Eliminating Complexity from Work: Improving Productivity by Enhancing Quality

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July 1986

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ABSTRACT

Traditional dogmas of quality control and economics state that improving quality increases cost. Fuller makes it clear that this is not true and explains how poor quality increases "complexity" which in turn increases cost. Conversely, improving quality reduces complexity, and higher productivity and lower cost follows. Fuller describes how to find, measure and eliminate complexity in the work place. This paper is a convincing testimony to Dr. Deming's thesis that productivity increases with improved quality.

KEYWORDS: *Complexity; Cost reduction; Elimination of errors;*
Quality improvement;

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Traditional dogmas of quality control and economics state that improving quality increases cost. Fuller makes it clear that this is not true and explains how poor quality increases "complexity" which in turn increases cost. Conversely, improving quality reduces complexity, and higher productivity and lower cost follows. Fuller describes how to find, measure and eliminate complexity in the work place. This paper is a convincing testimony to Dr. Deming's thesis that productivity increases with improved quality.

INTRODUCTION

With the emergence of Japan as the worldwide quality and productivity leader in a number of industries, many U.S. manufacturers are embarking on company-wide programs of quality and productivity improvement. Many of these programs have been sparked by the teachings of W. Edwards Deming, the man who has been given credit for teaching the Japanese his powerful philosophy of making decisions based upon statistical principles. Hewlett-Packard is one of those companies studying and attempting to implement Deming's philosophy of managing better.

The Computer's System Division of HP began in 1981 to use Deming's methods in the manufacturing of its line of HP3000 general purpose business computers. A consultant, familiar with Deming's work, had helped guide a number of successful projects in the department that assembled and tested printed circuit boards. The results of these projects were the virtual elimination of solder joint defects and associated rework, reduction in component insertion defects, improvement in manufacturing cycle time, and reductions of inventory and space requirements.

After studying the results of the initial projects, managers in the division were beginning to realize that every time defects were reduced, productivity rose measurably. This increase in productivity could often be attributed to reduction in rework that followed the reduction of defects.

In late 1983 management was looking for more ways to improve productivity of the circuit board assembly process. The problems associated with late delivery of materials seemed to be a likely candidate for study and improvement. This study led to some manufacturing changes that produced startling improvements in productivity.

The success of these efforts convinced the author that tremendous productivity gains could be achieved by reducing the unnecessary work, or complexity, introduced by defects in the quality of materials, tools, equipment, and other process variables. This article is concerned with finding, measuring, and eliminating complexity in the work place.

COMPLEXITY IN MANUFACTURING: THE BACK ORDER PROBLEM

The assembly process for printed circuit boards in the Computer Systems Division consisted of a number of steps, beginning with gathering a kit of parts, continuing with auto inserting, hand loading, wave soldering, and back loading, and ending with testing. Boards were built with lot sizes of 20 to 200 and were controlled through work orders issued through the material requirements planning (MRP) system. Work orders were started as close as possible to the time that kits were issued, even if some of the parts were missing.

When the assembly process was started before all parts were in hand, the process would generally proceed as far as the wave solder operation. If the missing parts had not arrived by this step, the partially completed boards were pulled off the line and stored on shelves. When the missing parts arrived, the partially completed assemblies were brought back to the line and the assembly process continued.

The logic behind the process of building incomplete kits was related to two beliefs held by management:

1. It is important to keep people busy working, even if the overall task cannot be completed. If production workers are idled by missing parts, labor hours are wasted; and
2. In order to meet production schedules, the assembly should proceed as far as possible so that when the missing part arrives, it can be quickly inserted and the lot of boards can be expedited through the remainder of the process.

Data which had been collected on the parts back order problem showed that, on average, about 98 percent of the kit parts were in the stores area when the work orders were pulled. Materials management felt that due to the number of vendor problems and the variation in the production schedule, this performance was acceptable. However, from the point of view of the production department, it was less than desirable. Since the majority of the kits required as many as 100 different parts, numerous kits had backordered parts when they were pulled to the production floor. The data showed that about 75 percent of all the kits pulled had one or more back orders when delivered and that, on the average, each kit had from one to three missing parts.

Production management had been working with the materials group for some time to improve the availability of parts but was unable to achieve higher than the 98 percent in-stock level.

AWARENESS OF THE PROBLEM

Although management was aware that back orders were a problem, it was not considered serious enough to make improvement a high priority objective. Most similar assembly operations in the company were experiencing the same degree of difficulty in procuring parts. One of the reasons for this was high demand in the chip market, which was causing a number of suppliers to miss promised shipping dates or to allocate scarce parts among their customers instead of sending complete orders.

One particular event raised the back order problem to a higher priority within the management group. The assembly department of the Computer System Division had been experiencing a higher than normal demand for completed boards and was having difficulty meeting the production schedules. A neighboring division was faced with less than expected demand for its products and had a number of surplus production workers. An agreement was worked out to borrow some of these workers to help the assembly operation.

After a week or two in their temporary assignment, the loaned workers approached management with complaints about the working conditions in the assembly department. Their comments included statements like, "We don't like working here. Things are too disorganized," and "Every time we start working on something, we run out of parts and have to find something else to work on. We didn't have these problems at out other job."

The assembly management was quite concerned over these comments, especially because it had thought that the department was quite well organized and that morale was relatively high. When asked about the differences between the two departments, the loaned employees stated that in our own department no work orders were started until the kits were complete.

THE NEW PROCESS

The department manager thought about these comments and decided to try an experiment to eliminate the problems associated with back orders. He proceeded to modify the parts-pulling process as follows:

1. Stores would continue to pull kits of parts according to the MRP schedule;
2. Complete kits were to be delivered to the assembly area as usual;
3. Incomplete kits were to be placed on shelves in the hallway with a note indicating which parts were missing; and
4. When the back orders were filled, the completed kits would be delivered to the assembly floor.

