PILOT — A Simple Process Improvement Tool for Small and Midsize Manufacturing Companies

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PILOT (Process Improvement by L.O.G.I.C.A. Operational Team) is a complete process improvement pilot study application, providing data collection, entry, analysis and decision making. It is designed primarily as a simple, easy-to-use diagnostic tool for production process description, problem identification and improvement in small and midsize manufacturing companies, characterised by relatively small amounts of data emerging daily. The analysis of the information collected facilitates tracing down the sources of the identified production related problems and finding means for eliminating or minimising them. The statistical methodology utilised includes simple, but useful tabular and graphical techniques, such as Ishikawa's Seven Tools, but also some sophisticated exploratory data analysis methods, e.g. correspondence and cluster analysis. Furthermore, the results of PILOT constitute a good basis for developing more advanced studies, utilising statistical and/or simulation methodologies, and for setting up SPC charting information systems or designed experiments. An effective PILOT application in a midsize company manufacturing department is described for illustrative purposes.

1. Introduction

Within the modern movement for quality and productivity improvement, statistics is seen as a major contributor to improved management practise (Deming, 1986). Regardless of this broadly accepted fact, the great potential for useful application in business that statistical methodology has, is neither realised wherever it could be, nor is it exploited to the extend it should be, as pointed out by Roberts in his excellent review of the applications in business and economic statistics (Roberts, 1990). One of the areas where statistical applications are very rare, but potentially extremely useful, is process improvement in small and midsize manufacturing companies.

However, statistics by itself cannot be effective in the company lacking what leading writers on quality (Deming, 1986; Juran, 1964; Ishikawa, 1985) denote as favourable organisational culture. A key factor contributing to this culture is a shared dedication throughout a company to problem solving based on evidence rather than intuition or opinion. In small and midsize manufacturing companies the organisational culture is, in general, more intuitive based than in the bigger ones. The process of achieving this cultural transformation in such companies is, therefore, neither short nor easy. Often an effective way to alleviate it is to demonstrate the advantages of having data at hand and being able to use it for process improvements. The PILOT application has been developed with this major goal in mind. In order to achieve it, the following facts had to be considered:

1. According to Japanese Union of Scientists and Engineers (JUSE, 1991), the foundation of Total Quality Control (TQC) is making decisions and taking actions based on data. Hence, the first and foremost step leading to TQC is to collect and analyse proper information, pertaining to the production process in question.

2. The data collected should be such, that it includes basic quality characteristics of the process and products, but also certain important el-

ements of site technology (in-house knowledge and expertise).

3. Specific features of small and midsize manufacturing company production processes, such as very specialised, complex, long-term production, relatively small number of products, none or inadequate use of computers and software, diverse production, work cycles, flexible machines, etc., have to be taken into account.

4. The most common problems encountered in such companies are related to inability to plan the production and to predict the total production time. Consequently, measuring effective, waiting and lead time is of special interest.

5. On the other hand, the data collection process itself should be easy to implement and perform, broadly applicable, clearly defined and not time-consuming.

6. Implementation should not require any special information technology device such as bar code readers, other types of data collectors or computers. In order to comply with most of the requirements mentioned, it was decided to design certain data collection forms for the production follow-up. The forms are aimed at measuring only the most important characteristics of the process and products being analysed. These include such items as: type of material, number of equal parts, number of defects, effective machine time, etc.

All the data are collected by using some of the available form types. Depending on the specific character of each company and problems indicated, usually based on some initial screening, decisions about the extent, duration and sampling scheme of the data collection process have to be made. Neither all forms have to be used, nor all items available on the forms have to be entered.

Detailed description of the forms and the data collection process is available in written form. Training of the employees responsible for the project and instructions for filling out the forms are offered, where needed.

After the planned data collection is completed, data are entered, corrected and transformed as necessary, and analysed. Results of the analysis, numerous tables and graphs are described and presented to the managers, personnel involved in the project, and all interested. Discussion of the results, such as the Pareto charts, showing the most critical problems, in frequency and duration; the most critical machines, tools or operators, in terms of unavailability, and their effects on delays in production, is always very beneficial for all personnel. Focusing on the most critical problems, their effects and causes, is the first, but principal step to the solution and to process improvement.

