CHAPTER 2.9

CASE STUDY: REDUCING LABOR COSTS USING INDUSTRIAL ENGINEERING TECHNIQUES

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To achieve productivity improvements in manufacturing companies, application of new technology or adoption of mass production may not always be possible. The most practical approach is to attack the work process itself—that is, review and redesign the operations and apply automation and mechanization. In such cases, a productivity audit employing industrial engineering (IE) techniques is used for evaluating the existing manufacturing situation and identifying the potential for increased productivity. Additional industrial engineering methods are applied to develop improvement opportunities.

In this chapter, we introduce various industrial engineering techniques and use a case study to show how these techniques are applied in practice. The case study presented is from Company A, a bathtub manufacturer. The improvement process began with an audit of the current productivity situation. Then, following a master plan, productivity improvement actions were taken one by one. The result was a 20 percent reduction in cost after a two-year project. Because it is not possible to cover all aspects of the project in this chapter, the focus will be on the activities aimed at the reduction of labor cost. We also explain how the scope of the application of industrial engineering techniques is expanding.

INTRODUCTION

Productivity improvement measures can be roughly classified into four groups: (1) redesign of operations, (2) automation and mechanization, (3) use of mass production, and (4) application of new technology—each of which can be effective in specific situations. However, in practice, the opportunities to apply appropriate new technology may be few. In addition, with increased diversification of customer demands resulting in more product models, fewer products can be made in volumes large enough to justify mass production. Consequently, when it comes to productivity improvements in manufacturing companies, the approach that is usually the most effective is to focus on the work process itself. Improvements are then made through redesign of the operations and application of automation and/or mechanization.

The techniques for accurately evaluating the actual situation of a manufacturing process, identifying the potential for increased productivity, and identifying the approaches for making improvements fall within the scope of industrial engineering. Through continuous development and refinement, IE technology for many years has been applied to solve a variety of problems, and the technology is still effective. However, in today's world, not only because manufacturing processes have become more complicated but also due to more varied product mixes and greater diversification of customer requirements, the actual IE techniques must be adapted to each situation as they are applied.

Industrial engineering techniques can be used for two main purposes: (1) to discover problem areas in the manufacturing process being studied, and (2) to solve those problems in a practical and concrete way. In this chapter, the use of IE techniques in the audit stage of a productivity improvement project will be introduced as well as an actual case study of the application of IE techniques to achieve productivity improvements. Other chapters of this handbook describe specific IE techniques.

BACKGROUND OF THE CASE STUDY

The situation at Company A, a bathtub manufacturer, prior to starting the productivity improvement effort was as follows.

First, the bathtub business had experienced major progress in the area of product materials. Recently, customers had begun to demand much more advanced products than before—for example, products made of artificial marble. In pace with this trend toward more sophisticated products, the market was strong and Company A was forecasting a 30 to 50 percent growth in production volume over the following three years. On the other hand, price competition was becoming severe, and for the two years prior to launching the improvement activities, the bathtub business of Company A had been in the red.

The cost structure of the product was 60 percent materials, 20 percent processing cost (cost of in-house labor and subcontracted processing), and 20 percent other costs. There was a strong possibility of further increases in both material and processing costs. Moreover, accompanying the trend toward more sophisticated products, at the factory level, was a substantial variation both in the first-pass yield (number of nondefective products not needing rework ÷ the number of units processed) and the final yield. In addition, while the forecast for larger future production volumes (in response to greater demand) was welcomed, there was a concern over increasing labor cost. Other potential problems included finding and keeping a sufficient number of qualified employees. If the traditional staffing standards were kept, many additional employees would be needed, and a drop in the average skill level was likely to occur.

With this situation as a background, Company A organized a project team that included outside consultants. The mission of the team was to initiate activities aimed at productivity improvement and increased profitability.

Productivity improvement projects, in this case, are generally conducted in three phases as shown in Fig. 2.9.1. Phase I, productivity audit, and phase II, short-term problem solving, will be discussed in the subsequent sections. A general introduction to the methods used and a case study of labor cost reduction through the application of IE techniques will also be covered.

PRODUCTIVITY AUDIT AND DEVELOPMENT OF A PRODUCTIVITY IMPROVEMENT MASTER PLAN (PHASE I)

The main factors contributing to the success of any productivity improvement project are (1) to correctly understand the present situation in regard to productivity, (2) to clearly identify the problems, and (3) to apply appropriate IE techniques to achieve and maintain improve-

