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Pareto's Law and Modern Management

C. Jay Slaybaugh

What many businessmen have known instinctively for a long time — that a small percentage of salesmen make the majority of sales, that a small percentage of products account for most sales volume — was expressed mathematically by a nineteenth-century Italian engineer, Vilfredo Pareto. Here are some other business applications of value to management —

PARETO'S LAW AND MODERN MANAGEMENT

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PARETO'S LAW states, in essence, that the significant items in a given group normally constitute a relatively small portion of the total items in the group. Thus, a majority of the items in the total will, even in the aggregate, be of relatively minor significance.

This law was developed at the end of the nineteenth century when Vilfredo Pareto, while studying the concentration of wealth and income in his native country, Italy, found that a very large percentage of the total national income was concentrated in the hands of about 10 per cent of the population. Pareto had worked twenty years as an engineer and was mathematically oriented so his natural inclination led him to express this concentration of income in mathematical terms. The graphs shown in Exhibit 1 on page 54 demonstrate that Pareto's formula represents a family of curves depending on the value assigned to ∞ [mathematical symbol for infinity. Ed.].

The cumulative curves were developed from the income–number of persons curves. These cumulative curves will be the basis of the following discussion.

Pareto's Law in industry

For many years this relationship was considered an interesting phenomenon with very little practical use. However, shortly before World

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War II inventory control analysts discovered that when inventory items were plotted on a cumulative percentage graph in order of descending value, Pareto's relationship seemed to emerge. They observed that 10 to 20 per cent of the items in a given inventory accounted for 80 to 90 per cent of the total dollar value of the inventory. The remaining large number of items then accounted for a very small portion of the inventory dollar value.

Subsequent observation of other areas of business management has shown a widespread applicability of Pareto's Law. For example, 20 per cent of the products of a company usually account for 80 per cent of its sales, 20 per cent of a firm's employees normally account for 90 per cent of the tardiness, 10 per cent of a firm's accounts receivable may account for 80 per cent of the dollars receivable, and 10 per cent of a firm's engineers may be responsible for 90 per cent of its patents. Indeed, Pareto's Law appears to have almost universal application.

Uniform control systems

In many instances this relationship is not recognized by managers, but even when it is recognized it often has little or no influence on the management systems used. For example, although a company may recognize and respect Pareto's Law we can usually expect to find uniform inventory records and controls for each inventory item. In this inventory each item will be stocked in three- or four-month-usage quantities, each item will require a material requisition for withdrawal, each receipt or disbursement of the item will be posted to the inventory records, and periodic counts will be taken to verify or correct the inventory records.

This uniform control system will be used if the items are high-usage fifty-dollar items or low-usage twenty-five cent items.

In examining other areas of management one often finds that when a shop or office is covered by time standards management will feel that there should be equally precise standards on each task. In a typical project control system we find the same amount of control effort allocated to each item in the project. In systems design, management will normally attempt to provide a consistent level of detail for each and every task in the total system.

In any of the above uniform control situations we can expect that occasionally some very critical items will not be given sufficient attention and the control system will appear to be inadequate. To solve this problem management usually raises the general level of uniform control across the board; records are made more detailed, standards are made more precise, and so on. However, if Pareto's Law is applicable, the majority of this increased control effort is being directed toward an area of little significance. In terms of importance the low-dollar-value or trivial items will be greatly overcontrolled. Typically, we find that 70 to 90 per cent of our management effort is spent on 10 per cent of the total dollar value of the items being controlled and only

EXHIBIT I

PARETO'S LAW

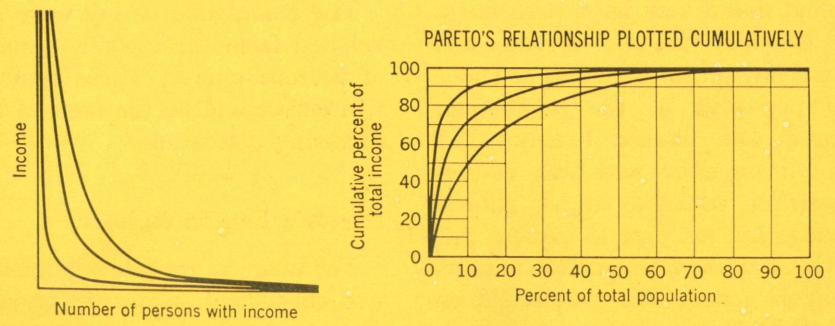
Kindall, M. G. and Buckland, W. R. *Dictionary of Statistical Terms*, Hafner Publishing Co., New York, N. Y., 1960.

