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THE APPLICATION OF PARETO DISTRIBUTION PRINCIPLE TO QUALITY CONTROL IN REPAIR WORKSHOPS

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ABSTRACT

Pareto principle of maldistribution is based on the fact that in the manufacture or repair of hardware there are almost always a few kinds of defects that loom large both in severity and frequency of occurrence. In either case, these defects are significant because they are costly. The principle states that a relatively few items will account for a disproportionately large amount of total effect. It has been described as a method for distinguishing the significant few from the trivial many.

The paper presents a case study where pareto analysis is applied to the defects that are encountered in the machining and assembly processes in an automotive engines major repair workshop. The kinds and distribution of defects are recorded. The vital defects that should take a great deal of consideration if the quality is to be improved, are found out. This enables stressing on quality weaknesses and sheds light on vital problems and rationalizes decisions for solving quality problems.

INTRODUCTION

The "Pareto principle" has by this time become deeply rooted in our industrial literature. It is a shorthand name for the phenomenon that in any population which contributes to a common effect, a relative few of contributors account for the bulk of the effect.

Vilfredo Pareto, an Italian sociologist and economist, discovered an analytical method that has come to have very important value in the economic control of quality. Pareto observed the phenomenon of maldistribution as applied to distribution of wealth and advanced the theory of a logarithmic law of income distribution to fit the phenomenon. Applications of this principle to quality control appears to have been introduced by Joseph M. Juran (3) & (4), previously applied effectively in industrial engineering in reducing losses in manufacturing processes and production controls.

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In the field of quality control, the principle is based on the fact that in the manufacture of hardware there are almost always a few kinds of defects that loom large both in severity and frequency of occurrence. In either case these defects are significant because they are costly. Pareto principle thus, indecates where to direct one's effort which is of tremendous benefit. One of the benefits is to efficiently allocate inspection manpower according to the relative importance revealed by the "Pareto" analysis in the sense that some parts will receive more inspection than the others (1). Another benefit is to find out the defects that should be reduced in order to improve quality and reduce cost (2). Those are the vital and significant few defects as distinguished from the trivial many.

The undertaken research, aimed at applying "Pareto" analysis to all kinds of defects that may occur in the machining and assembly processes included in the major overhaul of automotive engines in order to rocgnize vital defects and take actions to treat their causes. The analysis of defects at the considered repair workshop during a period of one month was utilized in addition to interviewing quality personnel and workers. It is to be said that the findings are to a great extent result of the specific circumstances of most of the similar workshops in Egypt including the problems encountered in materials and spare parts supply, technical status of the equipment and other factors affecting the performance of manpower that are the problems of the industrial sector in general. It is believed that the results, therefore, apply to any other similar workshop.

It was intended to deal with a case of a repair workshop in this research bearing in mind that, in Egypt, the application of quality control techniques to repair workshops is not given the same amount of concern as compared to the concern given in case of factories. The research revealed that all the techniques of analysis of defects apply.

ANALYSIS OF DEFECTS IN REPAIR WORKSHOPS

Needless to say, the efficient quality control system depends mainly on an efficient system for data gathering, recording and analysis in the field of quality especially data concerning defects. Unfortunately, in Egypt, the activity of keeping quality history for different kinds of defects does not take the sufficient deal of concern. That is, the inspection process is usually performed to examine the quality level at a certain moment and actions are taken immediately according to the situation without recording the results of inspection and the actions taken which enables building up a quality history over a certain period of time. Thus, the opportunity of gaining benefits from the analysis of defects history is wasted.

In short, one of the major deficiencies of the quality control system in the Egyptian industry is the lack of quality information. The activities of data gathering, recording, storage and retrieval are not performed in the right way. Quality managers are in most cases unable to submit reports about quality because they, first do not have the enough recorded data and second they are usually not asked to submit such reports by their superiors.