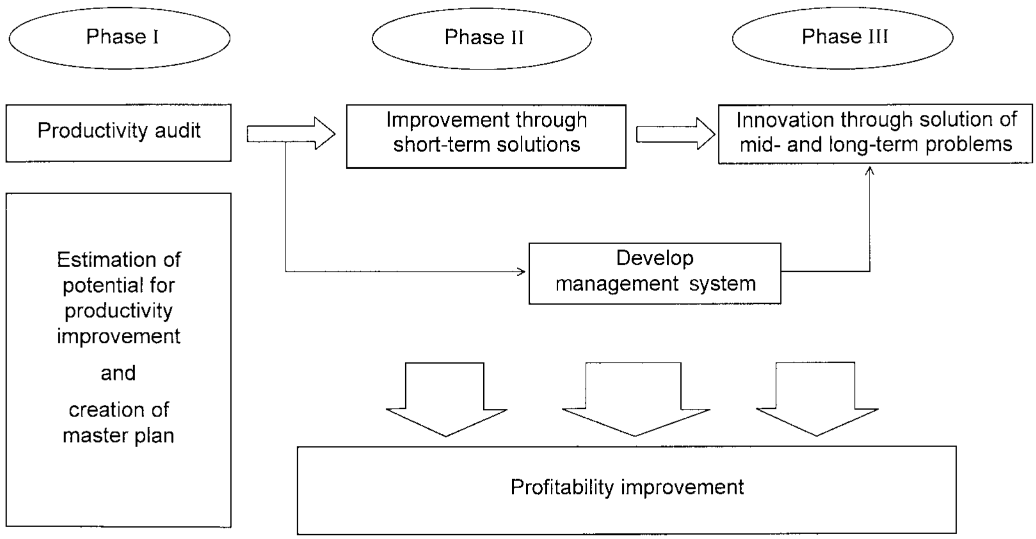


FIGURE 2.9.1 Flow of productivity improvement activity.

ments. Of course, to tie the productivity improvement results to an actual improvement in business performance, during the audit phase it is necessary to clarify the fundamental objectives of the improvement in productivity.

Industrial engineering techniques are useful for making improvements in individual situations, but they are also valuable in the audit phase for correctly evaluating the existing situation and for quantifying the potential for improvement. To evaluate the existing situation quantitatively and objectively, IE techniques are indispensable. Management problems require unified companywide (and in some sense even subjective) judgments. However, such judgments must start from a correct understanding of the facts. The reason why IE techniques are used in productivity audits is that they are indispensable for providing a common understanding of the facts to all parties involved. The case study described in this chapter followed such logic; in Phase I a productivity audit was conducted and the productivity improvement program was drawn up. Then the improvement plan was implemented.

The Purpose of a Productivity Audit

Productivity audits are conducted so that productivity improvement activities may be undertaken and monitored based on statistical data. Accurate data derived from an audit also makes the following actions possible:

- Determine the target for productivity improvement.
- Select techniques for the introduction and control of the productivity improvement actions.
- Quantitatively forecast the potential for productivity improvement if the chosen techniques are applied.
- Draft the general plan for the productivity improvement project.
- Promote common "ownership" of the project (throughout the entire organization) based on a clear understanding of current problems, as disclosed in the audit report.

The audit is conducted in three parts: considering manufacturing methods (methods), work performance (performance), and application of resources (utilization). These three aspects of any business unit (abbreviated as MPU) are the three sources of productivity "losses," meaning levels of productivity that are lower that what could potentially be achieved. Specifically, we refer to

- *Methods losses:* excess labor hours or machine time required due to inefficient methods
- *Performance losses:* losses in potential productivity due to low performance of operators and/or equipment
- *Utilization losses:* losses derived from underutilization of labor and/or equipment

We will focus on the three areas of MPU, not only to identify losses, but also to seek improvements. The IE techniques applied in auditing (and later improving) each of these factors will be slightly different. In particular, regarding utilization, it is important to complete the audit, not only from the viewpoint of a simple calculation of a utilization ratio, but also considering opportunity losses (i.e., the creation of opportunity profit). For that reason, such things as the effectiveness of the quality assurance and maintenance systems must also be objects of the audit. Of course, the audit will also address all management levels involved in planning and control, including the production planning and control systems.

Audit Procedure

The procedure for an audit consists of five steps:

Step 1. Selection of the target area to be audited

Step 2. Identification of the MPU losses occurring in the current situation

Step 3. Study of the potential for making improvements and estimation of the increase in productivity that can be obtained

Step 4. Determination of the issues to be addressed by the productivity improvement project team

Step 5. Preparation of a master plan for productivity improvement

The purpose and general content of each step are as follows.

Step 1. Selection of the Target Area to Be Audited. Even in the case of surveying an entire factory, the characteristics of each manufacturing process are different, and the methods of auditing each process will therefore be different. Similarly, the procedures for achieving productivity improvement may be different in each area. For example, there are processes for which the simple productivity improvement yardsticks of *direct decrease in input* or *direct increase in output* are not appropriate. Likewise, there are workplaces that do not work at full capacity the entire time. Nevertheless, the results of the audit must be translated into a forecast of the potential for increasing productivity to enable the selection of control techniques to be applied.