The production control supervisor confronted the assembly management with the prediction that "if you let work orders sit around and don't start working on them, you will never meet your production schedules," but the assembly manager held firm and the experiment was begun on a Monday. Immediately, material began to build up on the shelves in the hallway. The work load in the assembly area began to slow noticeably. When work-in-process began to flow out of the area, the supervisors showed some nervousness as they saw their people idle more and more often. For the first week very little new material flowed into the department.

One day the department manager found a supervisor rummaging through the incomplete kits in the hallway trying to combine two partial kits to make one full kit in order to give some work to his people. The manager asked him not to do that. "Instead," he said, "why not do some training? Hold

your staff meeting. If you've nothing else to do, take your crew to a movie. Just don't be concerned if your people aren't busy. I'm not measuring supervisors on how busy their people are anymore." He also requested that they not expedite late parts. He suggested that they wait until the kits were complete and then do their best to build them as quickly as possible.

Soon the material in the hallway became noticeable to higher division manager. "You can' have a million dollars worth of expensive RAM's sitting in the hallway like this. There's no control," they said. Moreover, the division mangers were not convinced that the experiment would work. But they supported its continuation. A compromise was reached whereby the incomplete kits would be stored in a special area that could be more tightly controlled.

In addition to the lack of work in the assembly department, other changes became noticeable. The work-in-process shelves gradually emptied as more of the old back orders were filled. The department manager decided that it might be possible to eliminate some of the shelves. Some of the idle production workers were given the task of dismantling the shelves and getting rid of them. Significant pockets of vacant space opened up in various parts of the department, and it began to take on a cleaner look. Three weeks after the experiment began, almost all of the work-in-process shelves had been emptied.

THE REMARKABLE RESULTS

As the experiment went into its fourth week, the manager noticed that the production workers were still often idle, even though work had begun to flow through the process again. A quick check of the production output showed that weekly production had climbed back to the level maintained before the experiment began. He also noted that a number of the production workers had been loaned to work in other departments.

Concerned, he asked for a review of the actual hours of work being recorded to build a set of boards and compared this to the current labor standards. Incredibly, the amount of labor to assembly a kit of boards had been cut nearly in half by this single process change.

It appeared that as much as half the activities of about sixty people had been to set up and take down jobs, expedite, move material, count material, and do other tasks that were unnecessary in the new process.

As the department began to adjust to the new procedure, other problems began to surface. As the

work-in process queues disappeared, an extreme variability in work load became visible. At times the workers were almost idle, at others they were inundated with work. Previously, the work-in-process queues had hidden the variation. Production control was called in to study the problem; as a result of the study, lot sizes were reduced significantly. Smaller lots of each board type would be delivered several times each week. High-volume assemblies would be delivered daily. It also became apparent that the new process could not tolerate significant downtime of critical equipment, such as the automatic insertion and automatic test equipment.

The data now showed that a significant reduction in cycle time had been achieved. With the reduction in lot sizes not yet in effect, the cycle time appeared to average five and on-half days, down from sixteen and one-half days before the experiment. Sorting the cycle time data by lot size revealed that further improvements would be achieved as smaller lots reached the assembly area.

The manager decided to collect more data to see how the new process affected his ability to expedite critical boards that were late because of missing parts. Data from before the experiment showed that a lot of boards was partially assembled up to the wave solder step, it would take approximately two days to expedite them through the process when the missing parts arrived. Data now showed that a lot of boards could be expedited through the entire process, from start to finish, in less than 12 hours. Production control's prediction had been proven wrong.

Clearly, the experiment was a success. Significant improvements in every measure of productivity had been achieved by improving the quality of the incoming kits. It should also be noted that no additional work was required of anyone outside the production department. The data showed a tight link between quality and productivity. Improved quality had eliminated the need for many complex process steps. Less complexity meant less work required to produce a given output.

Let's now look at a model of this process change and describe in detail how this improved quality leads to a reduction in complexity and increased productivity.

THE COMPLEXITY MODEL

Figure 1 is a process flow diagram of a simple assembly process. The process is designed to have three steps: get the kit; assemble it; and move the material. If one asked supervisors to draw a flow

diagram of such a process, most of the diagrams would look like this one. However, if one actually followed the flow of material through the shop, one would probably find many more steps in the process than are shown here. The extra steps would in most cases be related to unexpected problems such as late parts, defective parts, and poor procedures.
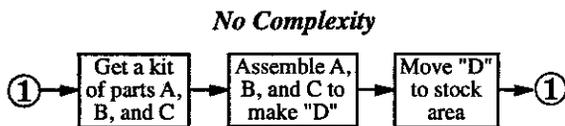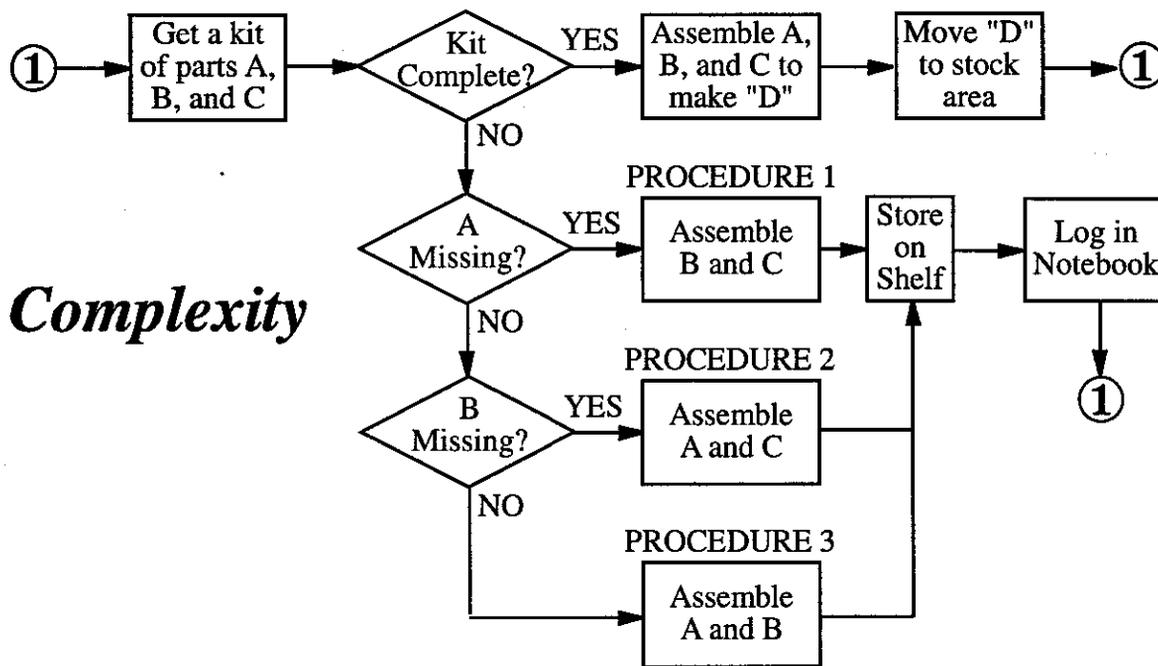
No Complexity

