or meanings of operations. Consequently, it is difficult to offer suggestions for improvements based on experiences in production site operations, and it is difficult to notice

problems with quality. Furthermore, "no matter how long operators are stationed at production sites, it is impossible to understand the whole of 'automobiles,'" and "there occurs no increase in knowledge" on production processes "even if experiences are accumulated." If the statements here are to be rephrased in line with the theme of this Chapter, it follows that in assembly plants prior to the introduction of "complete process," it was difficult for the contents of routine operations, namely "usual operations" as called by Koike, to lead to dealing with changes and problems, and that the relevant complete automobile manufacturer itself came to the conclusion that in order for operators engaged in "usual operations" in assembly processes to be able to easily achieve skills and knowledge for covering "unusual operations" as well, it is necessary to reexamine the fragmentation of assembly operations, thereby changing the quality of "usual operations."

2-2-3 Realization of "complete process"

(1) Criteria for operation formation in "complete process"

Let us proceed to the study of "complete process" for changing the quality of routine operations, which are "usual operations" in assembly processes (for details, see [1] and [15]). In "complete process," it is so arranged that "assembly operations are classified according to the automobile functions, thereby creating united pieces of operations (or coherent work), and 'standard assembly sequence' [13, p.85] of such assembly operations are specified" [1, p. 107]. The criteria for classifying assembly operations according to functions in accordance with the concept of "complete process" are broadly divided into two sets of criteria as thought of by persons concerned. One set of criteria is that "the functions that each constituent element of any automobile should have as the said constituent element in order for the said automobile to normally function as an automobile" [1, p. 108]. If this is stated in a conclusive way, assembly operations are subjected to grouping in accordance with the classifications of functions possessed by components and modules that are constituent element of any automobile.

The other set of criteria, which is not expressly stated in documents or the like announced by people concerned, is one expressed as the "ease of instruction, ease of remembering, ease of manufacturing, and ease of building quality into each process" (based on the record of a hearing held in the Motomachi Plant of Toyota Motor Corporation in March 2002). This is said to mean that complete process is formed by also taking into account the workability consisting of the "ease of instruction, ease of remembering, ease of manufacturing, and ease of building quality into each process." We are unable to clearly explain the contents of the second set of criteria. According to our surveys, the abstract set of criteria consisting of the "ease of instruction, ease of remembering, ease of manufacturing, and ease of building quality into each process" is

applied pragmatically by people responsible for manufacturing on a case-by-case basis, and it is considered that this second set of criteria has not been conceptualized yet.

In the case of Uddevalla system of Volvo, parts classification ("assembly oriented logical product structure") was developed from the viewpoint of assemblers for the purpose of enabling parallel product flow assembly system with extremely long-cycle work. On the basis of this parts classification, various work elements of assembly operations were formed into work modules by taking into account items such as unique conditions including plant facilities and equipments. Such work modules were combined together to create tasks having extremely long cycle time for all operators. In the case of classification criteria for parts categorization based on the viewpoint of assemblers, not only the functions possessed by all constituent elements of automobiles but also the following items can be mentioned, among others: part-whole relationships; similarity; spatial proximity; bilateral intra-product symmetries; bilateral inter-product symmetries; and contingent inclusion relationships. Furthermore, consideration is given to rough assembly sequences determined by product architectures and also to times required to assemble parts included in major parts groups [6]. In light of these classification criteria, the second set of criteria pertaining to workability, which is said to be classification criteria for "complete process," still remains to be abstract undifferentiated criteria. It is considered that this set of criteria can be conceptualized through more detailed scrutiny.

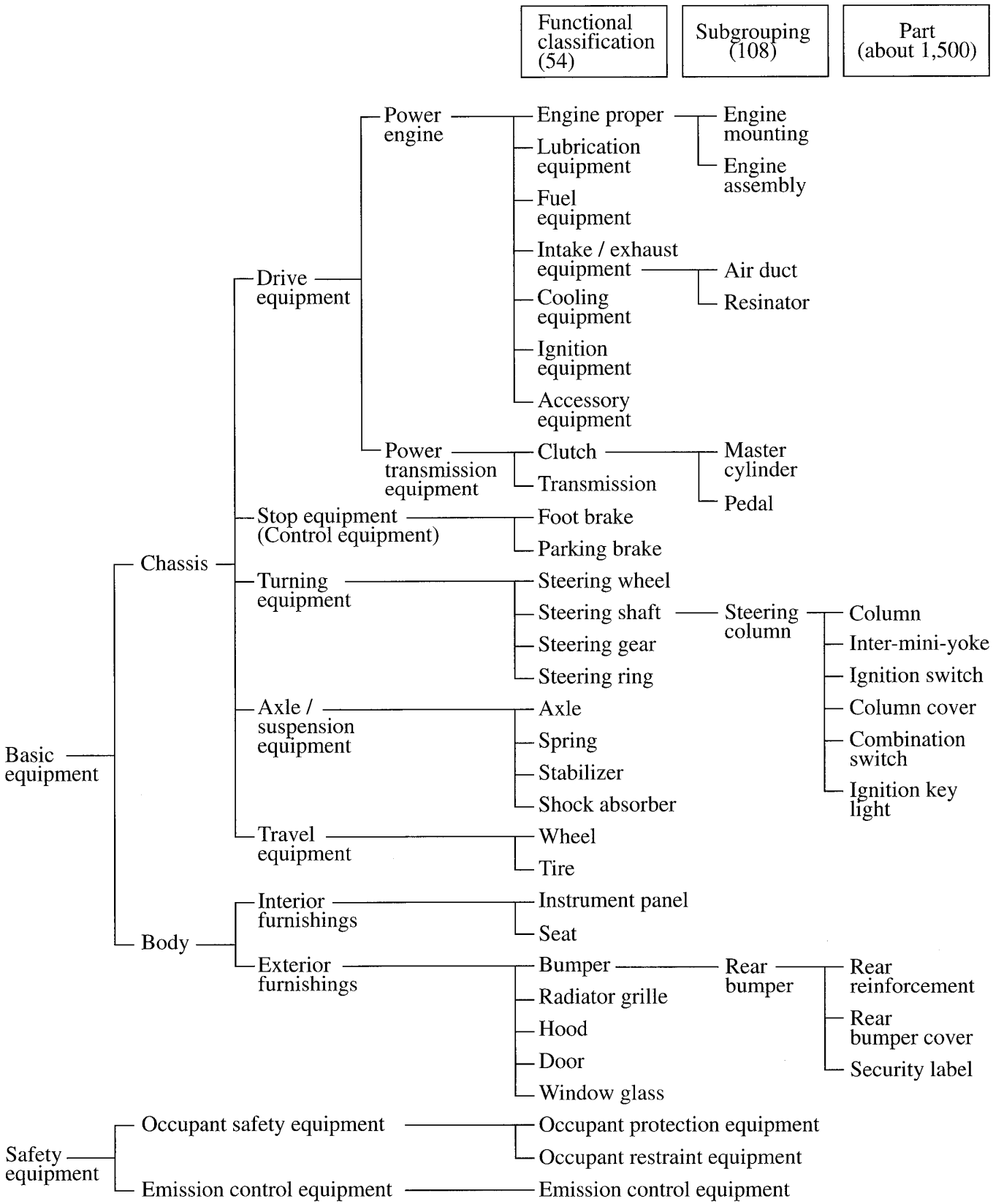
(2) "Complete process" and classification of parts

