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〔Article〕

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1. Two Aims

The objective of this paper is twofold. First, field research used to be a mainstay in labor economics (see, for instance, Doeringer and Piore). As more and more quantitative methodologies became widely available to applied economics researchers, field research became a forgotten trade among most labor economics. In recent years, however, interest in field research has been rekindled among a new generation of labor economists (Ichniowski, et al.[1997], Hamilton, et al. [2003], and Kato and Shu [2008]). I have been conducting extensive field research in a variety of workplaces in multiple countries over five decades. Using some of my recent field research projects, this paper demonstrates vividly the value of field research as an important complementary methodology in labor economics.

In my view, field research has three notable advantages. First, some key variables in labor economics, such as worker skill, are difficult to quantify, and field research proves to be critically important in understanding such variables. Second, field research can provide vital insights on the actual mechanism through which worker skill affects productivity, and exactly what kinds of worker skill are particularly productivity-enhancing. Such insights will help policy makers and practitioners develop and implement strategies to enhance competitiveness at the micro level as well as at the macro level. Third, field research when conducted effectively provides fresh insights which will help economic theorists develop a new theory.

The second and related purpose of this paper is to explain the theory of “intellectual skill” which I developed using insights from my own field research in diverse workplaces in multiple countries over several decades. In so doing, I hope to be able to elaborate on my main message (the value of field research in labor economics). Let me begin with explaining what I mean by “intellectual skills”.

2. Intellectual Skills

Take for example a final assembly line in car industry, say Toyota. A quick glance at those assembly line workshops gives inexperienced observers a false impression that skill requirements for those assemblers are quite low. A closer look at the same workshops for at least two hours reveals quite a different picture. There appear to be two kinds of operations which production workers perform; usual operations and unusual operations.

Usual operations are just routine and repetitive, say, to attach a left forward door of Corolla every 60 seconds. No skills are required for conducting these operations. And people tend to imagine that all operations in the final assembly line are of this kind. [1)]

Yet, a longer and careful observation reveals a variety of unusual operations, which occur far more frequently than imagined. Unusual operations handle “problems” and “changes” that are not always predicted fully in advance. A set of skills required to perform such unusual operations effectively are called “intellectual skills”. In my view, it is those “intellectual skills” that make a significant difference in workplace productivity even if similar equipments are used.

The “problems” which are solved in unusual operations are not fully known beforehand in terms of their nature, timing and magnitude. A defect in product quality is a good example. We cannot predict exactly what kind of defects will occur, when they will occur, and how crucial they are for productivity. If we had been able to predict all of these problems beforehand accurately, then we could have designed a computer program to identify and to handle product defects efficiently, so that no workers skills are necessary.

The “changes” which are dealt with in unusual operations are also uncertain in their extent and timing, although their nature is known in advance. An obvious example is a change in output. The demand for products often changes, almost unexpectedly, both in timing and degree. If production workshops cannot effectively adjust to a change in demand, many unsold cars will pile up in the stockyard, which would not only be a large additional cost to the firm, but would also waste scarce resources of the society.

To explain the theory of “intellectual skills”, we will focus on two specific examples of unusual operations (for brevity, we discuss only two specific examples. For a more comprehensive list of extraordinary operations, see the appendix).

3. The Easiest Case: Identifying Incorrect Parts or Missed Parts

3.1 What Are Revealed by In-depth Field Research

Least Costly On-line Identification

On a final assembly line in the car industry, for example, the most visible, and hence the easiest to identify, defects are incorrect parts being attached or required parts not being attached. Although these are seemingly simplest defects, they are not easy to be identified during a flow of operations, since the cycle time, or process time, of an operator is as short as around 60 seconds in an ordinary situation. (The cycle time becomes longer when markets are slack, as explained in the appendix.) Within such a short period of only 60 seconds, it is not easy for an operator on the line to identify those defects which occurred earlier while engaging in their own tasks.