PARETO'S LAW: An empirical relationship describing the number of persons x whose income is y, first advanced by Pareto (1897) in the form

$$x = Ay^{-(1+\alpha)} \qquad 0 \leq y \leq \infty$$

The expression is now used to denote any frequency distribution of this form whether related to income or not. The variable y may be measured from some arbitrary value, not necessarily zero.

The coefficient α in the expression for the Pareto curve is generally referred to as the Pareto Index. It affords evidence of the concentration of incomes, or, generally, of the concentration of variate-values in distributions of the Pareto type.



10 to 30 per cent of our management effort is spent to control 90 per cent of the dollar value.

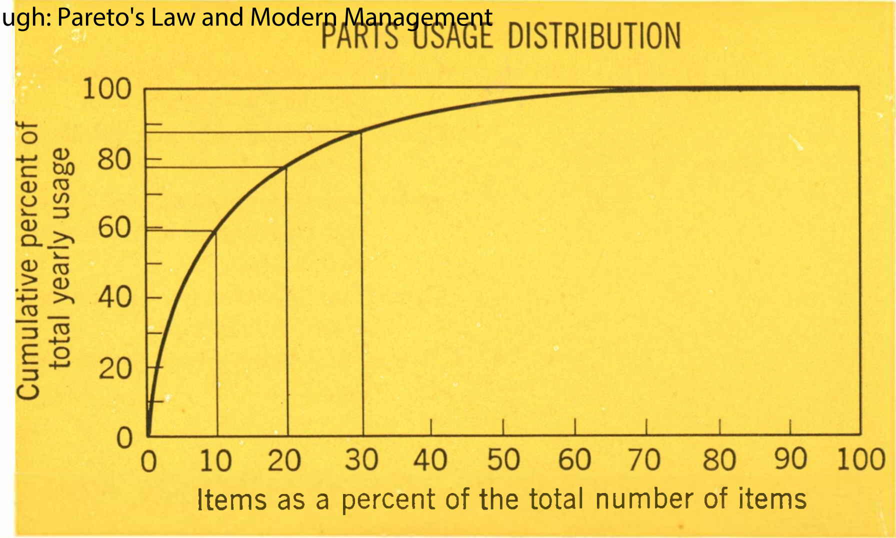


EXHIBIT 2

Efficient management

In terms of return on the investment of our time and effort the uniform control approach is not sound. Efficient management exists when the amount of management effort applied varies in direct relationship to the importance of the item being managed. A uniform control system that provides adequate control for the high-value items overcontrols the low-value items. The uniform system that is economically justifiable for the low-value items does not provide adequate control for the high-value items. Effective management requires the isolation of the vital factors of an operation from the insignificant factors and the development of management systems that are economically justified for each of these groups.

How does this concept affect the individual manager? If he is to be effective, each manager must segregate the important elements under his control from the insignificant ones. He must then allocate large amounts of his time, effort, and executive skill to the most important items in his sphere of operations. In short, these are the areas where his capabilities and judgment can accomplish the most for his company.

What happens to the less important items under his control? These items can be delegated to subordinates as training assignments with amounts of supervision varying with the importance of the item. As an alternative, many of these items can be put into data processing systems and controlled by the exception principle.

The really unimportant or trivial items that fall to the extreme right of Pareto's curve should be grouped for exception reporting, or some kind of rough, virtually automatic, system should be set up to control them.

The following examples demonstrate the application of this concept to actual management problems. The reader should not infer from the few examples that this general approach is limited to these or any other particular areas of management. The number of examples is limited only by space and consideration of the reader's time.

Inventory management

Inventory control provides a classic example of the application of Pareto's Law. The graph shown in Exhibit 2 above is the actual parts usage curve of a small manufacturer of electronic instruments. It shows the dollar usage plotted cumulatively with the highest-use items at the left descending to the lowest-use items at the right. Both the number of items and the dollar usage are plotted as percentages of their respective totals.