How to connect the productivity improvement to overall business results must also be explained in the audit. Because of these complexities, to make the audit more manageable, the factory should be divided into several groups of processes, each called a *module.* By focusing on individual modules, it becomes easier to select the best audit technique for each and to estimate the potential for productivity improvement in each module. In the case of Company A, it was decided to divide the bathtub factory into 15 modules—for example:

Module A: mold coating

Module B: laminating

Module C: mold setting

Module D: actual molding

Module E: base assembly

Included among the modules were indirect areas, such as *repair of mold* or *warehousing of parts.*

Step 2. Identification of the MPU Losses Occurring Under the Current Situation. The existing situation is outlined quantitatively and objectively in this step. To be specific, an evaluation is made of how efficiently all applied resources (input), including personnel, equipment and machinery, and raw materials, are converted into output—finished products. As described in the previous section, productivity is divided into three factors—method, performance, and utilization (including planning and control)—based on the different IE techniques that are applied. For each factor, IE techniques such as work sampling and time studies are used to evaluate quantitatively and objectively the effectiveness of the applied resources in the existing situation and to determine where and to what degree MPU losses are occurring. The system for such audits is shown in Fig. 2.9.2, of which some additional explanation may be useful.

The Method Factor. The objective is to search for opportunities to raise the levels of the work standards. These standards may include the operating procedures, equipment, and machine setup conditions that have been accepted, as well as material-related standards based on the current design of the products. Accordingly, it is important not only to confirm

		Operator	Machine	Material
Method factor	Actions	•Confirm percentages for basic functions •Estimate the operator reduction factor	•Determine actual machine time •Estimate the potential for reduction of machine time	•Determine losses caused by product design •Estimate the potential (%) for improvement of yield
	Techniques	•Work sampling •Direct time study •Pitch diagrams •Human-machine charts •4W (what, who, why, where) charts	•Pitch diagrams •Sequence charts	•Design review •Value-added analysis
Perfor-mance factor	Actions	•Confirm present performance level •Estimate performance improvement potential (%)	•Confirm the facility performance •Estimate the potential (%) for improvement of performance	•Confirm the quality of materials and parts •Estimate potential for increasing first-pass yield
	Techniques	•MOST analysis •Direct time study •Output analysis	•Work sampling •Material analysis	•Yield analysis •Analysis of failure causes •Analysis of materials
Utilization factor	Actions	•Confirm utilization loss •Estimate the potential (%) for improvement of the utilization factor	•Confirm utilization loss •Estimate the potential (%) for improving utilization	•Confirm utilization loss •Estimate the potential (%) for improving utilization
	Techniques	•Analysis of setup procedures •Investigate the impact of staffing changes •Work sampling	•Downtime analysis •Work sampling •Analyze space utilization	•Scrap rate analysis •Inventory analysis •Investigate alternative materials

FIGURE 2.9.2 System for surveying the potential for improvement.

the losses resulting from the current situation, but also to endeavor to continue the audit activity far enough to estimate the amount of improvement potentially possible.

For example, in the case of evaluating a current situation with regard to labor productivity (see the Operator column in Fig. 2.9.2), the existing situation is clarified through the application of various techniques. The ratio of basic functions (work that directly contributes added value) is analyzed through work sampling, while time studies are performed to determine the extent of balance losses and interference losses. The results are presented in pitch diagrams or on human-machine charts.

The Performance Factor. The audit evaluates the extent to which established standards are adhered to. Not only the current performance level, but also the variation in performance (e.g., by the time of the day, between operators) is investigated, and the potential for improvement is estimated. Because a proper standard is normally available in examining labor productivity from the performance aspect, estimation of the potential for improvement can be done relatively easily by comparing actual operating time to the standard time (for example, analyzed by MOST®).

The Utilization (Planning and Control) Factor. Through direct observation, current nonconformities in regard to planning and control are investigated. Here it becomes necessary to carry the investigation further to estimate how much the profitability could be increased and productivity improved through a more effective management of the operation. The important thing, while working to understand the current situation, is to consider to what extent production time (utilization) could be increased through improved planning and control.

In production environments where labor productivity is the problem, it is important to clarify losses of all types (within the broad categories of M, P, and U) occurring under the current conditions. To do that, the appropriate methods must be applied: for example, work sampling to reveal the causes of line stoppages, or study of documentation and records to specify the impact of planning changes, trends in changeover and setup times, and so forth.

In the case study presented here as a concrete example, labor productivity was the main problem, but the audit procedure is not limited to such cases. Whatever the situation is, the primary methods used are those presented in Fig. 2.9.2.

Step 3. Study of the Potential for Making Improvements. Based on the findings in Step 2, the possibility for improvement is explored and the potential for productivity improvement is estimated. From a method aspect, the potential to reduce the applied labor or applied labor-hours is considered, while from the performance aspect, the potential for increasing earned value (output) is estimated. For planning and control, the possibility of increasing productive time is evaluated. Step 3 is almost an extension of Step 2, and the techniques illustrated in Fig. 2.9.2 will be applied in Step 3 as well.