The "parts classification for realization of complete process for assembly work" performed on the basis of the above-mentioned two sets of criteria, is as follows, although such criteria are not clear (see Figure 3).

In the "parts classification for realization of complete process for assembly work," the first stage consists of the following eight categories: power engine; power transmission equipment; stop equipment (control equipment); turning equipment; axle / suspension equipment; travel equipment; interior furnishings; and exterior furnishings. These eight categories are classified only according to function. In lower hierarchies of the classification, parts are classified in such a way that not only functions but also factors like workability are taken into account. In the "functional classification," which constitutes the second stage, parts are classified into 54 categories. In the "subgrouping" which constitutes the third stage, parts are divided into 108 categories. It is said that in further lower hierarchies of the classification, the number of part categories amount to about 1,500. These 1,500 categories of parts can be thought of as delivery units [15].

A delivery unit refers to a unit consisting of a batch of parts that is transported from a parts

Figure 3 Part Classification for Realization of Complete Process for Assembly Work



Source: [1, p. 110]. The title was revised.

shed to a parts rack located beside the relevant main line or is transported by an automatic conveyance device synchronously with the main line. For example, a meter and an air conditioner are each a single part. However, if the meter and the air conditioner are installed in an instrument panel on a sub-line and are transported to the main line in such a way as to be integral with the instrument panel, then the instrument panel with the meter and the air conditioner installed is counted as a single delivery unit. The above is an outline of the part classification.

The "functional classification" consisting of 54 categories and the "subgrouping" consisting of 108 categories are common "standard classifications," regardless of automobile type or automobile model, or irrespective of plants in Japan. On the other hand, the lowest hierarchy of the part classification consisting of about 1,500 categories, namely about 1,500 delivery units, differs depending on automobile type and plant, and therefore, is not common to all automobile types or all plants. Parts subgrouped into 108 categories are installed to constitute parts "functionally classified" into 54 categories. Furthermore, 54 categories of "parts" are assembled into eight categories of units, thereby completing a passenger automobile. This installation sequence, namely this "standard assembly sequence," came to be unified throughout the company and became the same, regardless of automobile type, automobile model, or plant. Efforts are made to establish a standard assembly sequence and to fix and clarify the following: which operation group (kumi) is to install which of the 108 "subgrouped" categories; and which subsections are to install which of the 54 "functionally classified" categories. Completeness rates at which 108 "subgrouped" categories are installed in operation groups by way of coherent operations are not exactly known. However, it seems that these rates were 50 percent or 30 to 40 percent in the past but have risen to 80 to 90 percent.

(3) Functional completeness in assembly operations

As seen above, "operation groups (kumi)" as work groups became work organizations corresponding to "subgrouped" part categories, and operations having functionally meaningful relations are completed in operation groups. Operators came to be aware of such a principle of assembly process formation. It follows that the contents of "complete process" consist of a new principle of assembly process formation such that standard assembly sequence should be obeyed, and that functionally complete operations corresponding to work groups centering on operation groups should be distributed. In the case of this principle of assembly process formation, it is so arranged that production processes are formed centering on operation contents such as functions and workability. Thus this principle is fundamentally different from the principle of attaching importance to line balancing in which assembly processes are formed centering not on operation

contents but on cycle times. Standard operations in conventional assembly work were formed centering on times, namely, short cycle times. However, in the case of complete process, a set of criteria was added to the effect that operations regarding "subgrouped" categories should be completed in single groups. Thus the coherence and completeness of operations are established in such a way as not to fragment operations to any further extent. The coherence and completeness of operations were assumed as a premise for the establishment of standard operations, and "in standardizing assembly work, the relevant method was standardized." In this sense, "it can be said that the second stage of work standardization is entered" [1, p. 15]. Thus constraints were placed on the deprivation of functional relations among work elements, thereby curbing the fragmentation of operations.

Was it that the operation completeness in terms of individuals was enhanced due to the introduction of complete process? Realization of complete process prepares the concept of "operation series" at individual levels in addition to functional completeness in terms of groups. The term "operation series" is abstractly explained as that which "specifies the minimum unit for subdividing operations" with respect to an individual. Specifically speaking, this term refers to "a unit involving 10 to 20 seconds." For example, a series of various element movements consisting of the following steps are taken as operation series for a single operator: a part is brought in; temporal tightening is performed; final tightening is carried out; and then wire connection is implemented. In the establishment of conventional standard work whereby importance was attached to line balancing, there were cases where even such various element movements were broken down into standardized work for multiple operators. "Operation series" serve to curve extreme fragmentation of operations. However such operations are a matter of an operation range pertaining to a unit involving 10 to 20 seconds. They are not a matter of a level where functional relations among work elements and functions of parts are confirmed and turned over in the relevant operator's mind through assembly work. Thus complete process is such that functional completeness is intended to be secured in terms of operation groups (kumi) as work organizations. At the individual level, such processes are limited to partial operations. However, in a range of groups (kumi) consisting of 10-odd to 20 workers, it becomes easy for individual operators to catch sight of functional completeness and totality of operations, and it becomes easier to grasp functional completeness during operations, by accumulating experiences through job rotation.