Figure 1. *The Perfect Assembly Process.*

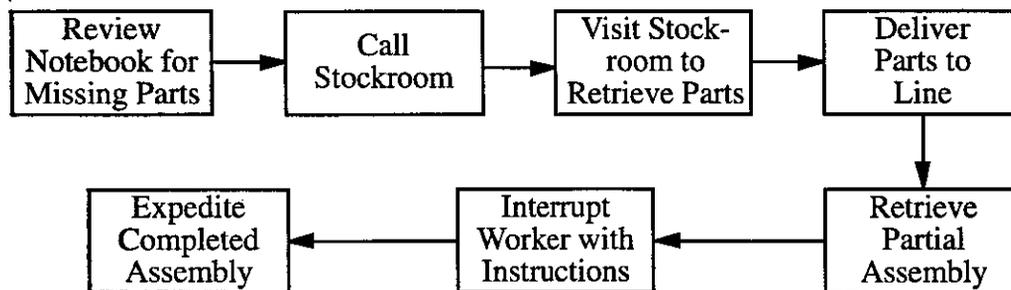Why would most supervisors leave out these critical steps? One reason may be that Figure 1 represents the most common path through the process. Another reason may be that the process was designed this way by the supervisor and due to lack of knowledge of the process, he or she thinks it operates this way – or at least wishes it would operate this way. In any case, we know that in the real world problems do come up and they have to be dealt with.

Let's now add a quality problem to the perfect process shown in Figure 1. Suppose that when a worker goes to pick up a kit, one of the three parts is missing. Also assume that our standard operating rule is to try to keep busy and work around problems as best we can. How could we redraw the Figure 1 diagram to show the additional steps needed to handle the problem of missing parts? Figure 2 shows how this new process might look.

Complexity

Supervisor Functions

Figure 2. *An Assembly Process with Errors.*

Across the top of the diagram one additional step has been added to the process, an inspection step. The person who picks up the kit of parts now is required to make a decision: if all the parts are in the kit, the standard process applies; if one of the three parts is missing, there are some different steps to follow. Let's suppose that inspection finds that one of the parts is missing. Now we must know which one is missing because in order to partially build the assembly, we need to know which of three special procedures to follow.

The next step is to assemble the parts on hand and then find a place to store the material until the missing parts show up. In order to keep track of all the work in process, a special log or computer entry may be required to describe the location of the WIP.

The job has thus become more challenging for employees. More training is required because there are more than twice as many process steps for them to perform. More space is required to store the WIP. A cabinet may be needed to store the procedures. In some cases an employee with a higher level of skills may be required to perform the work.

Also, another process has been added for the supervisor. In the perfect process shown in Figure 1, the supervisor could spend all available time hiring, training, and otherwise helping his or her employees develop good work skills. In the first process the supervisor played no part in the actual accomplishment of the tasks. Once he or she was trained, the worker had complete control of all the steps of the process.

In our new process the supervisor has many new jobs to do. The supervisor may have a "hot list" of all the critical parts he or she is waiting for and another list of customers with the most urgent needs for late assemblies. The supervisors now becomes an expediter in order to attempt to satisfy his or her customers. The supervisor will also likely be the one who goes to get the critical parts the minute they arrive in the stockroom, the normal delivery procedure being much too slow.

Once the parts are in hand, the supervisor must find someone to install them. He or she must decide who should be interrupted and must ask the employees who are selected to put away their current work and set up and perform the critical work. The supervisor may help by finding and retrieving the partially completed assembly. When the job is complete, the supervisor may be the one to deliver it to the customer, as the delivery system may again be too slow.

ENUMERATING THE EXTRA WORK

Now we have two processes, and the second one just described clearly involves more work than the process described in Figure 1. In the second process, each time a kit is received an extra inspection step is required; so even the error-free process takes a little longer. In addition, when a missing part is discovered, many extra steps are required. The second process will always take more time than the first and will require several times more work than the first if every kit has one part missing.

However, we have only begun to enumerate the extra work associated with the second process. Let's assume that at every step of the process, errors can be made. In the simple process, errors could be made in three places: the worker could get the wrong kit of parts; a mistake could be made in the assembly step; and the completed assembly could be delivered to the wrong place. The frequency of errors will depend on a number of things, but the quality of the initial training and the amount of practice the worker has had will certainly be the main contributors.

With relatively few different types of possible errors, the recovery process for each error can be described and practiced. Therefore, we can assume that the simple process will probably have relatively few errors, each of which can be quickly corrected.

But in our second process we have a different situation. We can expect a few more errors in the standard procedure (the top line of steps in Figure 2) because there is an extra step in each repetition of the process. What can we expect in the special steps required to handle missing parts?

Since some of these process steps are performed infrequently, the worker may have little chance to practice them. In addition, the initial training may not cover all the possible steps in the process. This implies that the error rate may be substantially higher in these nonstandard steps. Now consider what happens when the worker tries to recover from a second-level error.