In the following three sections we describe: characteristics that can be measured and those computed by PILOT (Section 2), the methodology used for data analysis and the application itself (Sections 3), the results of an application of PILOT in a midsize manufacturing company department (Section 4).

2. Components of the Pilot Application

The application is composed of three separate components:

– ISHIKAWA

– FMECA

– FORMS,

each of which can be used independently as a useful tool for process improvement. However, in order to alleviate the initial screening process and help to implement the application in an optimal way, i.e. in such a way that most critical information be obtained in minimal time and with lowest effort, tools like ISHIKAWA and FMECA (Failure Mode, Effect and Criticality Analysis) are made easily accessible at screening time. Resulting ISHIKAWA diagram and FMECA table serve then as a basis for setting up the efficient data collection process.

All three components are easy to use, menu-driven applications, well suited to users without programming or statistical experience.

Due to the fact that in most of the companies, data collection process has to be tailored to the individual demands, needs, production processes and problems indicated, the application FORMS is designed to allow a great deal of flexibility in entering as well as in analysing the data. Data entry from the forms is simple and is performed in a full-screen environment. A powerful control mechanism, that is automatically executed during and after the data entry, provides means for thorough data checking and updating. The analysis part of the FORMS application includes the following:

– Computation of new variables (productivity and quality measures)

– Tables of summary statistics

– Histograms;

– Pareto charts

– Control charts

– Correspondence Analysis

– Cluster Analysis.

All of the tables, histograms, Pareto and control charts can be created for any measured or computed variable, and for all data, or for data stratified by a specified factor, such as machine, operator, day, etc., provided all necessary data have been collected.

Correspondence Analysis may be used for visualisation and for relating delays in production to problems, machines, operators, etc.

Cluster Analysis is included as a tool for classifying operations, products, parts, tools, etc. The application is developed with SAS 6.04 under DOS operating system, and utilises modules base, STAT, GRAPH, QC, AF and FSP (SAS Institute Inc., 1990,1991).

3. Data Collection and Estimation

The forms used by the PILOT application were designed for collecting data on the following items: products, operations, problems, machines and process characteristics. In addition to the variables that are observed and entered directly, many new variables are computed from those observed. These computed variables include various productivity and quality measures.

It has been observed that, in the manufacturing companies with a complex, long-term production, management and technical staff are very often confronted with the problems of establishing efficient schedules, that should increase the level of productivity and decrease delays and waiting time between successive operations. The first step leading to these goals is monitoring current production. Therefore, a group of forms have been designed specially for the follow-up of a product from the first to the very last operation. These are:

– Order-Products Form,

– Product-Operations or Traveller Form, and

– Problems Form.

In such a way, useful data on production processes and time they take can be collected. This type of approach is suited to multioperation processes, and to products for which work cycles already exist or can be set up easily.

For a production process in which defect prevention and problem identification are most critical, data collection process can be organized in a different manner, using one or both of the other two forms available with FORMS:

– Machine-Operations Form, and

– Characteristic-Measurements Forms.

Machine-Operations Form is applied at a single station over a defined period of time and serves for performing problem analysis and productivity/quality check-up at a selected machine.

Characteristic-Measurements Form is a general form that can be used for auditing over a fixed predetermined period of time at single or multiple stations and it is aimed at performing capability study of a selected characteristic.

Order-Product Form may be used either separately or in combination with some other forms. Therefore, it could be either posted at a certain spot, a station, a selected machine, or it could travel together with the Traveller Form.

Variables measured and computed are categorised accordingly into five groups, as follows:

Order-Products Form

Besides the identification variables, such as order, product and part number, other variables entered from this form are mostly qualitative: material type, design type, product type (new/old), level of complexity, priority, utilisation of special tools. Quantitative variables are: planned production start and end dates and number of equal parts (i.e., batch size).

In order to relate planned to actual production, and to measure and analyse production efficiency, the following time-related productivity variables are computed:

– Total actual time (hours) is total actual duration of all operations;

– Total planned time (hours) is total planned duration of all operations;

– Total delay time (hours) is total delay time of all operations;

– Total waiting time (hours) is total waiting time of all operations;

– Actual duration (days) is the number of days between the start date of the first operation and the end date of the last operation;

– Planned duration (days) is the number of days between the planned start date and the planned end date;

– Delay time (days) is the difference between the actual and planned duration;

– Delay per last operation (days) is the number of days between actual and planned end dates;

– Hours per day is the ratio between total actual time and actual duration.