Steps 4 and 5. Determination of the Issues to Be Addressed, and Preparation of a Master Plan for Productivity Improvement. Productivity improvement cannot be accomplished through use of just one IE technique. Therefore, in Step 4 the techniques that are to be emphasized in addressing each targeted problem are listed and tied into the master plan in Step 5. In Step 5, a program is planned for effectively solving the targeted problems and the system/organization for promoting the program is set up.

Case Study: Company A's Actual Situation and the Direction for Improvement Activities

Let us first consider how to proceed by mapping the present situation of a production area and how to determine from that the direction for the improvement activities. By examining the productivity improvement activities of Company A, it will be possible to see precisely what is involved in Step 2 of the audit procedure.

The Method Factor and Direction for Improvement. Figure 2.9.3 shows the results of the utilization analysis through work sampling. The average results for the 15 modules that were the subjects of the audit were 79 percent of the time in operation and 21 percent not in operation. Furthermore, the breakdown of the 79 percent was 32 percent basic functions (operations directly related to adding value) and 47 percent auxiliary functions (operations such as transportation or adjustment of test systems). Therefore, it was clearly revealed that under the present operating procedures, although operators were moving around a lot, little of the work was directly related to generating output, thus making the value of the labor low. Furthermore, to better understand the actual work methods being used, they were analyzed in detail using pitch diagrams (Fig. 2.9.4) and human-machine charts (Fig. 2.9.5.) In this way, M (method) losses associated with the existing operating procedures were made clear.

The Performance Factor and Estimation of the Potential for Enhancing Productivity. The potential for performance improvement was estimated based on (1) variation in output at different times of the day, and (2) comparison of standard times to actual times. Figure 2.9.6 shows the distribution of the performance level (standard time / actual time × 100 percent). The average for all modules is 76 percent, which shows that from the performance aspect alone (simply by having work accomplished according to standard times), there is the potential to improve productivity by 25 percent or more.

The Utilization (Planning and Control) Factor and Estimation of Potential for Enhancing Productivity. Productivity improvement through the planning and control is achieved by minimizing utilization losses by more effective planning, management, and control. For example, in the present case, when the results of work sampling were further analyzed, it was found that at the beginning of each shift, a waiting time equivalent to 6.6 percent of the available labor-hours was occurring. Furthermore, considering output by the time of the day (on the basis of a monthly average), it was confirmed that output for the 8:30 to 10:30 time period was low compared with other two-hour periods (Fig. 2.9.7). This U (utilization) loss could be prevented through better daily scheduling and improved allocation of personnel at the start of each shift.

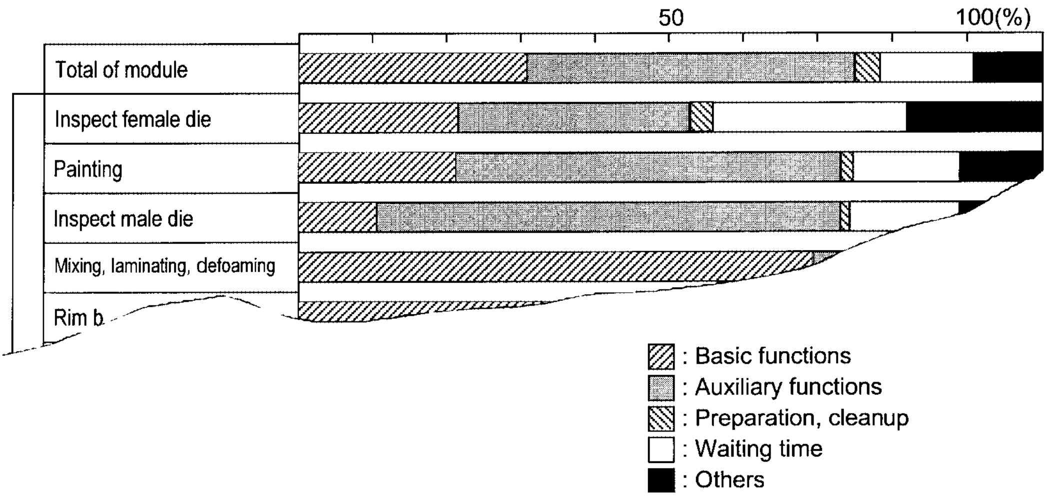
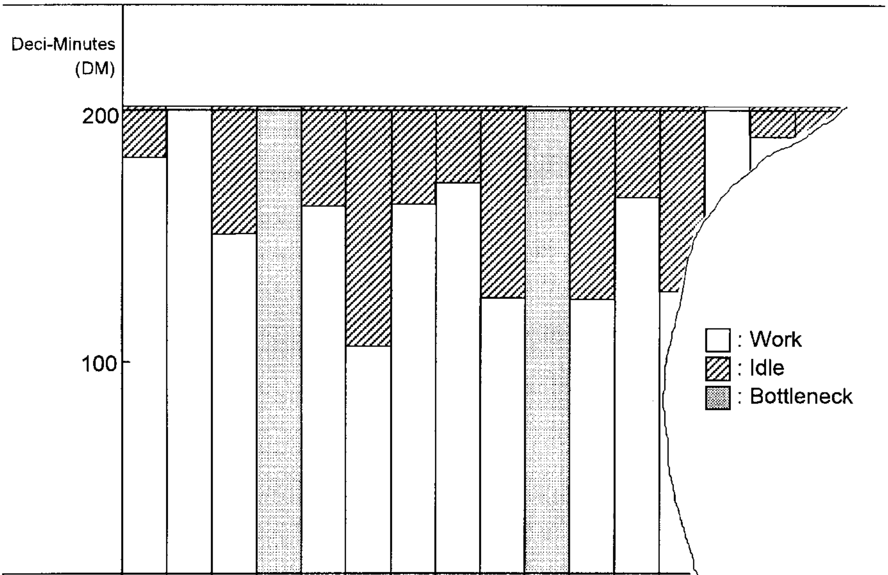