Suppose that part "B" is missing from the kit and an attempt to put "A" and "C" together is made. Let's also suppose that a mistake is made when the entry is made in the log that records the location of the partially completed assemblies. Now when the parts arrive and the partially completed assemblies can't be found, what process should be followed to find the assemblies and get things straightened out?

It is likely that a new procedure will be invented on the spot to handle what has now become a crisis. It is likely that a new procedure will be invented on the spot to handle what has now become a crisis. It is at

this point when things really begin to go wrong. Tempers get short, one person blames another for the problem, and so on.

Let's now define process complexity as being extra process steps that are required to deal with external errors ahead of the process or extra process steps to recover from errors in the process, or internal errors. Reducing external and internal errors improves productivity through the following sequence:

1. Error reduction permits elimination of some process steps, such as disposition of faulty material, and reduction of the number of times that some process steps, such as rework, need by repeated; and

2. Now that less rework steps are being performed, there is less chance of internal errors. This reduces some lower level rework steps. Fewer rework steps at this lower level lessens the chance of internal errors at that level and therefore reduces the number of rework steps at a still lower level, and so on.

In sum, reducing errors can lead to elimination of work at multiple levels of the process and therefore highly leverages productivity improvement.

Experience has shown that eliminating errors will produce extensive gains in productivity that far exceed potential gains achieved by trying to improve the efficiency of an error-ridden process. Automation of an assembly process that is full of errors will likely force everyone into a crisis situation. Implementation of Just-in-Time manufacturing techniques (JIT or Kanban) without first reducing quality problems will likely have similar results.

Our model has suggested that the addition of one external quality problem to a perfect process can introduce a significant amount of complexity that substantially reduces productivity. In the majority of departments, whether manufacturing or administrative, most standard processes have far more steps than the simple one in our model. In addition, many types of errors can flow into the process and many other types can be introduced into the process itself. Every error requires extra process steps to deal with it. If the error is not discovered in the process, the customer will likely find it and will be required to deal with it.

This implies that in most processes in our offices and factories where no long-term process improvement efforts have been in place, most of the activities undertaken by people are part of the complexity and few activities represent "real work" that people would like to be doing. As William

Conway, former president of Nashua Company, put it, "There is just not much working in anything."

HOW TO FIND THE COMPLEXITY

We have shown that in a typical operation or department, much of the work being done might be complexity that has been introduced by errors. Unfortunately, much of this complexity is usually not apparent to the manager of the department. We have been doing these unnecessary tasks for so long that we see them as part of the standard process.

Some people have jobs that are largely the result of errors which have been introduced into the system. Consider these examples:

1. A person who opens and restocks customer returns;
2. A customer service representative who follows up on customer complaints;
3. A collector who calls customers who are late in paying for merchandise;
4. An expediter of late parts or products; and
5. An inspector who looks for defects.

All people who are engaged in performing a standard process spend some portion of their time solving problems. All people make mistakes and must correct them; however these activities are seen as normal parts of their jobs, and no special notice is taken of them. If a copy machine breaks down occasionally and sometimes produces poor copies, working around the inconveniences is considering the mark of a good, resourceful employee. Each employee builds into this job some informal procedures to overcome the little problems faced each day.

Only when several copy machines break down at the same time and there are loud complaints does management grasp that there is a problem that needs to be solved. Now something will be done, even if it is only a temporary solution to get the work moving again. Let's explore some techniques we can use to begin to find and measure the complexity in an operation. Then we can discuss some techniques for removing it.

THE "REAL WORK" MODEL

Figure 3 depicts that part of a typical employee's time during which no work is possible. The circle represents the total eight-hour work day. The shaded area is an estimate of the time that is lost due to sanctioned benefits, company-sponsored activities, and unsanctioned business that take the employee out

of the work place. Some examples of sanctioned benefits are vacation time, coffee breaks, and sick leave. Company-sponsored activities include staff meetings, training, United Fund meetings, and fire drills. Unsanctioned personal business includes unscheduled rest breaks, personal phone calls, late arrival, and early departure.

It has been the author's experience that this unavailable time is as high as 25 percent of the total time in large organizations with a full range of employee benefits. This leaves approximately 75 percent of the eight-hour day that potentially could be used for doing work.
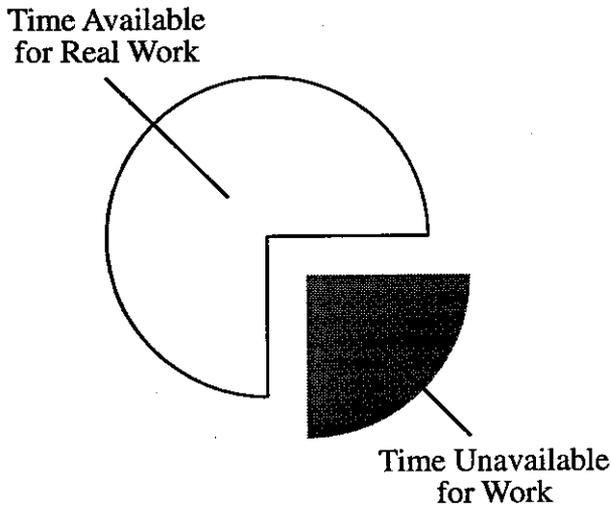
Time Available
for Real Work