The inventory shown in the graph included 1,164 items. The 233 highest-use items (20 per cent) accounted for 76 per cent of the total annual dollar usage. The rightmost 50 per cent (582) of the items accounted for only 6 per cent of the annual dollar usage. This definitely fits into the family of curves represented by Pareto's Law.

Before this relationship was demonstrated to the company, it had one policy and system for the control of all of its inventory items. When the graph was completed, it became obvious that on the basis of economic importance the 233 items at the left of the graph called for more management attention than the remaining 931 items.

Once a distribution fitting Pareto's Law has been identified the management system should be established in such a way that the required management effort and cost vary in relationship to the importance of the items being managed. In inventory control, the classic "ABC" approach is normally the best method of reaching this objective.

Some commonly used "ABC" systems arbitrarily define the 20 per cent of the items accounting for the highest dollar use as A items, which are ordered in quantities approximating one month's

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$$Q_o = \sqrt{\frac{2C_sS}{rC_p}}$$

WHERE

Q_o = The economic order quantity, EOQ (units)
C_s = Replenishment cost (dollars per order)
r = Inventory holding cost (dollars cost per year per dollar of inventory)
C_p = Purchase cost per unit of the item (dollars/unit)
S = Total yearly usage (units per year)

HIGH-DOLLAR-USAGE ITEM	LOW-DOLLAR-USAGE ITEM
Assume:	*Assume*:
C_s = \$5 per order	C_s = \$5 per order
r = \$.20 annually per dollar of inventory	r = \$.20 annually per dollar of inventory
S = 1200 units per year	S = 1200 units per year
C_p = \$20 per unit	C_p = \$.05 per unit
Then:	*Then*:
EOQ = Q_o = 55 units per order	EOQ = Q_o = 1100 units per order
½-month usage \$1,100 per order	1-year usage \$55 per order

ECONOMIC ORDER QUANTITY

EXHIBIT 3

usage. The next 30 per cent of the items are classified as B items and are ordered in quantities equivalent to two months' usage. The remaining 50 per cent of the items are classified as C items and are purchased in six months' quantities.

Industrial engineers have developed precise techniques to determine the Economic Order Quantity (EOQ) for a particular inventory item. By interrelating for each item the cost of replenishing inventory, the cost of carrying inventory, the purchase price, the effect of quantity discounts, and total yearly usage it is possible to determine the optimum order quantity for the item. The EOQ model employs the rationale implicit in the "ABC" approach but does so on a basis of minimizing the costs involved. This is demonstrated in the EOQ illustration in Exhibit 3 on this page, which shows that the high-dollar-usage item may be purchased in half-month quantities while the low-dollar-usage item is purchased in one-year quantities.

The "ABC" system and EOQ computation both establish reorder quantities that require more frequent observation and evaluation (ordering) of the high-dollar-usage items. Thus, in the order cycle, management attention is directed to the more significant items and away from the less significant items. This more frequent ordering of the high-dollar-usage items (20 per cent of the items—80 per cent of the dollars) usually causes significant reductions in total inventory, and the less frequent ordering of the low-dollar-usage items (50 per cent of the items—5 per cent of the dollars) tends to reduce the total number of orders written.

When made for each item in a large inventory a manually performed EOQ calculation can be a formidable task. However, the application of computers to this task has made it relatively simple. In the absence of a computer, nomograms (alignment charts) can be used to achieve the same results by drawing a few lines. This can easily be done by clerical personnel.

'A' items emphasized

After the order quantities and reorder points have been established, the A items continue to receive the majority of the available inventory management attention. The value of these items can justify large amounts of management judgment, attention, and time. Each time an A item comes up for reorder, a new usage forecast is made, based partially on history and partially on management judgment. Each time one of these items is ordered, the purchasing agent will attempt to find a less expensive source or a source that will stock the item and deliver it as needed. Inventories of these items are held at a minimum. This requires close scrutiny and added supplier expediting.

While the above measures are time-consuming and expensive, they cover only 10 per cent of the items in inventory, and the resulting savings will more than justify their cost. The management time required for this additional control of A items is normally made available by reducing the time required to manage the C items, which constitute 50 per cent of the items and 5 per cent of the total dollar value. This reduced control of C items will be discussed below.