It is so easy to keep records about defects by using especially designed data sheets in which each quality characteristic is given a code number and the frequency of out of control occurrence for each characteristic over a period of time is recorded. The careful study of defects history enables the quality manager or quality engineer to recognize the significant defects and try to find

out their causes. He may find that a specific defect is caused by one or more of the causes that belong to one or more of the following Ms:
Material - Machining & Mounting - Man - Material Movement - Maintenance.

The possible causes that belong to each one of the Ms mentioned above are given in what follows.

1. Material
   a. Improper composition.
   b. Improper mechanical properties.
   c. Discontinuities (voids, cracks, holes, ...).

2. Machining and Mounting
   a. Deterioration of material due to temperature during processing.
   b. Fracture of material due to forming.
   c. Faulty equipment or tools-improper adjustment of equipment or tools.
   d. Improper mounting or improper fits between parts.

3. Man
   a. The operator's skill is not sufficient.
   b. The operator works under fatigue.
   c. The operator has problems in muscular control.
   d. The working environment is not suitable.
   e. The operator is not alert or not paying enough attention.
   f. The operator is physically or psychologically unfit for the job.
   g. The operator is not satisfied with his compensation.
   h. The operator is not completely familiar with the process know-how.

4. Material movement
   a. Environment during shipping are not suitable.
   b. Materials or parts are not properly stored.
   c. Technical requirements of maintenance during storage are not fulfiled.
   d. Materials or parts are not properly handled or transported.

5. Maintenance
   a. The machine needs calebration.
   b. The machine needs periodical or seasonal preventive maintenance.
   c. Excessive wear of some parts of the machine.
   d. Lack of technical operating instructions.
   e. Maintenance operators are not efficient.
   f. The capability of the machine is no longer adequate.
   g. The life time of the machine is over.

Once the cause of defect is recognized, action can be taken to eliminate or reduce the effect of that cause. The cost analysis, on the other hand, may shed light on the defects that are cost consuming which calls for taking actions to treat the sources of these defects. The Pareto analysis is used as an effective tool for pointing out the sources of trouble, thus directing efforts towards the right way to quality improvement. The technique of Pareto analysis with some suggested development and the technique of plotting Pareto chart are elaborated through the following case study.

THE CASE STUDY

An automotive engines repair workshop that performs major overhaul with a production capacity of 20 engines per day is considered. The main sections of the workshop are: disassembly section, parts preparation section, machining section, assembly section and the section of running test. Inspection is performed in the five sections according to the quality plan the efficiency of which appears in the final running test. The defects are therefore detected during the running test which is performed for all the engines. The system that was followed before in the workshop is to treat the detected defects without keeping records about the defects. Before the study starts, a special data sheet for recording defects data was designed and put in use in the five sections.

The study extended to cover one month production (500 engines) for which the defects detected during the final running test are recorded in the data sheet.

The analysis of defects started immediately after accumulating data for the 500 overhauled engines. The two usually followed ways for ranking the defects are:

a. According to cost incurred in treating the defect.
b. According to the defect frequency of occurrence.

It was suggested in the considered study to combine the two ways in one composite way that take into consideration the two factors, cost and frequency, according to their relative weights. It is though that a weight of 60% for cost and 40% for frequency would be convenient.

Concerning the cost factor, it was suggested to classify defects according the cost of repair into the following categories:

- Category A: defects that necessitate engines disassembly and remachining or replacement of major parts, e.g, cylinder walls excessively tapered or out of round. Defects of this category may be given 50 points out of 60.
- Category B: defects that necessitate engine disassembly and adjustment of some parts without remachining or replacement of major parts e.g, bent crankshaft. Such defects are suggested to be given 40 points out of 60.
- Category C: defects that call for disassembly and remachining or replacement of a major part e.g, cylinder head needs surface grinding. Thirty points out of 60 is thought to be fair enough for the defects of this category.
- Category D: defects that are treated by disassembly and adjustment or replacement of a minor part or more than one part e.g, cylinder head gasket failure. The suggested number of points is 20.
- Category E: defects that necessitate adjustment of a part or some parts without disassembly e.g, adjustment of the tightening torque of cylinder head bolts. An earning of 10 points out of 60 is suggested.