Time Unavailable
for Work

Figure 3. *Complexity Model – Amount of Time Not Available for Work*

COMPLEXITY CAUSED BY EXTERNAL ERRORS

Now let's make some estimate of the activities that are going on during the remaining hours. From the back order case discussed earlier, we can estimate that, on average, people spend up to half their working time fixing problems caused by errors introduced into their process from other sources. The activities comprising this time are designated in Figure 4 as complexity due to external errors. Added to time unavailable for work, it further reduces the amount of time available for "real work", which can be defined as activities that an organization is in business to carry out and that, in the absence of errors, would still be performed. Now only 35-40 percent of people's time is available for real work. Table 1 lists examples for five departments of activities representing real work and complexity resulting from external errors.
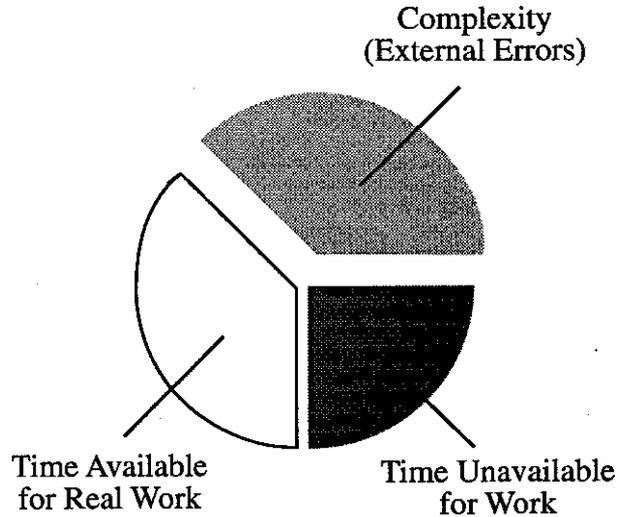
Complexity
(External Errors)

Time Available
for Real Work

Time Unavailable
for Work

Figure 4. *Complexity Model – Amount of Time Lost Due to External Errors*

Table 1.
Examples of Real Work and Externally Induced Complexity in Five Departments

DEPARTMENT	COMPLEXITY	REAL WORK
Accounting	Collecting overdue accounts resulting from carrier delivery problems	Mailing invoices
Production	Rework of faulty incoming materials	Assembly
Marketing	Handling customer complaints about poor quality materials	Helping customers buy
R & D	Redesign due to market research error	Asking customers about their needs
Personnel	Handling a lawsuit from employee who was mistreated in manufacturing	Training new managers

COMPLEXITY CAUSED BY INTERNAL ERRORS

Referring back to the complexity model presented earlier, we recall that even a process using high quality materials will still have internal process

errors. So we can expect a number of errors while people are doing real work.

Some of these errors are mistakes in carrying out the steps in the process, while others are problems with tools, supplies, equipment, and other items associated with the process. We might say that the real work activities are made up of "subactivities", some of which are complexity caused by errors within the process. By breaking up activities into very small parts and adding up those that are rework for internal errors, we might estimate that as much as 75 percent of the real work is complexity. In Figure 5 the shaded area of the circle has again been increased, this time to account for the subactivities devoted to fixing internal problems. Now less than 10 percent of people's time is available for real work.
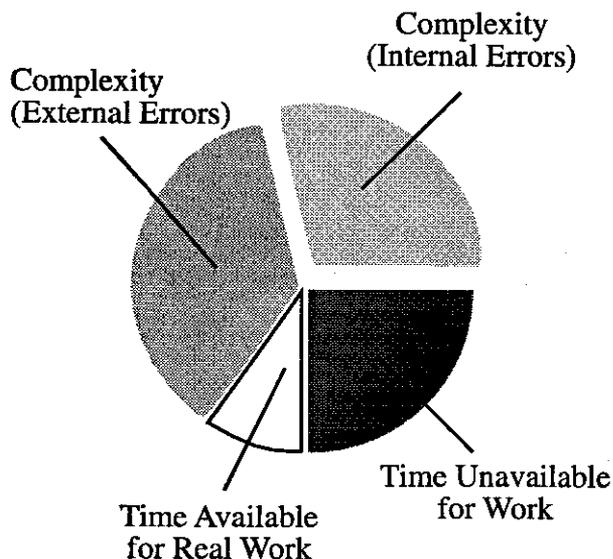

Figure 5. *Complexity Model – Amount of Time Lost Due to Internal Errors*

Following are some subactivities categorized as complexity or real work.

Activity:
  • Training new managers (Personnel).

Subactivities:
  • Reserving a conference room (real work).
  • Resolving a meeting room conflict caused by a mistake in scheduling (complexity)
  • Leading a group discussion (real work).
  • Having a discussion about why the handouts can't be read because of copy machine problems (complexity).

  • Watching a videotaped lecture (real work).
  • Waiting for all the participants to arrive so the meeting can start (complexity).

Again, by visualizing the perfect process, one can sort these subactivites into two categories: real work (subactivities that would be required even if everything were to run perfectly) and complexity (subactivities that could be eliminated if the process were to run perfectly every time). It might follow that if one would break the subactivities into even smaller pieces, one could repeat the analysis and could categorize more activities as complexity at each iteration. Again, it appears that there truly may not be very much work in anything.

HOW TO MEASURE COMPLEXITY

To decide where to start the quality and productivity improvement process, it helps to have some idea of the relative amounts of complexity in various parts of one's organization. The more complexity in an area, the more quickly and easily significant improvements can be made.

Often, one can make a rough estimate of the level of complexity in an operation by just walking around the work area and making visual observations of certain conditions. Seven conditions indicating a high level of complexity, and seven corresponding conditions indicating a low level, are listed below.

INDICATORS OF HIGH COMPLEXITY

1. Lots of work-in process materials. many shelves in the work area to hold material.
2. Many people walking from place to place, standing in a line waiting for something, standing idle.
3. Work areas that are in disarray. Dusty boxes on the floors, bookcases full of dusty binders, and desks and walls covered with little scraps of paper serving as reminder notes.
4. People who can give only a brief, vague explanation of what they are working on and why it is important.
5. Humorous signs taped to the walls that say things like, "You want it when? Ha! Ha!" or "A clean desk is a sign of a sick mind."
6. In office areas, piles of processed and unprocessed documents stored in the work area.
7. Supervisors and managers pacing around the area trying to find out what's going on, ascertain who made a critical mistake, and expedite late orders.