It may be argued that inspection staff, who locate at inspection stations in the middle or at the end of the assembly line, can fulfill this task than the operators themselves on the line who are busy with their own tasks. However, an inspection is far more costly than assembly-line workers in recognizing defects in products. This is firstly because a defect becomes excessively difficult to be identified later in the assembly line, since many parts that have been attached later conceal the original defect.

Even when the defect is identified during later production stage, rectifying it requires far more time and hence increased costs. The simplest defects, such as incorrect parts being attached, usually necessitate a series of operations to replace the defective part with the correct one, because many parts that have been assembled after the original defect was made have to be disassembled or overhauled. This is the second reason.

The consequent damage to productivity is enormous, when this is compared with the case in which the operator on the very job next to the one that caused the defect find the defects, or at the latest, during the last job in the workshop where the defect occurred. It is simple because not many other parts conceal the original defect. And even if no time is allowed for the operator to replace the defected part, he or she can put a red tape to indicate the defected part, and hence it takes only a couple of minutes for other workers to replace it at a shortest gap of the assembly line.

Yet, this is subject to an important condition that the operator on the assembly line has capability to identify the defect in such a short cycle time busy with one's own operations to be conducted. Then, what is the content of the capability? Is it simple commitment to the job or loyalty to the company or the work group?

Broad Experience in the Workshop

A series of in-depth interviews with veteran foremen who know the situation of the workshop most intimately disclose that the best way to acquire the know-how for identifying incorrect parts or missing parts is to have had experience in working on the preceding jobs in the same workshop. The reason is clear: to identify the defect in such a short time as 60 seconds, knowledge of the normal situation without any defect is indispensable. If an assembly worker has this knowledge, a glance is enough to identify something as incorrect.

Work experience in the subsequent jobs in the workshop also significantly promotes a workers' capability to inspect for defects. While an operator is carrying out the subsequent jobs in the workshop, he or she becomes more aware of what points in the operations should be carefully attended in order to decrease defects. When the worker is deployed in the preceding jobs with experience of subsequent jobs, minimum defects naturally follow.

A simply broad experience is not enough, however. Without an experience of the job for a long period say not a couple of days but for several months, it is almost infeasible to identify the defects at a glance. If we extend this logic reasonably, it is natural for a worker to experience almost main jobs (ten to fifteen jobs) in the workshop to acquire the know-how to identify the defects. Here we can obtain an effective measure of workers skills by a broad experience. And it is necessary to require not a short period, say 7-8 years for building the skills to identifying the defects.

High Frequency

Yet, a crucial question might be raised: how frequently these defects in product quality occur, so as to affect the productivity significantly? This crucial question consists of a very difficult part to answer and of not so difficult one. To begin with the not so difficult part, the probability of incorrect part or missed parts could be unexpectedly high. The major reason of suspecting such high probability is, as well known in those scholars who study the Japanese car industry, due to an extremely large variety in the kinds of products. A final assembly line engaged in manufacturing one brand as Corolla has to handle an extremely large variety in the parts. To take for instance the engine for one brand of Corolla, there is difference in the capacity of engines such as 1200, 1500, 1800cc and so on. In addition, a further variety of engine follows. The emission regulation differs by region even within the US: stricter in California than say, Texas. Hence the design of engine differs even by region that has to be assembled along one assembly line. A long series is needed to refer to an extremely large variety of other parts that follow. Driving apparatus of shifting gears has another variety as 3 shifts, 4 shifts and five shifts, in addition to the difference between manual and automatic operations. And if we take into account of the difference in color, the number of difference in the mixture of all these varieties in parts is so enormous that it is almost inevitable for workers on the final assembly line to cause incorrect parts and/or missed parts even though a particular slip indicating each part is attached.