(4) Realization of "complete process" and skills of assembly workers

Due to the introduction of complete process, manufacturing operations have come to be formed in such a way that operations having functionally meaningful relations are completed in

units of work groups (*kumi*). As a consequence, the situation became such that if job rotation was performed inside of groups and if major production processes inside of groups were experienced, then it was possible for operators to become aware of complete functions of component parts in the course of execution of routine assembly operations. In assembly plants prior to the introduction of complete process, the situation was as follows: individual operators' work was "collections of diverse operations," and "the installation of a single part was dispersed to multiple groups and persons" ; therefore, even if operation spans were expanded through job rotation for example, it turned out that "diverse operations" were learned one by one; even if details of "diverse operations" were stacked up, it was difficult to increase knowledge on relations among various work elements, to say nothing of acquiring knowledge on overall structures of automobiles; and "no matter how long operators were stationed at production sites, it was impossible to understand the whole of 'automobiles.'" Subsequent to the introduction of complete process, by assembling complete parts having functional coherence, the expansion of operation spans broadened the possibility that through assembly work, operators would learn individual part functions and relations among parts, as well as assembly operations regarding whole automobile structures, and that the learning results would be caused to take root.

In defining skills in assembly work in the past, there was no other way than to say "skills required for installation itself, such as fine adjustments needing senses of eyes and hands" and "promptness in operations, as well as ability to make no errors in specified operations." However, it is said that with the introduction of complete process, it became possible to give the following definitions: "a state where mechanisms and functions of parts themselves are learned as knowledge" and "a state where operators are familiar with functions."

Assembly skills that are newly defined as a combination of "knowledge on mechanisms and functions" and "expertise in installation itself" give a technical foundation for building quality into each process in production processes, as well as a foundation for improving assembly work, by means of understanding functions and mechanisms of parts. It is true that routine operations regarding assembly are thus standardized. But, due to the introduction of complete process, a technical system where functionally complete operations are formed is applied, thereby broadening technical possibility that "unusual operations," which are dealings with changes and problems, are integrated and such integrated operations can be handled by production workers. Even if routine operations contained on standard work sheets are subdivided operations, the curbing of fragmentation of such operations will prepare a technical foundation on which the range will be extended or will be caused to be easily extended where the "integrated system" can be applied, the "integrated system" being such that "unusual operations" are entrusted to

operators engaged in "usual operations."

Toyota newly established the "Specialized Production Skills Mastering System" (in 1991) and reexamined the skills training system simultaneously with looking for complete process, when seen in terms of time ([16, pp. 185-191] [11, pp. 246-251]). The Specialized Production Skills Mastering System applies to all production shopfloors, and do not directly correspond to the implementation of complete process for assembly lines. However, there are common features in newly defined assembly skills and in the basic concept of the Specialized Production Skills Mastering System. Under this system, the following grades are established as skill levels: Grade C (elementary grade), Grade B (intermediate grade), Grade A (advanced grade), and Grade S (special grade). These grades were distributed to a total of 55 organizations on the basis of matrices by plant and by shop (involving 10 job types including machinery, body welding, and assembly). Each of these organizations establishes skill criteria for all grades. It is considered that in the case of Grade A, skills expected of core technicians in 10-odd years of continuous employment are visualized. In this connection, the qualifications to take an examination for Grade A were investigated on the basis of examples of criteria for skills evaluation and certification for assembly plants. The qualifications for an examination for Grade A consist of the following four items: ①work experience; ②skill level; ③quality assurance; and ④improvement ability. The requirements for these qualifications are as follows: ①the work experience shall be such that "the examination candidate shall have been in the Company's employ for 10 years or more and shall have obtained Grade B" ; ②the skill level shall be such that "the examination candidate shall be able to perform operations for about three to five assembly processes, and shall be able to carry out simple rework and troubleshooting, or shall be deemed by the skills certifier as one having skills equivalent to the above; ③quality assurance shall be such that "during the one month immediately prior to application for the examination, the number of quality deficiencies caused by examination candidate himself shall have been two or three and the number of recurrences of quality deficiencies shall have been zero" ; and ④the improvement ability shall be such that "the examination candidate shall be able to perform production process improvement and improvement in operation, and the average number of improvement suggestions made per month during the six months immediately prior to application for the examination shall be three or more."

Multiskilled worker training, which refers to a practice whereby job rotation is performed, thereby forming skills capable of handling multiple assembly process, had been carried out long before the introduction of complete process. Under this practice, abilities for rework and quality assurance were linked empirically to multiskilled worker training. In keeping with the realization of complete process, it happened that assembly skills consisting of "skills required for

installation itself, such as fine adjustments needing senses of eyes and hands" and "promptness in operations, as well as ability to make no errors in specified operations" came to be consciously linked to "a state where mechanisms and functions of parts themselves are learned as knowledge" and "a state where operators are familiar with functions." It is necessary to empirically grasp what actual situations are like on manufacturing shopfloors. In this regard, logically, multiskilled worker training and "the state where operators are familiar with functions" came to be consciously combined in skill formation. As a result, in terms of system, experiencing multiple production processes turns out to be compatibly linked to the abilities for simple rework and troubleshooting, as well as to the ability for quality assurance [1, p 159-166]. Thus due to the realization of complete process, the relations among various internal elements of skills that are assumed in the Specialized Production Skills Mastering System are strengthened to a greater extent than in the past with respect to assembly operators' skills as well.