FIGURE 2.9.3 Utilization analysis through work sampling.

$$\text{Balance efficiency} = \frac{\text{Total work content}}{\text{Pitch time} \times \text{Number of operators}}$$

$$= \frac{11524.1}{200\,x\,94} = 61.3\%$$

Balance loss = 38.7%



Process step	Inspect mold	Painting	Inspect painting	Painting cure	Move die	Inspect die	Laminating	Holding rim	Laminate curing	Laminate curing	Paste sealing	Funnel set	Air perforating
Amount of work (labor DM)	700	1000	144	-	140	440	1717	168	125	-	126	136	101
Number of operators	4	5	(2) 1	-	1	5	11	1	1	-	1	1	1
Pitch time (DM)	175	200	144	200	140	88	156	168	125	200	126	136	

A pitch diagram recognizes the fact that a product can only pass through an assembly line at the rate determined by the bottleneck process. In this case, Painting, with a pitch time of 200 DM is one of three equal bottleneck processes. Thus, even if the person responsible for moving the die can do this in 140 DM, he or she must waste 60 DM waiting for the next product. The pitch diagram is used to identify all such waiting losses on a line and determine the total loss, which is called the *balance loss* and is expressed as a percent.

FIGURE 2.9.4 Pitch diagram.

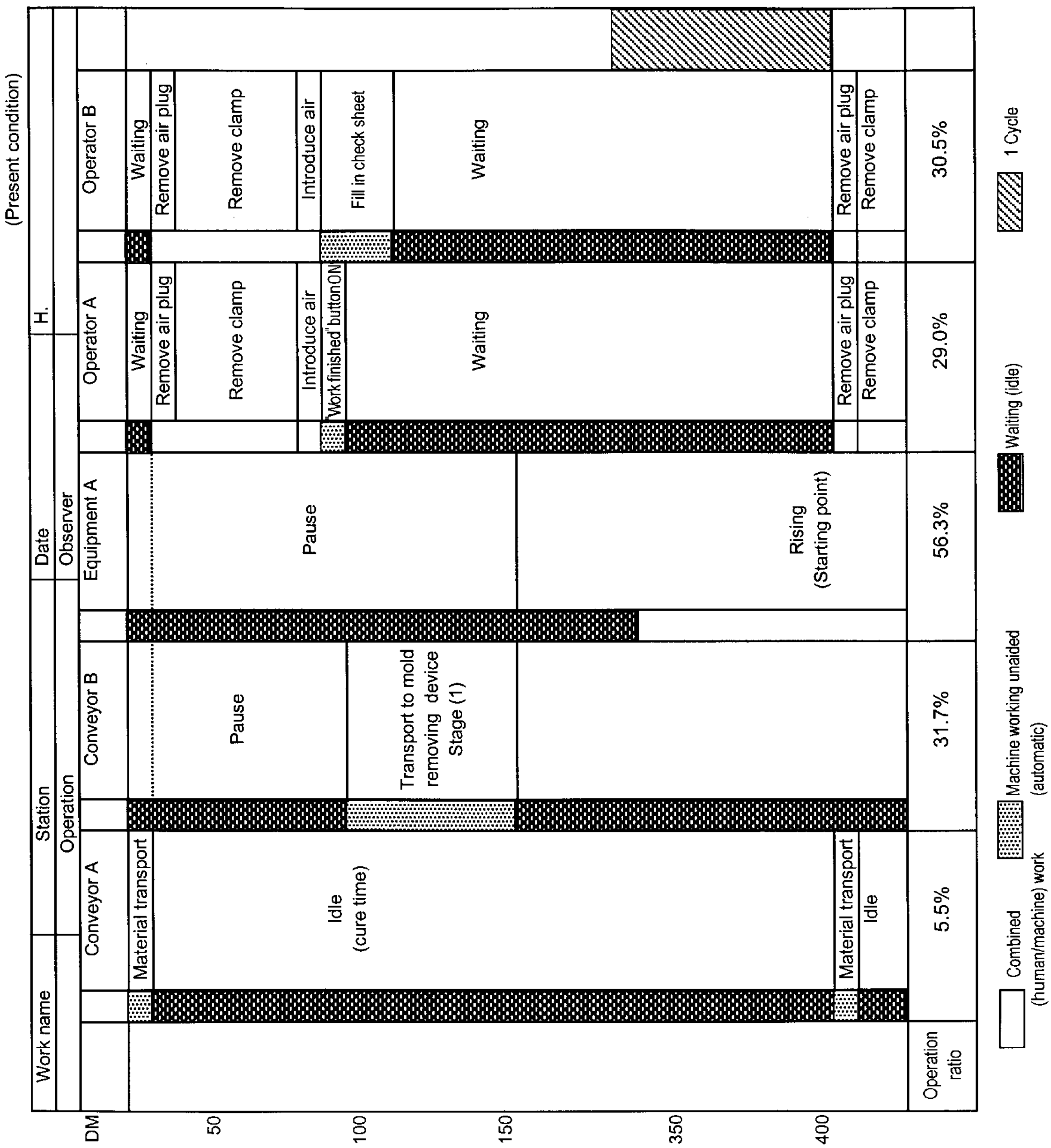


FIGURE 2.9.5 Human-machine chart.

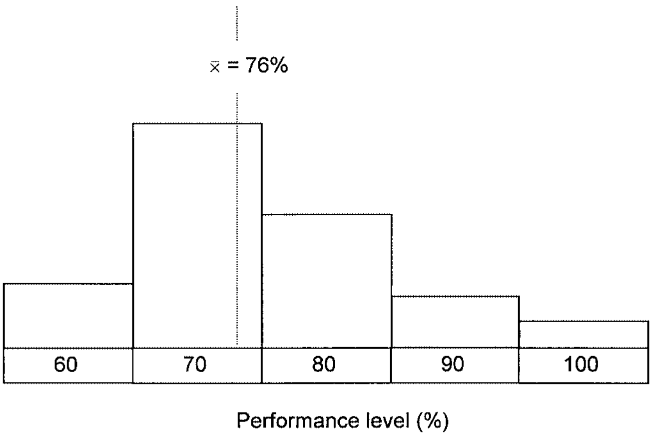
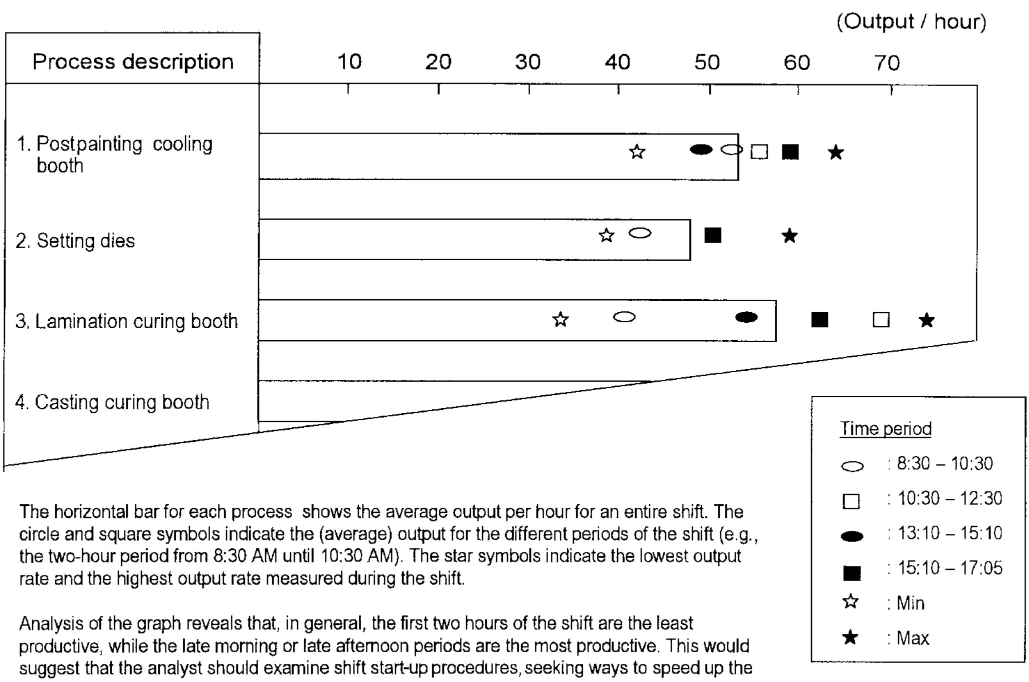


FIGURE 2.9.6 Performance level.



The horizontal bar for each process shows the average output per hour for an entire shift. The circle and square symbols indicate the (average) output for the different periods of the shift (e.g., the two-hour period from 8:30 AM until 10:30 AM). The star symbols indicate the lowest output rate and the highest output rate measured during the shift.

Analysis of the graph reveals that, in general, the first two hours of the shift are the least productive, while the late morning or late afternoon periods are the most productive. This would suggest that the analyst should examine shift start-up procedures, seeking ways to speed up the output.

FIGURE 2.9.7 Distribution of output by time period.