The other part of the question is much more difficult to address. Looking back the cases that we have discussed above in detail such as the importance of identifying the incorrect parts or missing parts within the workshop, it can easily be surmised that no official figure could be available even in the firm. So far as I know, the frequency data of defects available within the factory or firm are mostly confined to those identified by the inspection people at inspection stations on the assembly line. The figure of defects identified by the inspection people are discussed in the formal meeting consisting of managers and foremen in the department. In the meeting the foreman whose workshop has many defects identified by the inspection is strongly criticized and required to present the counter-measures how to decrease the defects. It is natural that this tough meeting prevents the foremen from referring to those defects that are identified and rectified within his workshop.

I was presented with two rare opportunities to discern the true frequency of defects in Toyota production lines. One is that I happen to pick up a slip of memorandum noting the number of defects by character for a certain week, which is never reported in the formal meeting of the firm. The slip suggests unexpectedly frequent defects. The other is the actual figures of defects occurred in the workshop disclosed by some foremen. I was fortunately enough to conduct in-depth interviews with those veteran foremen who were near retirement, and hence who had no apprehension in stating the real situation in the workshop. The frequency of defects is surely by far higher than usually imagined. I did not quote these figures in my book published, in an apprehension of possible damage to the future career of the foremen. I simply described the frequency as "considerably large."

The above story naturally suggests an enormous difference in productivity between the two cases; a. on-line identifying by operators, and b. identifying at the inspection stations by inspection people. This large gap can be understood when the above observation is compared with an ordinary analysis based on an ordinary field work.

3.2 Ordinary Results by Ordinary Field Work

Pitfalls in an Ordinary Field Research

An ordinary field research often conducts interviews with managers or engineers in a company meeting room only, not going to the shop floor. Even when interviewers visit the shop floor and talk with the foremen, mostly they are accompanied with managers. With managers accompanied, the foreman naturally tends to follow the formal policy of the firm, rather than candidly telling the shop floor practice.

Taking for example Toyota, the formal policy of the firm on the way of dealing with problems is, when an operator finds something unusual, "to stop the line, to call for the supervisor, and to wait for his coming". In other words, it is an imperative for an operator on the assembly line, not to deal with the problems by oneself, rather just to pull the 'andon' string to call for the supervisor. [2] Managers as well as engineers would tell this formal story in the meeting room, and even the foreman on the shop floor would state the similar story when he is accompanied by a manager or an engineer. And if this is to be the actual case, the line would stop so often that the efficiency of Toyota would be largely lowered than the fact. This could easily be surmised, when we think of the high frequency of defects on the line as stated above.

This formal policy had, in my understanding, two purposes originally. One is to identify and “visualize” the critical point of trouble in the flow of operations, so that the improvement could be efficiently invited. The other would be to prevent less skilled operators from being involved in work accidents, which are extremely costly not only for the worker oneself but also for the firm. Yet, practices on the shop floor have been continuously renewed, resulting in a large gap between the practice and the formal policy.

If a researcher is not aware of this gap, and yet tries to explain the relative high efficiency of Japanese assembly lines, then it is natural to overemphasize off-line problem-solving: famous as “Kaizen”, QC circle activities, and suggestion systems (Koike,2001). And this emphasis on off-line problem-solving consequently leads to a well established illusion that Japanese operators on an assembly line are subject to Taylorism, strict regulation by management. Although no doubt remains for a certain contribution to productivity by these off-line activities, no illusion can survive, once we remind the tremendous effects of handling even the easiest defects in product stated above. Before proceeding to the most demanding case, let me summarize the points for avoiding pitfalls in field research, though I am afraid they are too simple, yet not easy to implement.

Measures to Avoid Pitfalls

To avoid pitfalls, first, it is imperative to conduct interviews with multiple informants even on the same issue, not jointly but separately for confirmation. To disclose the way of treating the defects of the product quality, for instance, we need to talk with not only managers or engineers, but also the foremen or those veteran workers who know the practice on the shop floor most. And it is to be noted that the place of interview should be the one where the interviewee is the master of the place such as a foreman in one’s own office. According to my own experience, the second or third interview may often afford this opportunity.