INDICATORS OF LOW COMPLEXITY

1. A small amount of work-in process material. Few shelves in the work area to hold material.
2. Few people walking around carrying materials. Most people working at a steady, relaxed pace. No one waiting in line at copy machines, office supplies, stores.
3. Work areas that are neat. Everything in a department has a place and a use. People using time management systems instead of scraps of paper. Desktops containing only what the person is working on at the time.
4. People on the production floor or in an office area who can give complete descriptions of what they do, why they do it, who their customers are, and what's important to those customers.
5. The most common item displayed in department walls are monthly performance graphs, daily control charts of defects, Pareto charts of defects and problems.
6. In office areas all documents are received, processed, and filed. In baskets are clean.
7. Supervisors and managers who are relaxed, walking around the area talking with employees, asking them what they are working on, and looking for ways to make their employees' jobs easier and more satisfying.

After looking at these items, a manager should have an idea of the overall level of complexity. However, it may be more difficult to accurately categorize activities as real work or complexity and measure them. Simple work sampling can be used to make a good estimate of activities that are being performed because of errors introduced from outside the process and subactivities that are part of internal process complexity.

HOW TO PERFORM WORK SAMPLING

The advent of cheap, multifunctional electronic watches has made work sampling simple and easy for almost anyone to do. The basic idea is to look periodically at what a person is doing so that a list of activities can be developed and the relative frequency of each measured. If we ignore non-work-related activities, the list can be sorted into the two categories of real work and complexity due to *external* problems.

Then subactivities can be similarly grouped into real work and complexity related to *internal* process

errors. When these data have been prepared, management can pull together interdepartmental task groups to eliminate the external errors. Work group improvement teams led by a supervisor can address the internal problems by solving the ones over which they have control and collecting data on the others so that management can take the proper action.

WORK SAMPLING PROCESS

Step 1. Select the Process to be Studied.
This may be determined from the data gathered previously by the department walk-through.

Step 2. Procure a Watch that has a "Repeating Countdown" Function.
This function allows setting a countdown timer to a particular number of minutes and seconds. When the countdown feature is turned on, the watch counts down to zero, beeps one or more times, resets itself automatically, and begins the countdown again.

Step 3. Determine the Sampling Procedure and the Sample Period.
In some cases one may wish to look only at the activities of a single person. If so, the person will wear the watch, start the watch each morning, and turn it off at the end of the day. Each time the employee hears the beep, he or she is to immediately stop working and make several entries in his or her log or check sheet. The employee should record the time, place, activity, and subactivity.

This procedure will be most successful if a list of the major activities is determined in advance so that sorting will be easy. Determine the number of observations needed. In general, the more activities that a person might be doing, the more observations are required to obtain a true picture of what the person is working on. In most cases 100 should be enough for one person. A larger department may require several hundred observations spread over many people during an interval of such length that weekly and monthly activities can be recorded.

It is important that the beep of the watch be a surprise to the work sampling subject. If the employee anticipates the beep, he or she is likely to modify his or her behavior in some way that will distort the data. Ideally, the turning on and turning off times of the watch should be random. But since the few watches have the capability to generate random beeps, the countdown timer should be set at an interval long enough and odd enough so the individual will be surprised when it beeps. Good results have been obtained with settings of 23, 41,

and 47 minutes but not with 60 minutes.

No matter what the setting, subjects are bound to change their behavior to some degree because of the study. However, this is potentially beneficial if the person is permanently imbued with an interest in studying the activities being performed.

Step 4. Train the Worker.

The work sampling process can be quite threatening to a person who does not understand how the data are to be used. The following points should be made clear to the person at the outset of the project:

1. The data should be used by the person doing the work to make improvements in his or her own process where he or she has control of it. For instance, the worker can control his or her personal business. The worker may also be able to improve the way work is done, within limits. He or she will be rewarded for helping in the project, especially if improvement suggestions are made.
2. The data will be used by management to look for system-type errors, either internal or external, and to eliminate them from the system. This will make the worker's job easier so that more of his or her time can be allocated to more productive activities.

Step 5. Start Taking Observations.

Visit with the worker after a few hours to make sure that he or she understands how to set and control the watch and that the watch is functioning properly. Check to see that the data are being recorded in the proper format.

Step 6. Analyze the Data.

After the required number of observations have been recorded, summarize the data. Some of the activities will fall into the unsanctioned personal time category and should be grouped separately. The issue of unsanctioned personal time is a highly sensitive area for the employee and should be handled carefully – management must take care not to criticize the person's use of time in order to encourage accurate data reporting. If the worker has any control, seeing the sorted data is usually good motivation to make changes for improvements in the use of time.

Now go through the list of activities. Decide for each activity whether it belongs in the category of real work or complexity due to external problems. Put together a Pareto chart for the top ten activities with an annotation on each bar showing the category.

Sort the sub-activities within the real work category, determining for each subactivity whether it is real work or complexity due to internal errors.

The manager should now have an excellent understanding of the amount of complexity in the department and the potential for improvement. He or she should also have an excellent understanding of the types and effects of errors from inside and outside the process. This exercise will usually motivate the manager to make a number of obvious improvements shortly after seeing the data. More data collection and tracking of process variables can be started to begin removing the causes of the more subtle errors.

TWO CASE EXAMPLES

The complexity model can be used to detect quality problems in clerical-related as well as manufacturing-related processes. Below, case examples are provided of the application of the model in a sales office and an order-processing function. The data collection techniques differ in some ways from those proposed above, but in fundamental respects they follow our methodology.

MARKETING ASSOCIATES IN A SALES OFFICE

Approximately 30 clerical and professional people worked in a Hewlett-Packard office taking orders for the company's products over the telephone. Management felt that a large amount of the work being performed was related to resolving problems caused by mistakes in processing and shipping the orders. It was decided that a study of the people's activities should take place so that management could have a better idea where the major problems were. Then, action could be taken to reduce the.

The work sampling plan was set up as follows:
1. The supervisor would wear the sampling watch.
2. When the watch beeped once every 42 minutes, the supervisor would walk around a group of about ten people and ask each one what activity he or she was currently performing. Out of area or nonwork activities would be excluded from the study. If an employee was away from his or her desk when the supervisor came to collect data, no entry would be made for that person.
3. The study would cover a three-day period.