Case Study: Analysis of the Audit Results for Company A and the Creation of a Master Plan for Productivity Improvement

After the completion of the actual audit in Step 2, the audit results are organized and presented in a chart, and the project proceeds to Step 3: estimation of the potential for productivity improvement. For example, from the method aspect, the extent to which balance losses and interference losses can be reduced in each process is examined, and issues like what actions can be taken to raise the ratio of basic functions are studied. In making such estimates, a broad, global perspective for evaluation is necessary, which includes consideration of the possibility of actually achieving each possible improvement.

Figure 2.9.8 is the summary of the estimated potential for improvement for the case of Company A. Noting that the present case anticipates productivity improvements from all three MPU factors, methods, performance, and utilization, a total improvement potential of 63 percent was estimated according to Fig. 2.9.8.

Next, based on this estimate, one proceeds to Step 5: creation of the master plan for productivity improvement. Creation of the master plan includes preparation of a productivity improvement program and establishment of an organization for program management. In the case of Company A, productivity improvement proceeded in three steps. The purpose of Step 1 of phase II is reengineering of the production system, optimization of personnel allocation, improvement of daily work scheduling methods, layout improvement, optimization of inventory, enhancement of product yield, and so forth.

Step 2 is a bridge from Phase II to Phase III. In it, based on the content of the improvement actions planned in Step 1, a management system improvement program is woven in, addressing issues such as building a solid production planning and control system, improving the efficiency of indirect management groups, and creating a productivity control system. Finally in Step 3, which corresponds to Phase III, a more efficient integration of the sales and manufacturing functions is explored.

Figure 2.9.9 shows the system for conducting and managing the project. With projects of this kind, the functions that each employee is to perform must be made very clear, not only for the staff, but also for the managers and frontline supervisors.

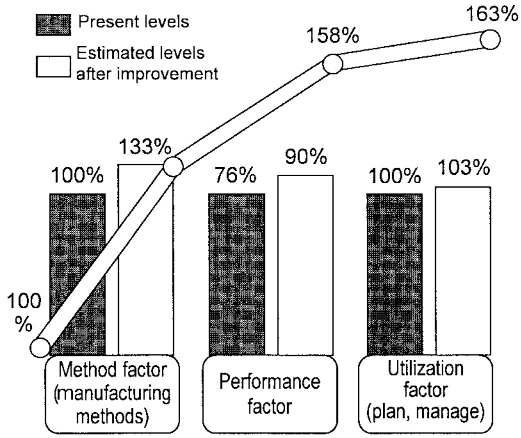


FIGURE 2.9.8 Estimation of total productivity improvement.