Second, it is important to conduct interviews with the same informant twice or more on different dates. Even if time allowed for second interview is as short as a half an hour, it is really precious. These multiple interviews not only help researchers clarify the ambiguous answers that are unavoidable in the method of interview, but also confirm the fact by asking slightly different questions. And most important is the informant’s relaxation or trust with the interviewer. Usually on the second interview, the informant is accustomed to the interviewer, in terms of knowing his interest and even trustworthiness, so that more fruitful answers are expected.

Third, according to my own experience, questions are needed to be concrete as much as possible. Suppose we ask the way to deal with identifying defects in product, for example. A question how a worker on assembly line identifies incorrect part attached or missed part is by far better than a question simply asking in general how an operator identifies defects in product quality. It is because the latter general type of question largely depends on the interviewee’s understanding of the question and hence there might be large possibility of misunderstandings, or a danger to employ a different standard in answering the question. And once an answer has been obtained, it is vital to ask the recent illustrations, and how they were handled and what problems remained. In other words, it is important not to stop the interview with a first answer, but rather to proceed for some knowledge sharing between the interviewee and the interviewer, which could afford an ample source of a new theory.

Fourth, it is preferable to even inquire the interviewee's reasoning why the problem occurred and how that was solved. When the interviewee is a veteran worker, his explanation would often be of extreme importance. And these answers of how and why can be an immense source of a new theory.

4. The Most Demanding Cases

4.1 Voice in the Design of a New Car Model

Pilot Teams

The most demanding working of intellectual skills is workers' voice in the new design of product, as well as workers' participation in the design of new production line. What follows are based on a comparative field research between Thai Toyota, NUMMI in the US, the UK Toyota and Toyota in Japan, during the period of 2002-2005, published as Koike [2008] in Japanese only. The focus here is on the workings of a "pilot team" of production workers, who are selected as being engaged in designing a new production line with production engineers as well as manufacturing engineers. Since similar groups can hardly be seen in other countries so far as I know, an explanation is indispensable.

A pilot team comprises one or two dozen members of production workers for one department as the final assembly, dependent on the stage of the process. Most members are of ten to fifteen years of experience as ordinary operators on the assembly line, none being supervisors, but assessed highly on the capability in dealing with changes and problems. Once they are selected, they are off-line for a half or one full year, mainly participate in the design of new production line in collaboration with engineers, and have voice in the design of a new car model

Let me start with observing their voice in the design of a new car model. At the stage of its conceptual design, members of the pilot team are requested to make comment on the conceptual design. According to field research that conducts a series of intensive interviews with production engineers as well as those veteran production workers who have been the member of the pilot team, the pilot team not only comments that this part of design is not easy for assembling and hence may cause more frequent defects, but also proposes even their own idea of modification of the design. The design engineers who are mostly with MA degree in engineering react to these comments faithfully: though the design engineers of the new product accept not all of these comments or proposals, they answer to these proposals with written documents stating the reasons why they do not accept these. Clearly the pilot team members are mostly high school graduates so that they have never been trained in the study on product design. And yet, why and how can they effectively not only comment but also propose some modification of the design?

Broad Work Experience

There are two points to be noted. First, the comments and proposals by the pilot team are based on their experience of assembling the current model of car. Through conducting operations on the assembly line, they become aware of the fact that a certain part is not easy to assemble and accordingly apt to cause defects, and that a small change in the design can remarkably decrease the difficulties and defects.

These skills are not acquired by most workers even with long experience; rather many cannot reach this level of skills. Roughly, those of the skills are confined to one-third for the cohort with ten or fifteen years of experience. And those who have been identified their potentials are encouraged to broaden their work experience not only to most positions in their workshop, but also to the next one in their career. It is from this skill group that the pilot members are supplied. Contrarily to an ordinary understanding that seniority commands Japanese workshops, tough competition between individual workers governs there.