After three days of collecting data, the supervisor

had a notebook containing 130 observations of the activities of 10 people. The date, time, and activity were recorded. Subactivities were not recorded.

The activities were then grouped by major category and counted. No attempt was made to determine whether the cause of any problem-related activities was internal to the group or external. However, the data suggested that most problems were caused by activities of people outside the department.
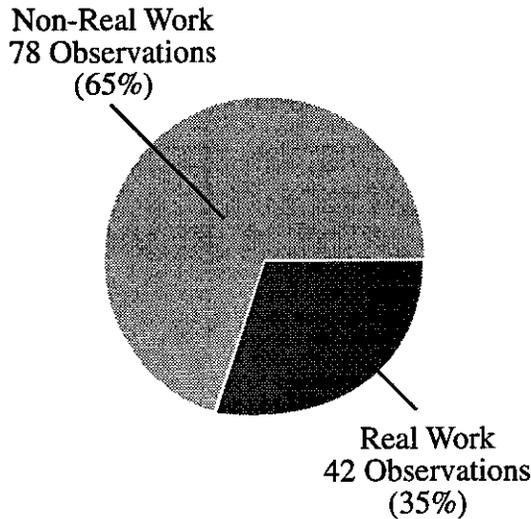
Non-Real Work
78 Observations
(65%)

Real Work
42 Observations
(35%)

Figure 6. *Marketing Associates: How Time Available for Real Work was Spent*
(120 Observations, 12/20/84, 12/26/84, 1/8/85)

The data were then grouped and sorted by frequency. The supervisor was asked the following question about each activity, "If there were no errors in the process and everything were running perfectly, would you be working on this activity?" If the answer was "no", that activity was categorized as complexity. If the answer was "yes", that activity was categorized as real work.

The real work and complexity activities were then counted and compared. Figure 6 shows the relative size of the two categories of work according to the number of activities in each category. The data showed that the supervisor classified 42 of 120 observations as real work and 78 as complexity.

Figure 7 shows the relative frequency of the seven most likely activities that were being performed by the marketing associates. The seven activities, in descending order of frequency, were:

1. Process customer returns (complexity).
2. Entering orders into the computer system (real work).

3. Converting orders to fix a problem (complexity).
4. Making changes to orders (real work).
5. Expediting shipments (complexity).
6. Answering questions from customers about the status of orders (complexity).
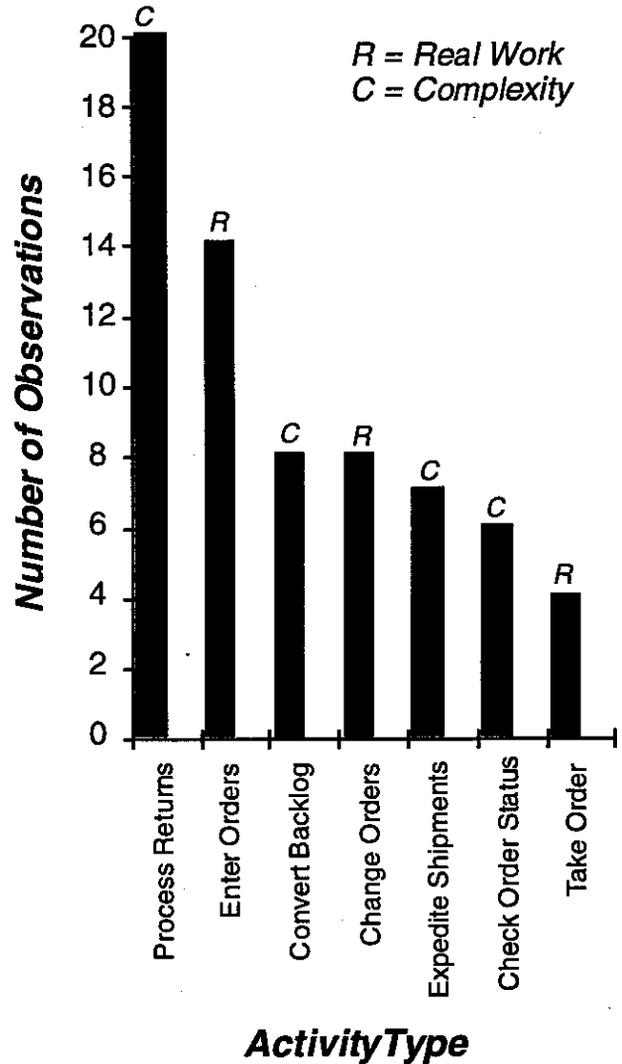7. Taking orders over the telephones (real work).

R = Real Work
C = Complexity

Figure 7. *Marketing Associate Work Sampling Results – breakdown of seven most frequently observed activities.*

Three of the seven most frequent activities were judged to be part of the standard process of taking orders and therefore were classified as real work. The most frequent activity was processing merchandise that was being returned by customers. The reasons given by customers included wrong product,

duplicate shipment, and wrong quantity. This activity was categorized as complexity.

Upon seeing the data, the supervisor had several reactions. One was that "15% of the time my people are processing customer returns. This is equivalent to six people. This is far too many, and we need to first streamline the way we process returns and then see what we can do to eliminate them." Immediately, the supervisor made changes in the work procedures to improve the processing of returns. The supervisor felt that seeing the data sorted in the form of a Pareto chart helped motivate her to make the change. At the same time, a task force was formed to reduce the number of products returned. One person from each department that could ameliorate the problem joined this team.

EMPLOYEES PROCESSING ORDERS IN A FACTORY

The second case example concerns a group of clerical and professional people working in a Hewlett-Packard factory processing orders received from the sales office. Some people entered orders into the computer system, some matched orders with available products, and others shipped and invoiced the orders.

Management believed that a great deal of the work time was being spent fixing the problems. It was felt that, as a result, employees were working a substantial amount of overtime and that morale was going down because people could see no end to the heavy work load. Management decided to study the activities of the people to see if the situation could be improved.