Product-Operations (Traveller) Form

This form is designed for entering product identification and operations related variables, such as: operation number and type, operation start and end date-time, planned duration, and problem, machine and operator codes. Besides these, directly entered variables, some time related variables are computed, such as:

– Actual time (hours) is the duration of an operation;

– Waiting time (hours) is the number of available hours (minutes) between two consecutive operations;

– Delay time (hours) is the difference between actual and planned time.

Problem Form

Each problem is identified by its code, order number, its start and end dates and time. Besides, machine/product/operation codes can also be entered in order to relate a particular problem to one or more products, operations or machines.

Machine-Operations Form

Variables measured and computed with the Machine-Operations Form are similar to those collected by the first two forms, except that only values generated at selected machine(s) are entered. Thus, this form serves for entering variables such as machine identification, processed product/part type, operation, operator, tool utilised, material, processing start and end times, problem, number of equal parts, number of parts controlled, number defective/rework/scrap.

Characteristic-Measurements Form

Besides the identification variables describing the characteristic measured, this form is used for monitoring the values (measurements) of the characteristic, operator, machine, problem and date/time variables.

If data collection is complete, i.e. if data pertaining to the entire production performed during the study period have been collected using the Order-Products and Traveller Forms or the Machine-Operations Form, then also some standard performance measures may be determined, such as productivity measures (productivity, utilisation, efficiency, total earned, actual and available hours, etc.) and quality measures (frequency and proportion defective/rework/scrap, etc.).

All of the measures described above may be computed for production as a whole, or for production stratified by machines, operators, weeks, months, etc.

4. An Example: the Analysis of the late Deliveries Problem in a Midsize manufacturing Company Department

One of the most critical problems pointed out by the management during the initial screening in a midsize manufacturing company have been difficulties in production planning and in meeting the delivery deadlines. Production in the selected department is very complex, diverse, and long-term, but, for most of the products, follows predetermined work cycles. Therefore, it was decided to perform a pilot study aimed at:

– analysing the productivity in the selected department,

– finding the most critical causes of late deliveries,

– facilitating production planning.

In order to monitor the production and obtain necessary information, it was decided to collect data over a three month period using the Order-Products, Product-Operations and Problem Forms. Such a long period was chosen because product cycles were estimated as taking approximately 6 weeks. As no defect problems were indicated as critical, and since the data collection process was to be kept simple, no direct quality measurements (e.g. number defective) were recorded. At the end of the specified period, data on eight products were gathered. More general and reliable conclusions could have been obtained, had the data collection period been longer and the entire production recorded. Nevertheless, the principal goals of the project were accomplished.

In a simple but highly informative Table 1, we present a number of time-related productivity measures. First of all, for all eight products total actual hours are compared to total waiting hours and delays in days (column 8). Products that are delayed usually also have excessive waiting time. This demonstrates the importance of finding the causes of a too long waiting time between successive operations. On the other hand, how well the available time was utilised can be observed from the last column of the table: The second product is manufactured most efficiently, with respect to the time utilisation (5 hours per day, in average), but also regarding the total waiting time (63 hours). However, the production took 13 days more than was planned. This clearly shows, that the exist-

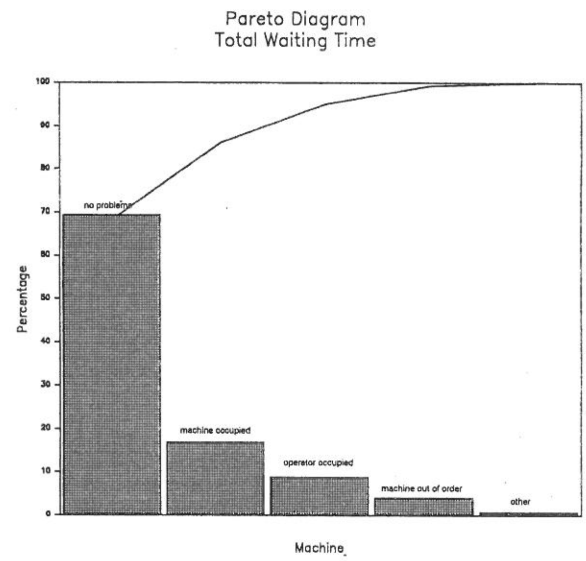

Fig. 1. Distribution of waiting time (hours), according to the absence/presence of the problems: no problems, machine occupied, operator occupied, machine out of order, other.