This is supported by the pay systems for the Japanese blue collar workers. Reverse to the common perception of the HRM people in Japan as well as other countries, the pay system for regular blue collar workers in Japanese industry is not for pay-for-job but for pay-for-job grade, basically similar for that of the white collar workers in both the West and Japan: yearly increments in base pay subject to merit rating are applied even for the regular blue collar workers. And this job grade system can well assess the workers skill level, in terms of the breadth of work experience, such as whether a worker can command most positions in the workshop at the level of conducting unusual operations. The pay system, thus, promotes blue collar workers skill development.

Second, development of information technology supports these activities of the pilot team. To have a voice in the conceptual stage of a new product design requires the know-how to understand the design chart. Till recent years, design charts have been only of a ground plan type, which necessitates a certain level of training for their understanding. Resultantly, this voice by production workers has been confined only to die-making workshops, where selected production workers are collected. This has been the finding of our field research in the middle 1990s (Koike, Chuma, and Ohta, 2001). Yet, new field research reveals this voice is now common even in ordinary workshops as those of the final assembly line, body welding, and others in general. This is clearly due to the development in IT: a virtual chart of three dimensions has made it feasible even for ordinary production workers to be able to understand the design chart and to describe their proposals cubicly. These workers skills would be extremely advantageous than those industries or countries where these are not available, since no design engineers have not such precious work experience of assembly operations.

4.2 Participation in Designing New Production Line

Now we proceed to the next stage, in which pilot teams participate in designing a new production line. Here it is necessary to mention other members who cooperate with the pilot team. Two groups of engineers are to be noted; production engineers who are chiefly in charge of designing a new production line, locating in the headquarters of the firm, and manufacturing engineers who are in charge of tackling serious problems on mass production lines, locating at each factory. Although the production engineers play the central role in designing the production line, other two, manufacturing engineers and the pilot team, cooperate effectively. Let me describe this cooperation mostly from the view point of the pilot team.

Designing a production line is composed of the following five phases; A. designing a general concept of the line, such as whether to employ a U-shape line or a mass productive line, B. selecting equipments including major jigs and tools, C. how to deploy these equipments in order to attain best efficiency, D. how to divide the whole operations into individual jobs, and E. to teach production workers in the workshop how to conduct the new flow of operations.

Phase A is naturally dominated by production engineers, though other two groups have their own voice. Even in Phase B production engineers still occupy the main role, though the voice of the other two groups become larger, since it is rather production workers who know better the actual performance of current machines and equipments because it is them who operate the equipments every day. And knowing current equipments is one of the most crucial sources in selecting new equipments.

Phase C is the place where the pilot team plays an important role. At a glance, this role seems to be dominated by the production engineers or manufacturing engineers. Take for example the issue of how machines are to be deployed, however. Theoretical principles to be adopted are simple and clear: the shortest walking distance of an operator in charge of a series of machines, and the security of safety in operations. Suppose a case in which an operator handles several welding machines. Subject to the first principle, it is an imperative to deploy machines as near as possible. Yet, if machines are deployed too near, then there is possibility of work accident that should be prevented by the second principle. And this possibility heavily depends on the particular gesture of a particular operation that is the favorite of veteran production workers, not of engineers.

Phases D and E are the places where the pilot team plays the major role. Those who know the actual operations best are undoubtedly the production workers, whose elite are the pilot team. Thus, they are most appropriate in designing each job on the new production line, though the whole number of manpower for that line is decided by the rule set by the headquarters. Needless to say, it is the pilot team members who teach the new operations to the fellow members in production workshops.

All these activities stated above suggest the content and character of the highest grade of workers skills that I have named intellectual skills.

5. Applicability

Not Specific to Japanese Industry

The workings of intellectual skills are not confined to an exceptional case like Toyota, but are commonly diffused as a most vital source of the competitiveness in Japanese industries. It is evidenced, though indirectly, by a comparative investigation of the rate of return from the overseas business activities, utilizing IMF Statistics that has been modified in classification since 1996 (Koike, 2008).