As regards operations on manufacturing shopfloors, new definition came to be given to skills in such a way that assembly skills are understood to consist not only of familiarization with fingertip operations but also of knowledge on parts. However, skill levels for assembly operations themselves in a narrow sense are grasped on the basis of "expansion of operation spans," which is "widening," and are positioned in a limited way in terms of "depth." In the company document where the "concept" of the "working life image in assembly shops" is shown, the following image of skill development is drawn: "(1) operators increase the breadth and depth of work while taking part in work with intra-group job rotation as a basis" ; and at the same time, however, "(2) operators gradually leave line operations through familiarization with operations and improvement in skills" (Company material, in the form of re-quotation from [16, p. 188]). What is assumed here is skill development of promotion type whereby operators gradually leave assembly lines due to promotion. This is different from the work development type, as in Volvo Uddevalla, whereby operators' job ranges expand in keeping with the acquisition of skills while operators are engaged in assembly operations.

Another point to which attention should be paid in the new definition of skills for assembly is as follows: the intention is to render operations of installation itself as easy as possible and to dilute elements pertaining to hunches and knacks, thereby rendering operations so easy as to be capable of being handled by anyone; and this intention is maintained and strengthened. As regards the realization of complete process, it is so arranged that individual work elements in assembly work are rendered easy to understand, and that training periods for those who have no experience in assembly operations are shortened. Since groups (kumi) are organizational units to take charge for a complete set of tasks of automobile functions, functional relations of work are easy to understand. Furthermore, minimum operational units are intended to be established in the

form of "operation series" and "operation batches" for the purpose of curbing the subdivision of operations for individual operators, and therefore, it becomes easier than before to remember operations of individuals. Moreover, in the past, there were cases where production processes were formed in such a way that when an automobile of a different type flowed down the relevant assembly line, different parts were installed. However, as a result of the realization of complete process, even if an automobile of a different type runs down the relevant assembly line, operators handle operations pertaining to the same area, and in this respect as well, it becomes easer to remember operations. As a consequence, startup periods for new models were shortened. Therefore, not only is it possible to carry out "vertical startup," where full operation stages are entered immediately after new automobiles are thrown in, but also it becomes easier to remember operations and training periods are shortened. Consequently, even if temporary workers, dispatched workers, or helping hands from different departments are thrown in to some extent, it is possible to operate assembly lines without lowering productivity or quality to lower levels than before.

Thus a possibility is opened that temporary workers or dispatched workers are utilized as regards a certain part of the assembly operators. We have not obtained appropriate information for passing judgment regarding the approximate upper limit of the percentage of persons not familiarized with assembly operations, such as temporary workers or dispatched workers, who can be thrown in without lowering productivity or quality. However, there is a fact that the situation is spreading where in Japanese automobile assembly plants, 20 to 40 percent of operators are accounted for by non-regular labor force. Non-regular labor force as non-negligible percentages of production workers which is utilized in automobile assembly plants is regarded, for the time being, as fluid labor force that leaves manufacturing shopfloors after being engaged in work for short periods of time. Temporary workers are stationed in production processes commonly called "beginners' production processes." During employment contract periods, such workers are basically not rotated to other production processes [11, pp. 245f]. They are persons who take charge of routine operations in specific production process and who are in charge of "usual operations" only, which have nothing to do with dealing with changes and problems. The "separated system" is applied, as a matter of fact, to such labor force, which account for certain percentages in automobile plants.

2-2-4 Sub-summary

In the case of the realization of complete process, as seen in this sub-section 2-2, functional completeness in operation groups called "kumi" is enhanced. In this regard, operations in which individual assembly workers are engaged on a daily basis are subdivided into partial

operations. However, fragmentation of operations is curbed. Thus the quality of assembly operators' "usual operations" is rendered different from that of operations on conventional assembly lines. Qualitative changes in "usual operations" are such that a possibility of forming new skills for assembly shopfloors are given from technical systems to core operators capable of handling several production processes in operation groups in automobile assembly plants, as well as to supervisors internally promoted from rank and file production workers. Thus changes in "usual operations" have an impact on the state of manufacturing shopfloor "unusual operations" handled primarily by core operators and supervisors, and are linked to new development of the so-called "integrated system." At the same time, however, the realization of complete process broadens the possibility of utilizing peripheral labor force including temporary workers, and the "separated system" is applied in this portion.

2-3 Cell production system in Japanese assembly shop of electrical machinery industry: Company N

2-3-1 Outline of Company N and conversion of production system.

It is considered that in the present-day electrical machinery industry, the number of manufacturing shopfloors where the cell production system is introduced amounts to a considerable level. Here, the assembly shopfloor of Company N, which is a manufacturing subsidiary of Company A Group will be taken up as a case study. The reason for subjecting Company N to studies is that in the first place, the case in Company N can be said to be a typical instance of the introduction of the cell production system. In Company A Group including Company N, the cell production system has been introduced, since the end of the 1990s, into assembly shopfloors not only in plants in Japan but also in overseas plants. Particularly, Company N adopted the cell production system the earliest in company A Group, and is a successful enterprise. The second reason is that the amount of information is relatively large, since it was possible to obtain the cooperation of Company N. From November 2000 to December 2003, we visited Company N several times, and we were able to conduct hearing surveys by interviewing mainly the manager of the Manufacturing Department and persons at the section manager level of this Department. Prior to making studies of the structure of the division of labor on the assembly shopfloor, a brief explanation will be given about the outline of company N and the conversion of the production system.

Company N is one of the major plants in Japan that manufacture one of the computer peripheral devices (herein referred to as Product X), but does not have a development and design organization or a sales organization, since this company is a manufacturing subsidiary of Company A. The number of employees of Company N is about 1,700, and the annual production

volume of Product X is about 1.25 million units (estimated value for 2002). In this regard, the number of employees and the number of units produced per year peaked in 1998, after which such numbers decreased. Besides, there is no labor union in Company N, but there is an employees' organization.

Assembly of Product X proper was performed by the belt conveyor line method for about 10 years after production was started in 1989. Namely, there exited a total of six mounting / inspection lines for products proper, and the length of each line was between 180 and 210 meters. The number of operators per line was between about 50 and 100. Between 1,000 and 2,000 units of Product X, for which the number of parts installed is 40 to 60, were produced per shift in a cycle time of 20 to 30 seconds. However, in connection with changes in the market environment, such as diversification and shortened life cycles of products as well as intensification of cost competition, there gradually surfaced problems which pertained to the conveyor line system and which continued to exist latently.