		Total actual time (h)	Total planned time (h)	Total delay time (h)	Total waiting time (h)	Actual duration (days)	Planned duration (days)	Delay time (days)	Delay per last oper. (days)	Hours per day
Ordered number	Part Number									
499/91	1	26.0	28.0	-2.0	113.0	21.0	28.0	-7.0	-7.0	1.7
622/92	1	145.0	153.5	-8.5	63.0	41.0	28.0	13.0	13.0	5.0
	4	152.5	148.5	4.0	202.0	64.0	28.0	36.0	9.0	3.3
631/92	1	37.5	37.0	0.5	68.0	16.0	21.0	-5.0	-5.0	3.1
	1003	12.0	13.5	-1.5	107.0	17.0	16.0	1.0	1.0	1.1
	1004	10.5	13.5	-3.0	101.5	17.0	16.0	1.0	0.0	1.0
	1005	10.5	13.5	-3.0	99.5	16.0	16.0	0.0	0.0	1.0
675/95	1	39.7	38.0	1.8	133.8	30.0	17.0	13.0	13.0	1.9
TOTAL		433.8	445.5	-11.8	887.7	222.0	170.0	52.0	24.0	18.1

Table 1. Time related productivity measures for the eight products.

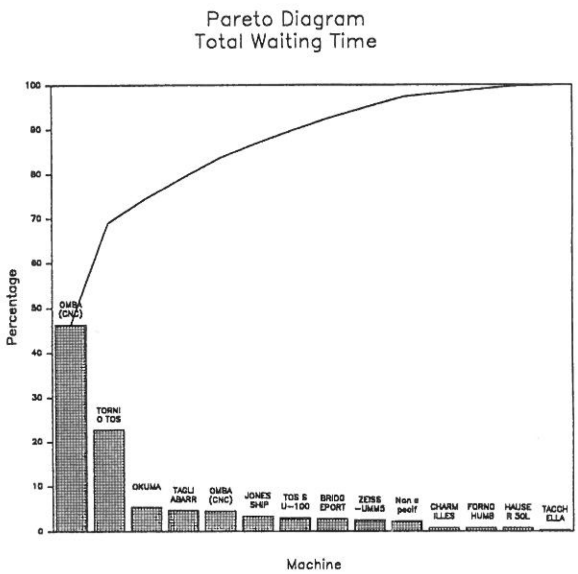

Fig. 2. Distribution of waiting time (hours) across different machines.

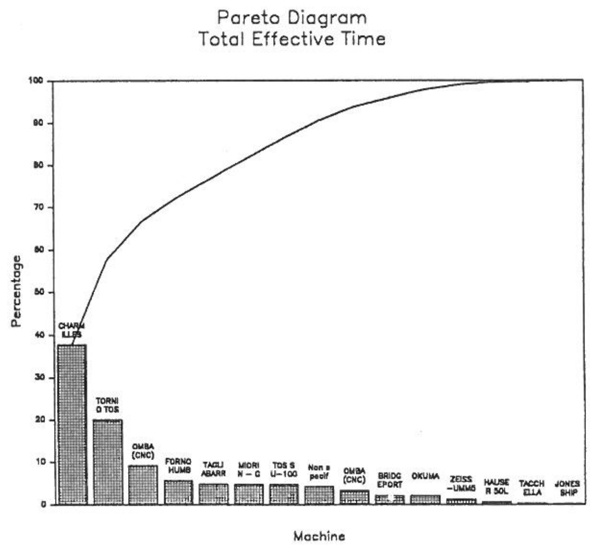

Fig. 3. Distribution of effective time (hours) across different machines.