Applicability is not confined to Japanese industry only but to other countries. Rather, even the highest grade of workings of these systems can commonly be identified in the US, the UK, and Thailand, so far as Koike [2008] has revealed. The works of the pilot team are generally ascertained in Toyota factories in these countries. They have voice in the conceptual design of a new car model, and participate in the design of a new production line, though the grade might be less than Japanese one.

Yet, there is a small difference by country in the working of pilot teams, or of intellectual skills, however: the grade of voice and of participation might, apart from Japanese cases, be slightly higher in Thai, NUMMI in the next, followed by the UK. There are several reasons why the grade differs though minutely. One is difference in the composition of the pilot team by country. For NUMMI in the US, strict seniority on the shop floor constrains to some extent the selection of members for the pilot team: best workers of production workshops are not necessarily chosen for the pilot team. Since pilot teams are the union members, selection process is not free from seniority. First it is subject to the volunteers for the pilot team, and among those volunteers, seniority shall govern. Moreover, those who have broad experience to cover most jobs in the workshop and even ones in the next workshop are rarely available because of seniority on the shop floor. This difference in the composition of the pilot team naturally produces the variance in the performance of pilot teams. Yet, we cannot overestimate this fact in explaining the variance in the working of pilot teams by country, since the UK Toyota has no seniority now.

A Long Period Required for Gain

By far more importantly, the difference in the period of overseas activities is to be noted, since this exactly reflects the variance in the grade of working of intellectual skills: Thai is the earliest, originated in the early 1960s, while NUMMI in 1980s and the UK Toyota in 1990s. This suggests that a long period is needed until the date when Japanese overseas activities have been turned out gainful. Why does it need a long period for gain?

In my understanding, the gainful working of intellectual skills depends largely on encouraging a large number of the middle level workers in any area of the globe. This requires a longer period to establish effective incentives to mobilize the vital people in the system, in comparison with alternatives such as mobilizing a small group of the excellent elite. For building up effective incentives, it would be common for both ways to show the precedent cases for followers to illustrate what performance and career guarantee for attaining promising positions in the organization. Yet, the time required for making promising precedents differs extremely between the two ways. For mobilizing a small number of the elite, it takes only one or two years to identify the candidates of high potentials and to show them the excellent precedents: once selected, quick promotions follow within a short period. To the contrary, it takes at least nearly ten years to identify promising members among the middle group, such as capable pilot team members: as pointed earlier, to identify the capable production workers for a pilot team, we need to let them experience most positions in the workshop that requires nearly ten years.

In addition, persuasion opportunities are naturally by far less for the intellectual skills way than the elite one. For either way, written documents or formal rules are not sufficient for the candidates to be convinced of their promising future careers. Instead, informal persuasions are indispensable. Yet, for persuading a small group, informal opportunities can amply be available, such as home parties, while informal measures are almost unfeasible for a large number of the middle group. Consequently, it would be almost unavoidable to take a long period for the intellectual skill way, or Japanese way, to make and mobilize a large number of the capable middle group.

Importance of Indirect Measurement

A final point of difficulty remains for the field research, that is, the one in measuring efficiency. Reminding of even the simplest case to identify the product defects again, no accurate measurement is available as explained earlier, though there is no doubt in surmising that this type of workers skills remarkably elevate productivity.

A proposal is to make good use of an ordinary measurement, usually employed in quantitative analysis. Two implications could be emphasized. One is that, though they are indirect to prove the each step of reasoning itself, this strengthens an ordinary measurement in the sense that this is backed up with more persuasive reasoning disclosed by in-depth field research, and that it makes possible for other firms to utilize the way of intellectual skills. The other is that the new theory suggested by field research can be supported with some evidence.

Appendix: The Major Components of Intellectual Skills

To list up

According to a series of field research, we can list up the major workings of intellectual skills as follows:

A. Dealing with problems, consisting of:
- A1. Dealing with problems in quality of product, subdivided into:
  - A11. Identifying the defects in product quality
  - A12. Identifying the cause of defects
  - A13. Rectifying the defects
- A2. Dealing with trouble in equipment
  - A21. Identifying trouble in equipment
  - A22. Identifying the cause of trouble in equipment
  - A23. Rectifying trouble in equipment.