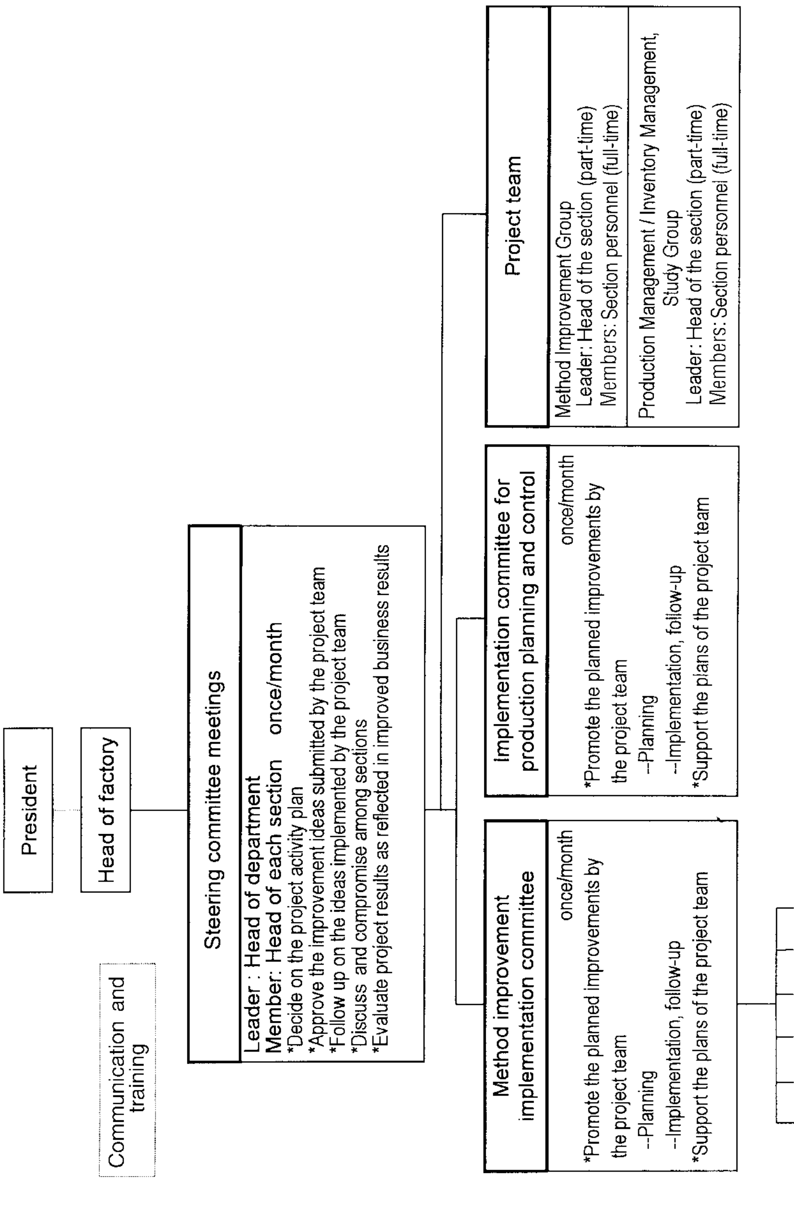


FIGURE 2.9.9 Project organization.

AN ACTUAL EXAMPLE OF IMPROVEMENT ACTIVITY (PHASE II)

The purpose of Phase II of the productivity improvement activities at Company A was reengineering of the production system. It consisted of three labor productivity improvement projects that were conducted in parallel: (1) optimization of personnel allocation, (2) creation of a solid planning and support system through improved scheduling (implementation of short interval scheduling), and (3) improvement of work-in-process inventory between process steps (calculation of stock points and optimum inventory levels).

Each of these projects is deeply related to the others. In this section we will focus on how Company A implemented optimization of personnel allocation. This activity consisted of allocating personnel in response to a given workload and was applied in this case to achieve improvements from the method factor as part of a design approach. The major steps are shown in Fig. 2.9.10.

As a result of conducting various method improvements, an assembly line whose structure prior to improvement required 30 operators, could be run with 15 persons. The major improvements accomplished were

- Reduction in the labor required for material handling through introduction of automated material transfer methods and a shortening of the line
- Improvement in efficiency through better organization—specifically, re-layout of each workstation and reallocation of work
- Improvement of jigs, fixtures, and tools and changes to work methods

In parallel with these method improvements, scheduling improvements and reduction in work-in-process inventory were also accomplished. Overall, work that required 171 people prior to the improvements could now be accomplished with 133 people (personnel reduction effect: 28

Procedure		Main action items
Standardize the current method	Determine product to be studied	*To perform method improvement efficiently. The number of products selected for the study should not be excessive, yet a broad range of processes should be covered.
	Establish target cycle time	*Establish the rate of production to maintain the current and monthly output.
	Establish standard model	*Perform analysis of current operations using MOST® and establish the standard time for each operation.
Create improvement plan using the design approach and submit	Basic design	*Extract improvement ideas and create/review alternative plans for product flow.
	Detailed design	*Thoroughly evaluate alternative plans and perform a detailed study of each process step and operation.
	Finalize the plan	*Explain improved layout, allocation of operators, and operation assignments. *Verify by using factory automation simulation.

FIGURE 2.9.10 Procedure for method improvement.

percent). In addition, cycle time reduction was also accomplished (cycle time reduction effect: 7 percent). Thus, over a one-year project, a total productivity improvement of 38 percent was accomplished for this one assembly line, focusing on the method factor alone.

The procedures for achieving method improvements have been shown in Fig. 2.9.10. Whether applied to the standardization of existing methods, development of an improvement plan, or a concrete plan implementation, all the methods used are basic IE techniques. For example, in the standardization of existing methods, the first step is a clarification of the procedure for each operation, followed by the standardization of those procedures and the standardization of time values using techniques such as MOST. Also, to generate improvement ideas, it is important to make effective use of IE techniques such as line balancing and determination of interference between operators and equipment through application of human-machine and machine-machine charts. While there is insufficient space in this chapter to describe each IE method or technique, we trust that the value of IE techniques when used in productivity audits and applied to productivity improvement activities has been made clear.

SUMMARY

In the current business environment, there is a never-ending escalation of customer needs; customers continue to demand improvements in cost, delivery, and quality. Consequently, in manufacturing situations, a continuous review of how work is done and how it can be improved is a subject of high priority. Use of new technology and application of automation and mechanization are indispensable for productivity improvement. However, correctly evaluating the existing production situation and proceeding to improve it through better methods and management are also important. To accomplish such activities, the effective application of IE techniques can play a key role, both in productivity audits and in making significant productivity improvements.

BIOGRAPHY

Shoichi Saito is a member of the board of directors of Japan Management Association (JMA) Consultants in Tokyo. He was born in Nagano Prefecture and received his bachelor's degree from Tokyo Rika (science) University in 1971. He joined JMA Consultants (JMAC) that year and became a senior consultant in 1989. His consulting work covers all aspects of productivity improvement, particularly management-related issues. He is an authority on methods engineering, work measurement, and other industrial engineering techniques and has worked on the development of several productivity-related tools that are now offered by JMAC. He is also active in the field of office productivity and is the coauthor of *A Practical Manual of Office Productivity Techniques* (in Japanese).