On the other hand, concerning the frequency of occurrence factor, the defect of greatest frequency of occurrence is given 40 points out of 40 and the defect of smallest frequency is given 5 points and the frequencies in between are given points by interpolation.

The defects are usually detected by their consequencies such as sound (noise, knocks, detonation, ...), leakage (water, oil, gas, ...), exhaust colour or smell (burning oil, ...) and deficiency of engine performance. Some of the consequencies are caused by several defects, therefore investigation should be started to recognize the specific defect that caused a certain consequency.

In the undertaken research defects recording was postponed until the discovery of the real defect. That is, our interest was recording the defect not the consequency of the defect since the main objective is recognizing the vital significant defects to treat their causes.

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The detected defects and their suggested code numbers are given in table-1. The frequency and cost category for each defect is shown in table-2. In the same table, the number of points estimated for each defect concerning frequency and cost are given, while the last column of the table includes the combined index obtained by the addition of the number of points representing cost to the number of points representing frequency. The defects are then ranked according to their indexes, the results are then plotted on the Pareto chart shown in Figure-1.

Table (1): Detected defects and their code numbers

Condition	Detected Cause	Code No.
Main Bearing Noise	- Excessive main bearing clearance	A-1
	- Excessive crankshaft end play	A-2
	- Insufficient oil supply	A-3
Connecting Rod Bearing Noise	- Excessive bearing clearance	B-1
	- Crankshaft connecting rod journal out of round	B-2
	- Misaligned connecting rod	B-3
	- Improperly tightened conrod bolts	B-4
Piston Noise	- Excessive piston to cylinder wall clearance	C-1
	- Excessively tapered cylinder wall	C-2
	- Broken piston ring	C-3
	- Loose piston pin	C-4
Valve Train Noise	- Bent push rod	D-1
	- Worn rocker arms	D-2
	- Worn trappet face	D-3
	- Broken valve springs	D-4
	- Excessive stem to guide clearance	D-5
	- Bent valve	D-6
	- Loose rocker arms	D-7
Power Not Up To Normal	- Leaking engine valves	E-1
	- Cylinder head gasket failure	E-2
	- Incorrect valve timing	E-3
	- Leaking piston rings	E-4
External Oil Leaks	- Broken oil pan side gasket	F-1
	- Broken oil pan front or rear oil seal	F-2
Burning Oil in Exhaust	- Worn stems and valve guides	G-1
	- Excessively loose piston rings	G-2
	- Worm cylinder walls	G-3
No Oil Pressure	- Oil pump malfunction	H-1
	- Sticking oil pressure relief valve	H-2
	- Loose oil inlet tube	H-3
Low Oil Pressure	- Weak oil pressure relief spring	I-1
	- Excessive oil pump clearance	I-2
	- Excessive camshaft bearing clearance	I-3
High Oil Pressure	- Inaccurate oil pressure sending unit	J-1
	- Oil pressure relief valve sticking closed	J-2

Table (2): Estimated Indexes of defects

Defect Code No.	Cost factor		Frequency factor		Cost frequency combined index
	Cost Category	No. of points/60	Frequency	No. of points/40	
A-1	A	50	38	28	78
A-2	A	50	5	6	56
A-3	A	50	6	7	57
B-1	A	50	35	26	76
B-2	A	50	5	6	56
B-3	B	40	26	21	61
B-4	E	10	42	31	41
C-1	B	40	16	14	54
C-2	A	50	26	21	71
C-3	A	50	9	9	59
C-4	B	40	7	7	47
D-1	D	20	56	40	60
D-2	D	20	7	7	27
D-3	D	20	9	9	29
D-4	D	20	9	9	29
D-5	D	20	13	11	31
D-6	D	20	33	25	45
D-7	E	10	9	9	19
E-1	C	30	5	6	36
E-2	D	20	19	16	36
E-3	D	20	13	11	31
E-4	B	40	9	9	49
F-1	D	20	14	12	32
F-2	D	20	11	10	30
G-1	D	20	10	9	29
G-2	B	30	5	6	36
G-3	A	50	9	9	59
H-1	C	30	13	11	41
H-2	C	30	3	5	35
H-3	E	10	5	6	16
I-1	C	30	10	9	39
I-2	C	30	15	13	43
I-3	A	50	8	8	58
J-1	D	20	45	33	53
J-2	C	30	7	7	37