B. Dealing with changes, subdivided as follows:
- B1. Dealing with changes in labor mix
- B2. Dealing with changes in product mix
- B3. Dealing with changes in output
- B4. Dealing with changes in production methods
  - B41. Dealing with designing a new production line
  - B42. Dealing with designing a new model of product

Since A11 and B4 have been explained in the main text, other types need to be explained though shortly.

A: Dealing with problems

Identifying the causes of defects in product quality (A12) is more crucial to productivity than identifying the defects in product quality (A11). Without this know-how, defects can repeatedly occur. If the causes of defects are not identified and accordingly not rectified, machinery continues to produce defective parts; and if operators stop machinery for fear of producing defective parts, production is naturally halted. In contrast, when the operator can identify the causes of defects and rectify them (A13), the difference in productivity can be remarkable.

This know-how (A12) requires a higher level of knowledge than the case of simply recognizing that there is a defect (A11). In order to identify the cause of defects, it is necessary to know the machinery structure and the production mechanism, because any trouble in the machinery or in the flow of production may cause defects in product quality. And this knowledge becomes the more demanding as machinery structure and flow of production becomes more ever complicated with the use of information technology and robots.

An example from another assembly-line workshop fully equipped with many robots of small size may serve to illustrate the point when robotization develops. This is a workshop in one of the largest part suppliers in the Toyota group. Sixteen workers under one foreman are engaged over two shifts in assembling small electric motors with almost two dozen small robots as well as automatic machinery. Automatic machinery and robots carry out most of the assembly work, and the only remaining operations for the workers are dealing with problems. Dealing with changes in products is not demanding here, since robots automatically handle changes in products; censoring the bar codes on products instructs certain products to pass through a specific robot, and the others to be assembled by the robots. When a machine or robot finds something wrong, the machinery stops and a sign lights up to call for an operator (Koike, Chuma, and Ohta, 2001, pp.43-59.).

Here, the ability to deal with equipment such as robots is vital in handling defective products, or, in other words, dealing with defects in products (A1) becomes inseparable from dealing with trouble in equipment (A2). Since assembling itself is almost done by machines and robots, most defects are due to some kind of equipment trouble. Take, for example, a problem in this workshop where products do not flow smoothly at a certain spot. Immediately after the worker in charge of that job has become aware of the slower flow, he or she tries to identify the cause. It is the practice of this workshop that the worker on the assembly line first tries to identify the cause rather than the maintenance people. And either defects in product or trouble in equipment can be the cause (A12 or A22). To take the above example, the slower product flow may be due to defects in products such as a smallest part being not correctly attached, which prevents products passing the censor, or it may be caused by problem in the censor itself or something else.

It is also the practice of this workshop that an operator tries, if feasible, to rectify it before maintenance people have arrived (A13 or B23). As it takes around 15 minutes for the maintenance people to come, the ability of workers to handle problems greatly contributes to efficiency.

B. Dealing with change

The easiest component of intellectual skills is the ability to deal with changes in labor mix (B1). Two cases are illustrative. One is a need to substitute for absent workers in the workshop. On a continuous assembly line, even one vacant position stops the whole line. Consequently, it is imperative to have workers who can substitute for many positions in the workshop. This necessity is of course common in any assembly line in any country. In the USA, these substitutes, called ‘relief men’ or ‘utility men’, are paid at a slightly higher rate than others in the workshop.

The other case is the need to teach less experienced workers in the workshop. It is common that a workshop has newcomers to replace those who have quit or retired. New workers need instruction to become accustomed to even the easiest jobs in the workshop and, thus, veteran workers who can instruct them are required. This capability to teach newcomers is an element of intellectual skills.