According to Company N, the following five items constituted the problems with the conveyor line system:

1. There occurred various types of wastage (balancing losses, handling losses, wastage in movements, wastage caused by losses in a single production process spreading to all production process, wastage due to double checks, wastage due to works in process, wastage due to finished goods inventories, and wastage in spaces).
2. High capacity, expensive, large size equipments typified by conveyors were used.
3. Additional time and costs were generated during adjustment when product models were changed.
4. Large numbers of indirect and support personnel were involved who did not produce values added. For example, on a certain conveyor line, indirect and support personnel accounted for 10 out of 60 persons (namely, a total of 10 persons consisting of two each of subsection chiefs, relief workers, troubleshooters, rework workers, and distribution workers).
5. Intellectual abilities of assembly line operators were not utilized (operators were engaged in simple job and in imposed work).

For the purpose of overcoming these problems, Company N removed all of the six conveyor lines for the product proper from November 1998 to June 1999 and made a switch to the so-called cell production system, which is a production system where production is performed on the basis of small operation units called cells each consisting of about one to 10 operators. Numbers of such cells underwent changes in connection with variations in production volumes. When production volumes were large, the number of cells rose to about 40, but as of December 2003, this number decreased to 15. Now studies will be made as to how the division of labor on

newly introduced assembly cell shopfloors is organized.

2-3-2 Division of labor on assembly cell shopfloors

Major operation processes for the assembly of Product X proper consist of mounting, inspection, and packaging. Standard operations handled by operation teams on assembly cell shopfloors include the conveyance of mounted parts and packaging materials, in addition to these three major production processes. Furthermore, these teams handle work other than standard operations, such as rework of defects and troubleshooting.

Systems of assembly cells as seen from the viewpoint of differences in the division of labor consist of mini-assembly lines without conveyor and single-operator assembly cells. A mini-assembly line without conveyor is an operation unit where products are assembled in such a way that all production processes in the cells are allocated to about 10 operators. The reason why the number of assembly operators of a team is maintained at 10 or so is that it is considered that the ability of the team can be easily demonstrated if the number of operators is at such a level. This type of cell accounts for a high percentage among all cells. For example, 10 out of 15 cells were mini-assembly lines without conveyor (as of December 2003).

A single-operator assembly cell, which is the other type of cell, is an operation unit where products are assembled in such a way that all production processes (or mounting / inspection processes) in the cell are handled by a single operator. Such cells are of two sub-types: the rabbit chasing type, in which multiple operators (about two or three operators) assemble products in such a way that each of them moves from one production process to another; and the single person type (fixed position type), where a single operator assembles products at an almost fixed position without moving from one production process to another. Here, there were more cells of the rabbit chasing type than those of the single person type. As to the reason why fewer cells of the single person type were adopted than were cells of the rabbit chasing type, it was pointed out that numbers of tools were larger and there were problems in terms of parts supply. In what follows, several cases of mini-assembly lines without conveyor and single-operator assembly cells will be taken up, and outlines of such cases will be presented centering on the way the division of labor is carried out in standard operations.

(1) Mini-assembly lines without conveyor

Case 1 Small size products (as of March 2002)

The operation team for this cell, which was composed of a total of 12 persons consisting of one cell leader, one person in charge of distribution, and 10 assembly operators, assembled small size products. The cell leader was a female regular employee, and all other team members were

employees of contractor companies. This team produced 657 products per day. The cycle time was about 44 seconds.

Case 2 Products for office use (as of March 2003)

This team, which was composed of a total of 14 persons, produced 168 units of products for office use (products for export to overseas regions) per day. The cycle time was about 171 seconds (2.86 minutes), the assembly time per unit was about 40 minutes, and the number of parts per unit was about 70. The division of labor among the operation team members (14 in number) was as follows:

- Cell leader (who basically stayed off the line and doubled as a rework worker): one person (male)
- Rework worker (who supported the person staying off the line): one person (male)
- Two distribution workers + 10 assembly operators = 12 persons (two males, two senior persons aged between 55 and 65, and eight females)
- Allocation of assembly processes (10 in number)
  Mounting: six processes are handled by six persons.
  Inspection: three processes (electrical measurement, image evaluation based on visual and instrument inspection, and finish checking) are handled by three persons.
  Packaging: one process is handled by one person.

Mini-assembly lines without conveyor are utilized mainly at the beginning of production of new product models and during production increase. This is because production startup periods are shorter than in the case of single-operator assembly cells. Moreover, it is said that this type is liable to be introduced for the assembly of products proper which are relatively large and for which numbers of parts are high. Furthermore, as in Case 1, it is often the case that except for the cell leader, employees of contractor companies handle operations. Contractor companies can be made use of, since in the case of mini-assembly lines without conveyor, operation training time required is shorter than for single-operator assembly cells, which will be discussed later. For example, there were a total of about 40 operators in four mini-assembly lines without conveyor of the Second Subsection of the Second Assembly Section. Among these operators, about 10 persons were regular employees (the ratio of males to females being 2 to 8), and about 30 persons were employees of contractor companies (the ratio of males to females being 20 to 10) . Besides, in this subsection, the ratio of female employees was as high as a little less than 50 percent. This is considered to be because products to be assembled are relatively small.

(2) Single-operator assembly cells

Case 3　Single person type (as of March 2003)

In this cell, 560 small size products were usually assembled in one day. The number of parts per product was 64. In the cell, there were 10 mounting stations (five stations each on the left and right sides), and at the center, there was an inspection and packaging station, which was a shared area. Mounting were performed with no operator moving from station to station. However, only in the case of inspection and packaging operations, the rabbit chasing type was applied, since equipments were shared by 10 operators. Specific operating procedures were as follows: 1) the relevant product was placed on a pallet, then the cover (body) was removed, and the product was moved to the mounting station; 2) mounting was performed at this station; 3) inspection was conducted on the inspection table located at the center; 4) packaging was carried out; and 5) the product was placed on a pallet.