ing schedules were not feasible. Thus, Table 1 not only provides a basis for establishing production plans, but also for focusing on potential productivity improvements, such as decreasing excessive waiting time. In order to accomplish this, special Pareto diagrams were created, where waiting or actual hours are treated as defect frequencies. In such a way, it is possible to visualise the most critical factors that total waiting or actual time could be attributed to. Figure 1 illustrates the fact that 70% out of total waiting time refers to the operations without any specific problem indicated, while the longest problem-related waiting time (15% out of total) is associated with the problem denoted as "machine occupied". The fourth problem in the order of importance is caused by machines not functioning. Therefore, another Pareto diagram was produced, as presented in Figure 2., showing how total waiting time is distributed across machines. Nearly 70% out of total waiting time is accumulated from the operations performed on just two machines. Yet, the first one accounts for less than 10% out of total actual time, as illustrated in Figure 3, showing the machines in the order of utilisation. It is interesting to note that almost 60% out of total actual production hours, recorded in the experimental period is attained at only two machines. Yet another display of the waiting time distribution is provided with the histogram, stratified by machines, as presented in Figure 4. Here, the actual values of excessive waiting times, the outliers, such as a single operation with 160 hours waiting time, could be identified.

Finally, the following principal conclusions have been reached:

– Productivity and late deliveries are very unequally distributed among the products. Recording of the actual and waiting time could ease the production planning, and, hence, decrease administrative delay rate, and increase productivity;

– The most critical factors increasing waiting time, and, consequently, number of production-related delay days, are utilisation of certain critical machine(s), product priority and level of complexity. In particular, problems with the

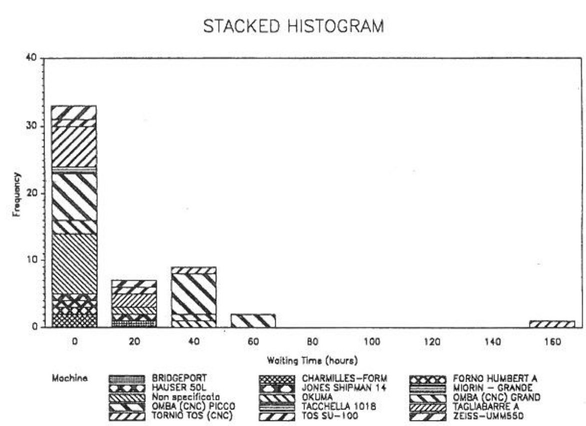

Fig. 4. Histogram of waiting time (hours), stratified by machines.

machines (occupied, out of order) are causing the longest time lags between successive operations, and the lowest productivity;

– Problem-free waiting time is too long;

– Actual labor hours are unequally distributed among machines and operators.

Thus, the results of the study provided a basis for enhanced decision making with respect to production planning and to the corrective actions, leading to process improvements.

5. Conclusions

A computerised, but simple process improvement tool has been described and demonstrated. It is primarily designed as a rough diagnostic instrument for the production processes in relatively small manufacturing departments, where no data are being collected nor recorded. Nevertheless, by utilising different forms available with PILOT for data collection, also the questions of productivity, efficiency and quality could be addressed. A large variety of available data analysis techniques and graphs, including the Ishikawa's 7 tools, makes it possible to visualise and present the data in a simple and self-explanatory way.

The application is specially suited to resolving the problems of high waiting and lead-time.

One of the most important characteristics of PILOT, though, is its simplicity to apply and use, with no special devices required. All the data entry, computation and analysis is, in general, performed off-site.

The main distinction between the more crude paper-and-pencil approach to process improvement and PILOT (data-entry-forms approach), is that the former, although easier to implement, does not allow for tracing down sources of out-of-control conditions. Thus, to a certain extent, even the most rudimentary type of data recording, without any data entry and analysis to follow, may help in controlling the variability of the process. However, when capturing all relevant information with specially designed forms, the cause-and-effect type of analysis may be performed, too.

The results of PILOT application serve primarily for measuring the productivity and/or quality in a selected manufacturing department, and for focusing to the most critical problems. Yet, they also provide a route to eliminating special causes of excess variability, to variance reduction and to process optimisation. Thus, PILOT may be employed as a first step toward more complex but more effective improvement implementations, such as complete statistical process control charting information systems, a designed experiment, or even a discrete event simulation study.

Nevertheless, it should be pointed out, that it is up to the management and technical staff in a company to implement the PILOT application in the best possible way, following the instructions provided, and to take subsequent actions according to the results obtained. If so, process improvements are sure to follow.

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