Another easiest element of intellectual skills is to deal with changes in product mix (B2). Changing consumer demand both for quantity and kinds may require one assembly line to accommodate various kinds of products. While small changes in the kinds of product need few jigs and tool changes, other changes require workers to change jigs and tools, which sometimes necessitate far higher skills than usual operations. When skilled workers change jigs and tools, not only must they undertake the exchange quickly, but also accurately, to obviate defects. This feature constitutes another component of intellectual skills.

Dealing with changes in output

More demanding component of the intellectual skills is the ability to deal with changes in output (B3). Demand for products sometimes changes significantly. If production does not sufficiently adjust to the quantitative change in demand, the firm’s profits will surely be damaged. Yet efficient adjustment on the shop floor is difficult unless the workers have acquired the two components of high skills required for making adjustments: namely, many of them being capable of doing most operations in the workshop, and some being so skilful that a redistribution of the operation into each job in the workshop is feasible.

The redistribution process is a famous part of the Toyota systems that has now been diffused widely into other industries. When demand decreases by 20%, for example, Toyota decreases the speed of production by 20% from, say, 60 seconds to 72 seconds for making one unit of car. (If the extent of change is smaller, an adjustment in working hours would be enough to accommodate the change.) A simple slow down in the speed of the manufacturing line results in an increase in costs. To prevent this cost increase Toyota naturally tries to reduce the number of workers in a workshop by 20%, say from 15 persons to 12. Yet no decrease in the kinds of operations should be made; if this were the case, cars without a left side door, for example, could appear. Suppose there have been 60 operations in the workshop carried out by 15 workers before and these operations now have to be done by 12 workers. This cannot be implemented unless many workers who can conduct many different operations in the workshop. Redistribution would not be feasible simply by adding 20% more operations to each individual worker, because each operation differs in length of time required when difficulties arise. Thus, the content of intellectual skills is, in this case, a capability of doing many difficult operations in the workshop at the level of not damaging the quality as well as the seed of production.

The more demanding element of know-how to deal with this change is the one required to conduct a redistribution of the operations, which needs two components of knowledge. One is to know well the features of all the operations in the workshop: how difficult or easy they are, and what the order should be in assembling. Another is to know the skill levels of individual members in the workshop who can currently conduct these operations. The best people with this knowledge are undoubtedly the veteran members of the workshop, since without having worked together there would be no opportunity afforded to know individual skill levels. This observation is a highly typical example of Hayek's 'specific knowledge.' If, instead, an engineer were to conduct the redistribution, the result would definitely be worse, since the engineer lacks sufficient knowledge due to not having worked with the workshop members on daily basis.

Notes:

1) The concept of intellectual skills is not originated in the field survey of car workshops, rather of other various industries. Yet, it would be more convenient to take examples from car industry for better understanding of readers.

The origin of this concept is my comparative field work between the US and Japanese manufacturing workshops during the 1970', whose results were published as Koike [1977] in Japanese and as Koike [1988] in English. Yet, the development of my concept was only partially, that is, simply in terms of breadth of work experience not in terms of depth. This latter part is well developed in my comparative field work between endogenous Thai and Malaysian workshops and endogenous Japanese ones conducted with collaboration of Profs. Inoki and Fujimura in the middle of the 1980', the results of which were published as Koike & Inoki [1987] in Japanese and Koike & Inoki [1990] in English.

Yet, the concept of the highest grade for intellectual skills, workers voice in the design of a new product has been disclosed in my field work that compares four Toyota Works, Thailand, the US , the UK, and Japan, published as Koike [2008] only in Japanese.

2) Toyota allows formally a part of production workers to deal with problems, provided they have acquired a company certificate of problem-handling. To obtain this certificate, it is necessary for a candidate to succeed in the test to rectifying the trouble artificially caused in machines in the workshop conducted after working hours, along with participating in a two days class room lecture. Yet, certification holders are practically confined to a small minority, and it would be unfeasible for a worker to have experienced of tackling trouble in practice before acquiring the certificate. This naturally results in a larger part of those workers who can deal with problems in practice.

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