The number of operators of the team was 12 (all operators being female regular employees). The breakdown was one cell leader (who doubled as a rework worker), one person in charge of distribution, and 10 assembly operators. Each of the 10 assembly operators not only assembled whole products at a mounting station, but also performed inspection and packaging operations. According to calculation, the average assembly time (including inspection and packaging) per unit for a single operator was as follows:

480 minutes $\times$ 60 seconds $\div$ 560 units $\times$ 10 persons

$\fallingdotseq$ 514 seconds (approximately 8.6 minutes).

In actuality, however, models with different specifications (product variations) flowed into each mounting station, and therefore, the assembly time per unit was about 10 minutes or so.

Case 4　Rabbit chasing type (as of March 2003)

Three regular employees were stationed, and 22 relatively small products for office use (products for sale in Japan) were produced in one day (when the production volume was small, there were cases where a single person carried out production). The assembly time (including mounting, inspection, and packaging) per unit was about 45 minutes. The number of parts per unit was about 80. The breakdown of the three regular employee was one male (who was a senior high school graduate, was employed in mid-career, was from the local area, was in about 14 years of service, and was the cell leader), one female (who was a senior high school graduate, was employed in mid-career, was from the local area, and was in 10 years of service), and one female (who was a senior high school graduate, was employed immediately after graduation from the said school, was from the local area, and was in eight years of service). Allocation of operations to these three members was as follows: mounting and inspection were allocated to

two operators; and packaging and distribution were allocated to one operator.

Single-operator assembly cells are utilized mainly during periods when production is stable and during periods of production decrease. This is because when new cells are started up, it takes about six months for numbers of units produced to reach levels for mini-assembly lines without conveyor. Besides, it is said that single-operator assembly cells can be easily introduced into the assembly of products proper whose sizes are relatively small and for which numbers of parts are small. Furthermore, unlike in the case of mini-assembly lines without conveyor, operators in single-operator assembly cells are limited to regular employees.

(3) Allocation of work other than standard operations

Assembly cell operation teams (each consisting of the cell leader and cell members) are not just engaged in standard operations such as mounting, inspection, and packaging. Now such teams have come to take charge of work which is other than standard operations and which these teams seldom handled at the time of the conveyor line system.

1) As already mentioned, in the case of the conveyor line system, support workers took charge of non-line operations (nonstandard operations) such as rework, troubleshooting, checking operations, and replacement of absentees. However, in conjunction with the conversion to the cell production system, some of these operations were distributed to cell leaders, and checking operations were distributed to operators in cells (such checking is referred to as successive checking, which means the act whereby an operator in a downstream process checks operations of upstream processes). Moreover, there are some of the operators (those who obtained Grade 1 as a multi-skill level) not only can perform mounting operations, adjustments, inspection, and packaging within standard times, but also can carry out rework, fault analysis, and data management.
2) In the days of the conveyor line system, staffers and leaders on lines performed the layout of assembly lines and the improvement of parts racks, as a whole. However, in the case of the cell production system, cell leaders and cell operators assemble and improve worktables or make suggestions for improvement of cell layouts. In specific terms, subsection chiefs create prototypes of layouts and worktables. These prototypes are improved by means of the following, for example: opinions of cell leaders and cell operators are adopted; operation teams hold improvement implementation meetings once a week; or overtime work is performed. Furthermore, during preparations for (or startup of) new products, there are cases where operation teams think out some of the layouts in consultation with cell leaders under limitations on operation contents, numbers of parts, and spaces.
3) In the days of the conveyor line system, the responsibility and authority for the following

matters were in the hands of subsection chiefs: securing of daily production volumes within specified times; and making decisions on overtime work if production volumes are not secured. However, in conjunction with the conversion to the cell production system, these responsibility and authority were delegated to cell leaders. Basically cell leaders stay off lines. There is one cell leader in each cell. The qualifications for any operator to be appointed as cell leader is specified to be as follows: he / she shall be in Grade 5 or above in the job ability system; and he / she shall be able to perform rework.

(4) Dealing with problems occurring in cells: state of division of labor

In assembly cells, various problems (troubles) occur on a daily basis. They can be classified into operation delay accompanying operational errors, quality deficiencies of products, and equipment deficiencies. In the first place, let us take a look at dealing with operational errors, to which operators are directly related. An operational error refers, for example, to a case where an assembly operator drops a part like a screw or where he / she breaks the thread of a screw. In company N, methods of dealing with operational errors are properly specified (in other words, relevant acts are non-routine operations). For example, it is specified that if a screw is dropped, the dropped screw should be discarded without being used and a new screw should be used. Furthermore, the occurrence of operational errors usually causes operation delays. Therefore, the ratio of allowance (5%) for making up delays is secured within standard operation times. Assembly operators and operation groups deal with this sort of problems.

However, dealing with quality deficiencies cannot now be performed only by assembly operators, and are carried out in the form of cooperation based on the division of labor among many workers. This is because many of the quality deficiencies here are related to defects of parts, and mean essential deficiencies that fail to achieve specifications when inspection is conducted. Major processes where such quality deficiencies are detected are as follows: the mounting, adjustment, and inspection processes; and the shipment inspection (sampling inspection) process conducted prior to packaging. Detection of deficiencies in the mounting, adjustment, and inspection processes is the job of assembly operators. Shipment inspection is handled by a subsection of the Quality Assurance Section of the Comprehensive Planning Department. In what follows, the focus will be placed on dealing with quality deficiencies.

Descriptions of instances of quality deficiencies detected by them are, for example, "The shape of such and such a part is improper," "Good images do not appear," "Adjustment cannot be made properly" and "The electric potential does not rise." The rules for dealing with quality deficiencies in such cases are as follows:

1. If the relevant assembly operator feels anything to be "improper," he / she turns on the red

light to call in the cell leader.