A work sampling study was set up with the following rules:

1. The supervisor would wear the watch, which would be set to beep every 41 minutes. If the supervisor was to be out of the area, some other member of the department would wear the watch.
2. At the beep the person with the watch would roll a 20-sided die to select three workers to be observed.
3. The person with the watch would ask each of the three people selected what they were working on at the moment. If any of the selected employees was out of the area, a note would be made of this fact. Upon returning, the employee was to be asked where he or she had been and what activity he or she had been engaged in. If the person was not working that day, no data were to be

recorded.

Work sampling was carried out over a period of six days. During that time, 265 observations were made and recorded. The activities were grouped, counted, and classified in the same manner as in the previous case example. Figure 8 shows the division of the activities into real work and complexity. Of the 265 activities, 113 were classified as real work and 152 as complexity.
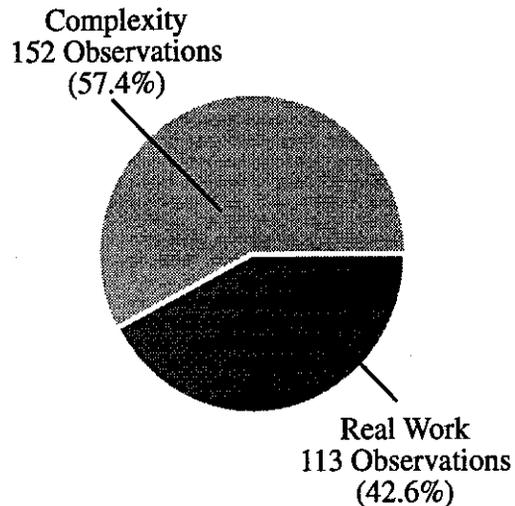

Figure 8. *Factory Order Processing: How Time Available for Real Work was Spent (265 observations, 2/2/85 through 2/10/85).*

Figure 9 shows the nine activities that were observed most frequently. The activities, in descending order of frequency, were as follows:

1. Acknowledging order ship dates to customers (real work).
2. Sending messages through electronic mail (complexity).
3. Making computer entries to ship products (real work).
4. Processing customer returns (complexity).
5. Resolving billing mismatches (complexity).
6. Working on miscellaneous problems (complexity).
7. Working on quality improvement projects such as preparing graphs or training (real work).
8. Processing credits for goods returning or to correct other problems (complexity).
9. Out of area, miscellaneous problems (complexity).

"Sending messages" was classified as complexity because the purpose of most messages was to explain

problems or order status and because most messages were the result of errors in the process. Six of the nine most frequent activities were classed as complexity.
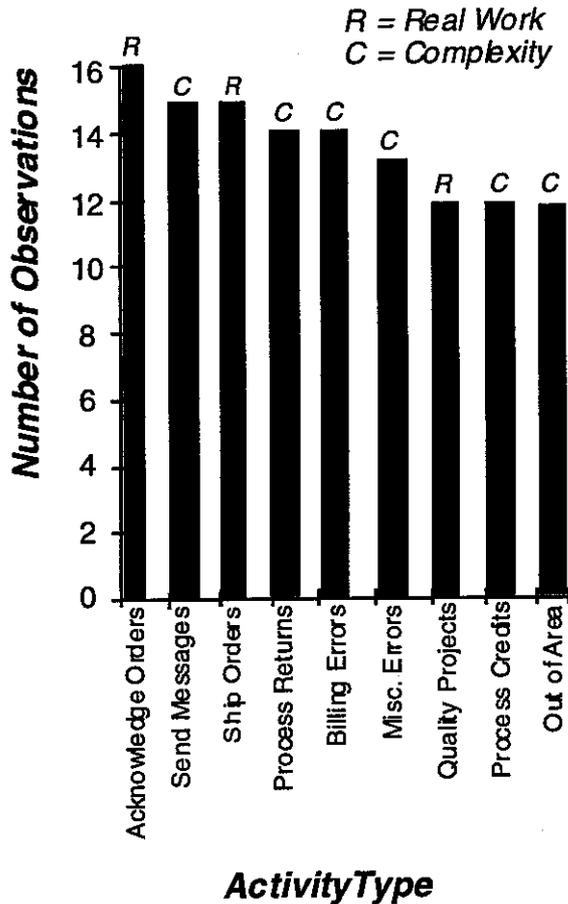
R = Real Work
C = Complexity

Figure showing a bar chart with vertical axis "Number of Observations" ranging 0 to 16, and horizontal axis "Activity Type". Bars labeled: Acknowledge Orders (R, 16), Send Messages (C, 15), Ship Orders (R, 15), Process Returns (C, 14), Billing Errors (C, 14), Misc. Errors (C, 13), Quality Projects (R, 12), Process Credits (C, 12), Out of Area (C, 12).

ActivityType

Figure 9. *Factory Order Processing Time Study Results – breakdown of nine most frequent observed activities.*

The data generated from this study confirmed management's belief that the people in the order processing department were spending a large portion of their time recovering from problems. A study was done to find the reasons for the large number of messages that were sent each day, and it was found that most were requests for status on orders. A project was begun to reduce order turnaround to improve customer satisfaction and to reduce the need to send messages asking for order status. Other projects were started to study the causes of the large number of customers returns and billing errors.

CONCLUSION

With experience in productivity improvement efforts comes increasing awareness that the bulk of the work we do in most large organizations is devoted to fixing problems. The data presented here suggest that far more than half of an employee's day may be spent either away from the work place or in the work place performing tasks that would be unnecessary if the quality of materials, tools, equipment, and other process variables were improved.

Elimination of errors in factory and clerical processes can have a dramatic impact on raising worker productivity, often at little cost, as was shown in the example of back-order kit parts.

The complexity model may be applicable to other business processes, as indicated by the case examples. On need only look carefully at the activities that are performed to see that many of the tasks we carry out can be eliminated if we improve the quality of the process of which they are a part.

Only management can make the process changes that can reduce the complexity in its organizations. Collecting and showing management work sampling data based on the complexity model can help motivate them to take needed action.

AUTHOR INFORMATION

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ACKNOWLEDGMENT