According to the Pareto chart shown in figure-1 investigation was started to recognize the causes of the significant defects that have relatively high cost/frequency combined index. In the considered case it is obvious that the defects of relatively high index are: A-1, B-1, C-2, B-3 & D-1. The analysis of defects causes contributed to the following findings:

1- Concerning the defects A-1 and B-1 that stand for "excessive bearing and connecting rod bearing clearance", it was found that the source of trouble was not the matching process of bearing shells but the material of bearing shells themselves. The long improper storage of bearing shells has resulted in changing their properties. The rest of the group were set aside and instructions were given about the proper way of storage including the application of first in first out system.

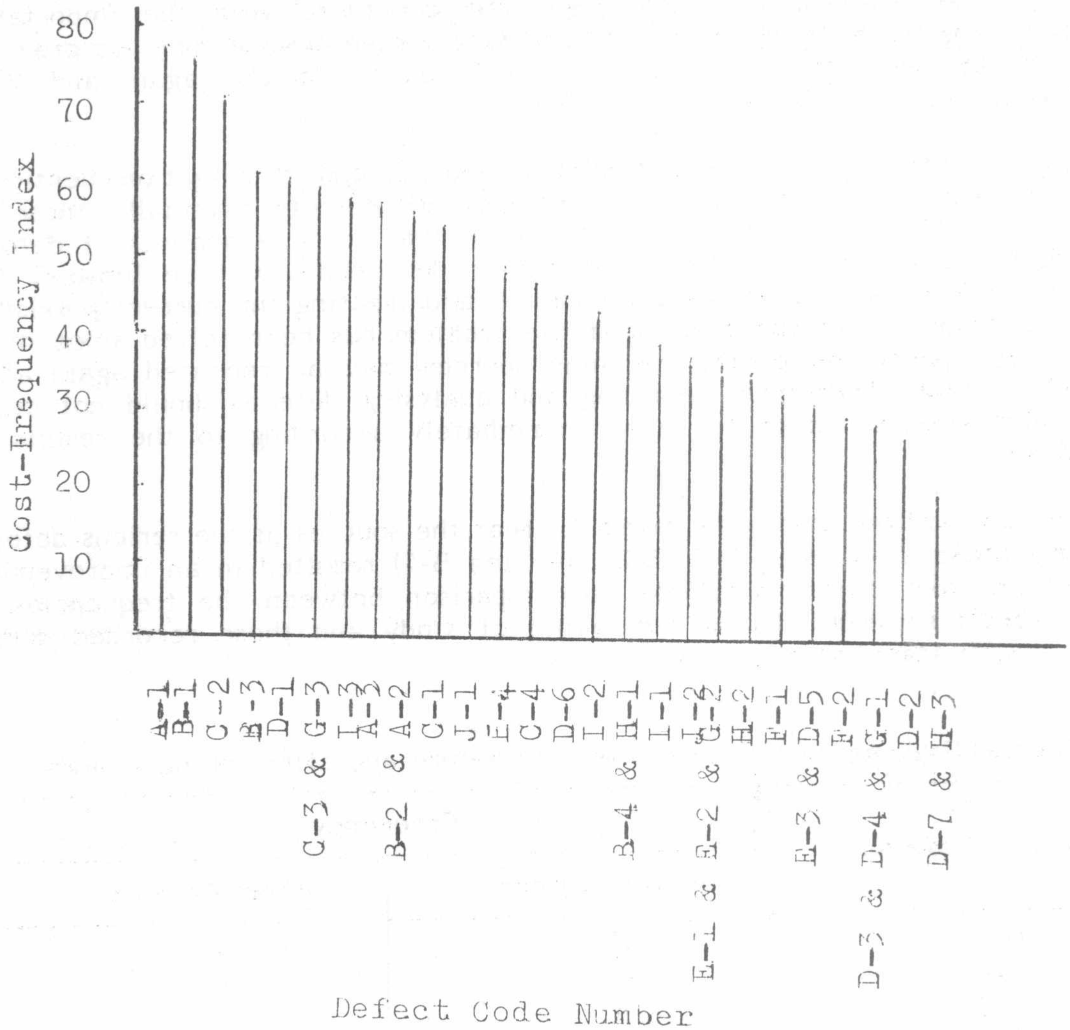

Figure 1 Combined Cost-Frequency Pareto Chart

2- Concerning the defect C-2 which is "excessively tapered cylinder wall," it was found that one of the workers is mistaken in the way of measurement. He was not following the instructions stating that the wear in the cylinder bore should be measured on three different spots, he was performing measurement on the top and bottom only. He was trained on the right way of measurement and the supervisors were notified to pay attention to the way of measurement followed by the other workers.

3- Concerning the defect B-3 "Misaligned connecting rod", the investigation revealed that the checkover for bending and twisting by using the connecting rod alignment jig was omitted. The quality personnel were directed to carrying out the misalignment test and the facilities of misalignment removal were put in use.

4- Concerning the defect D-1, that is "bent push rod", it was discovered that inspection processes do not include checking push rods for bending. A test stand for such an inspection was supplied and the inspectors were trained on performing it.

5- It was found convenient to take into consideration one of the defects that possess relatively low index however it shows relatively high frequency of occurrence that is, defect B-4 "improperly tightened connecting rod bolts". Some of the workers were seemingly not convinced with the importance of tightening the bolts to the right tightening torque despite they are provided with torque wrenches. They were warned not to do this again and their supervisors were notified to make checks.