2. The cell leader takes a look at the situation, and passes judgment as to whether he / she can solve the problem by himself / herself or a technical staffer (in charge of production processes) of the Quality Staff Zone of the Manufacturing Department should be called in.
3. If the cell leader cannot solve the problem by himself / herself, he / she calls in a technical staffer (probably via the relevant subsection chief), and this staffer deals with the problem.
4. If the technical staffer cannot solve the problem, he / she contacts, via the relevant subsection chief, an engineer of the relevant engineering section (the First Engineering Section specializing in electrical and mechanical equipment or the Parts Quality Assurance Section specializing in parts) of the Engineering Department, and then the technical staffer and the engineer undertakes to solve the problem in cooperation with each other.

Namely, it is a basic principle on this assembly shopfloor that the assembly operators detect quality deficiencies but do not judge causes or take countermeasures.

The last issue is dealing with equipment deficiencies. How is this matter handled? Major equipments, other than worktables, used in assembly processes for Product X are image inspection machines and tightening tools (such as screwdrivers). If any problem occurs in an inspection machine, the relevant assembly operator calls in the cell leader. Usually, the cell leader cannot deal with the problem either. Therefore, technical staffers (in charge of tools) of the Quality Staff Zone are called in, and they deal with the problem. If a mounting tool gets out of order, the relevant assembly operator calls in the cell leader to have the tool replaced. Just as in the case of quality deficiencies, the relevant work of assembly operators is limited to the detection of problems.

2-3-3 Features of division of labor

(1) Two types of division of labor

As mentioned above, there are two types of division of labor on the assembly shopfloor for Product X of Company N. One type pertains to mini-assembly lines without conveyor and the other type pertains to single-operator assembly cells. In either type, the contents of standard operations handled by one operator increased compared with the case of the conveyor lines that were abolished. Namely, the cycle time for a conveyor line was 20 to 30 seconds, but the corresponding time became about 40 seconds to a little less than 3 minutes in the case of a mini-assembly line without conveyor or about 10 to 45 minutes in the case of a single-operator assembly cell. Particularly, as regards a single-operator assembly cell, a single person not only performs assembly of whole products, but also handles a series of operations up to inspection

and packaging work. Namely, what he / she performs is not fragmentary subdivided work units but the assembly of whole products, which is functionally united standard operations, or in other words, standard operations of extremely high completeness. If attention is paid to this point, it can be said that single-operator assembly cells have a feature common to that of the production system of Volvo Uddevalla. That is to say, the common feature is the functional completeness of standard operations at the level of individual operators such as that achieved in the said system of Volvo Uddevalla.

On the other hand, in the case of mini-assembly lines without conveyor, such functional completeness of operations is not necessarily realized at the level of individual operators. Furthermore, the ratio of mini-assembly lines without conveyor is as high as about two thirds. This point is greatly different from Volvo Uddevalla. Nevertheless, standard operations of extremely high completeness are performed at the level of operation groups, since each operation team of about 10 members not only assembles whole products, but also handles a series of operations up to inspection and packaging work. Namely, it can be said that standard operations at the level of operation groups have something in common with those in the production system of Volvo Uddevalla.

(2) Features of cooperation based on division of labor

On this assembly shopfloor, major work other than standard operations participated in by assembly operators is dealing with operational errors, detection of quality deficiencies, detection of problems with equipments, assembly of worktables, and suggestions for partial improvement of layouts. Of these items, pieces of work other than dealing with operational errors and assembly of worktables are operations that are not completed only by assembly operators, namely operations that can be carried out only through cooperation based on the division of labor.

There are two characteristic points in cooperation based on the division of labor, particularly in the case of dealing with quality deficiencies. One is, as already seen above, the fact that a series of operations ranging from the detection of quality deficiencies to the cause analysis and the implementation of countermeasures are shouldered by many workers including not only members of manufacturing organizations but also engineers of other organizations.

The other is the fact that technical staffers of the Manufacturing Department and engineers of the Engineering Department address the solution of problems in close cooperation. However, in Company N, these cooperative relations are not necessarily thought of in a positive way. That is to say, on the part of engineers, these relations are recognized as a reflection of the situation where engineers cannot help providing cooperation, since technical staffers' ability is

insufficient. Nevertheless, these cooperative relations are very interesting as a state of division of labor. This is because it is considered, as stated below, that mutually complementary relations are established between technical staffers and engineers.

Ex-production engineers, as well as ex-assembly operators, account for about 50 percent of the technical staffers of the Manufacturing Department. These people are familiar with assembly sites while having engineering knowledge. Being familiar with assembly sites means the following: each technical staffer is well acquainted with assembly operations in general; and therefore, when a quality deficiency occurs, he / she can quickly get a fair idea of the problem area in the sense that "such and such a part is suspicious." However, technical staffers' abilities are a little insufficient in terms of specialist knowledge on electrical and mechanical equipment, and therefore, they cannot deal with technically advanced problems. On the other hand, engineers are divided into detailed categories based on specialization fields involving electrical and mechanical equipment, and therefore their expertise is deep but the breadth of knowledge is narrow. It is considered that the fact that these two types of people cooperated to address the solution of problems have resulted in quality deficiency problems being efficiently dealt with.

3. Tentative conclusions

As regards three case studies taken up in this Chapter, we have not been able to conduct a comprehensive analysis of structures of division of labor on assembly shopfloors. This is because the information obtained from activities including surveys is limited to partial knowledge. Therefore, the conclusions which are given below and which are pointed out as features of division of labor are tentative remarks.

As shown in Table 3, there is a tendency that the further the type of production system shifts toward "Single-operator assembly cells" from "Prot Ford," then to the greater extent is eliminated the fragmentation of standard operations carried out by individual operators or assembly operation groups, with the unitedness of operations (functional completeness) increasing all the more. Also observed at the same time is the following tendency: there occur increases in the totality of operations such that individual assembly operators do not carry out subdivided partial operations but one or several operators assemble whole products; namely, the division of labor is curbed.

The fact that the contents of standard operations undergo changes in such a way that the functional completeness and totality are recovered means that the operational self-containedness for individual operators or assembly operation groups is recovered. In this regard, degrees of recovery differ greatly depending on types of production systems. Recovery of operational self-containedness has an impact on the state of the division of labor on assembly shopfloors in two

ways.