As a result of the actions taken according to analysis and investigation mentioned above, an obvious decrease in the frequency of defects especially those of high cost, has been achieved. It is to be noted that such an analysis of defects is not to be done once and for all otherwise the results will be limited. The sources of defects are numerous and dynamic and treating the currently existing sources of defects does not mean that the problem has been solved since other sources may appear, moreover, the same sources may be repeated again after a period of time. Therefore, recording and analysing defects should not cease and suitable actions should be taken immediately according to the results of the analysis.

In figures, the actions that were taken to treat the sources of the serious defects mentioned above (A-1, B-1, C-2, B-2, D-1 and B-4) resulted in an improvement as shown in table 3 which includes a comparison between the frequencies of serious defects recorded during the month of study and those recorded during the next month after taking actions.

Table (3): Frequencies of serious defects before and after taking actions

Defect Code No.	Frequency	
	Before Actions	After Actions
A-1	38	3
B-1	35	3
C-2	26	1
B-3	26	-
D-1	56	5
B-4	42	4

CONCLUSIONS

From the above study we can conclude the following:

1- The main goals of the inspection process are not achieved without recording and analysing the detected defects. The results of analysis should be utilized as a basis for directing quality personnel towards actions that realize quality improvement.

2- The techniques of analysis of defects are applicable to repair workshops as well as to the factories.

3- The two usually used Pareto charts, that is frequency based chart and cost based chart, could be summarized in one chart that may be called combined frequency/cost based chart that considers and index representing cost and frequency.

4- The application of Pareto analysis and other related techniques results in improving the quality.

5- Analysis of defects is a dynamic process that not to be done once and for all otherwise the benefits will be limited.

REFERENCES

(1) Hansen, B.L., "Quality Control, Theory and Applications" Prentice-Hall of India, New Delhi, 1966, pp. 161-170.

(2) Hayes, G.E. & Romig, H.G. "Modern Quality Control" Glencoe Publishing Co. Inc., California, 1982, pp. 738-741.

(3) Juran, J.M., "Then and Now in Quality Control" Quality Progress, May 1975, pp. 8-9.

(4) Juran, J.M., "Quality Control Handbook" Third Edition, McGraw-Hill, 1974, pp. 2-16 to 2-19.