In the first place, if standard operations are limited to partial operations carried out within short cycle times, then the possibility of utilizing peripheral labor force such as temporary workers and employees of contractor companies is broadened. This is because the fragmentation of operations is eliminated and the unitedness of operation increases, thereby making it easy for operators to master operations. This fact is true of autonomous complete processes of Toyota and mini-assembly lines without conveyor of Company N. In such cases where peripheral labor force is utilized, the "separated system," where standard operations and nonstandard operations (manly improvements and dealing with troubles during mass production; and preparations for production) are allocated to different workers, respectively, is implemented. This separated system not only pertains to the state of the division of labor among assembly team members, maintenance workers, supervisors, and engineers, but also includes the fact that there occurs the expansion of division of labor among assembly team members, namely, the expansion of separation between the following persons: peripheral workers, team leaders, veterans, and qualified troubleshooters.

At the same time, this feature of division of labor, as seen in the case of Toyota and Company N, is that mainly operators at the foreperson and team leader levels (or cell leaders and rework workers), as well as troubleshooters, take charge of dealing with troubles that have been experienced (non-routine operations) and mainly engineers (production engineers, as well as manufacturing engineers and technical staffers) take charge of dealing with troubles that have not been experienced (unprecedented operations). Consequently, in order for dealing with troubles centering on non-routine operations to be sufficiently carried out, it is necessary for ordinary assembly operators to be promoted to team leaders (cell leaders) or forepersons. Namely, the method of delegating nonstandard operations is of the promotion type. Such a structure of division of labor may be said to be a convenient mechanism for training core workers on assembly shopfloors.

Another point is that if standard operations are carried out in long cycle times and if one or several operators assemble whole products, then the possibility is broadened that nonstandard operations (improvements and dealing with troubles during mass production; preparations for production; and partial involvement in product design) is delegated to assembly operators or assembly operation groups. If such a possibility is realized, the division of labor will be further curbed. This is because assembly operators deepen the understanding of products and improve the ability to carry out operations. What follows is not sufficiently verified, but it is considered that such signs can be found in parallel product flow system of Volvo Uddevalla and in single-operator assembly cells. Particularly, in the case of Volvo Uddevalla, all members of assembly

operations teams were provided with opportunities to handle nonstandard operations (to handle quality, production engineering, education, and maintenance, for example). Namely, in this production system, the method of delegating nonstandard operations is of the work development type, which is different from the promotion type in Japan. Such a structure of the division of labor can be said to be one in which importance is not attached to the training of core workers but one in which the abilities of all operators on assembly shopfloors are intended to be improved.

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Notes

1. The term "*tact time*" refers to the time required to perform each standard operation. Here, the word "tact" originates from the German word "Takt," which means a beat as in music.
2. This chapter was prepared in such a way that an internal document originally written as a proposal for the research method for our research group was rewritten for purposes of reporting at the 109th Convention of the Society for the Study of Social Policy (held on October 16, 2004). Sections 1 to 4 were touched up for purposes pertaining to the Society. However, as regards the final section 5, "Research Methods," the present writer did not have a mind to change the tone as a personal suggestion to our group. It would be appreciated if that point could be understood.
3. As pointed out in Chapter 1, in clarifying the state of cooperation based on the division of labor on manufacturing shopfloors, it is considered important to pay attention to "unusual operations" as argued by Koike. On such occasions, by carrying out the following, it is possible to gain opportunities to clarify structures of division of labor on manufacturing shopfloors: it should be investigated whether "job matrix (particularly, tables showing depth of experiences)," to which importance is attached by Koike as one of the means of judging the ability to perform "unusual operations," exist on manufacturing shopfloors of large enterprises in Japan; and the contents of such tables should be understood, if any (as is commonly known, the existence of "job matrix" put forward by Koike was criticized by Nomura [17] on a detailed and thoroughgoing basis). Consequently, we make it a rule to ask the following questions when opportunities are available on occasions such as visits to plants.
   (1) Do you prepare charts showing items such as skill levels of workers on production shopfloors, as well as education and training plans (or something like private memos of site supervisors)?
   (2) Do such charts (or memos) contain information such as numbers and levels of jobs (operation processes) experienced by individual workers (namely, indicators showing the breadth of experience), as well as ability to deal with problems (indicators showing the depth of experience)?
   (3) By whom are such charts (or memos) prepared and revised? Also, how long have they been prepared?
   (4) Are there cases where such charts are posted?
   (5) If there is any production shopfloor where there exists a chart (or memo) mentioned in item (1) above, investigation will be made about the division of labor among the following employees: 1) engineers (design engineers, production engineers, and manufacturing engineers); 2) site supervisors (employees at

the foreperson or team leader level); 3) direct workers at production sites (core workers and others); 4) specialized workers (such as maintenance / repair workers, tooling workers, and inspection workers); and 5) semi-direct workers other than specialized workers (such as workers handling distribution and workers handling improvements).

Entries regarding structures of division of labor in Table 3 were prepared on the basis of information obtained by asking the above-mentioned questions. Since the information is limited, the entries are not comprehensive, thus serving as a tentative draft.

4. Some explanation will be made as follows: (1) totality refers knowledge on articles in bird's-eye views, namely, knowledge on entire automobile bodies to be assembled; (2) relations refer to relations between parts and tools; relations among parts, tools, and automobile bodies; and relations between them and human beings; (3) details refer to knowledge on relations of relevant assembly operations [14, pp. 70-71].
5. Why is it that such acquisition of skills is not linked to the raising of ranks? The reason is that in Sweden, neither improvement of skills or nor development of work is regarded as a matter in the framework of enterprises only, but with regard to the key point of the improvement of skills, emphasis has been placed the development of work contents. In Sweden, this concept regarding work development has been agreed to in labor unions. Partly because labor unions are not organized in terms of enterprise but their organizations are formed in terms of industry, it has been rare that work development has been understood in the sense of promotion. This is a reflection of historical development of Swedish society.

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