The B items are handled in the usual manner. These items normally require little special attention but do justify issuing requisitions, posting of inventory receipts and disbursements, and periodic counts to correct the perpetual records. Each time these items are reordered, the EOQ and reorder point can be easily evaluated using the computer or nomograms to reflect current usage, cost, and delivery conditions.

The C item reorder points are set slightly higher than normal. This will add very little to the total cost of inventory but will reduce the danger of stockout that might result from the fact that C item purchase orders are not followed up or expedited under normal conditions.

Where possible, the C items are expensed on receipt and used as they are needed without preparing stores requisitions or updating inventory records. The stock level for these items is then controlled by a two-bin system. This procedure eliminates a significant amount of the clerical effort and operates automatically. Thus, the management effort is minimized on the 50 per cent of the items in inventory that account for only about 5 per cent of its dollar value.

Experience has shown that inventory control systems based on Pareto's Law invariably reduce the costs associated with inventory. These systems minimize the clerical effort devoted to the large majority of the items that account for only a small percentage of the total dollars in inventory. At the same time they reduce the capital in inventory by making significant reductions in the high-dollar-usage items that aggregate 80 per cent of the inventory dollar value of the inventory. This in turn reduces the cost of this capital, reduces taxes, reduces insurance cost, reduces obsolescence costs, and reduces the storage space required.

In addition to the cost savings, a system of this type will maintain or improve customer service by taking reorder decisions out of the "seat of the pants" control of clerks and establishing reorder points and safety stocks (shortage control) on a sound analytical basis.

The subject of inventory control cannot be adequately covered in a discussion of this short length; however, this discussion has illustrated a specific application of Pareto's Law to an industrial inventory control problem and has served to demonstrate the use of a virtually automatic system to control the items at the right of Pareto's curve.

Work measurement

Pareto's Law also may be applied to work measurement.

A large nationwide wholesale distribution company wanted to set time standards for the clerical functions carried out in each of its twenty-nine offices. A study was inaugurated to determine how many clerks were required in each office and to give top management an indication of how efficiently each was functioning. Additional benefits expected from the establishment of clerical standards were to point out the most profitable areas for clerical systems work, to provide a sound estimate of savings to be achieved by systems changes, and to evaluate the effect on clerical costs of system improvements after installation.

There were nearly 300 different clerical tasks carried out in the twenty-nine offices. As might be expected, the time and money available to develop the standards was limited. The problem, then, was one of determining how to establish workable standards with limited resources.

The graph in Exhibit 4 on this page shows the percentage of the total clerical hours in the offices plotted against the percentage of the total number of clerical tasks. The time values are plotted cumulatively with the most time-consuming task at the left, descending to the least time-consuming task at the right.

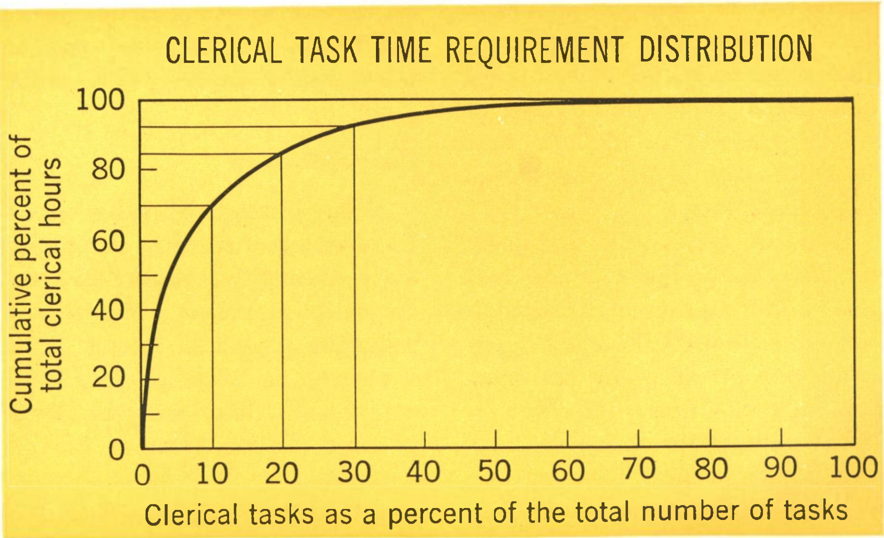
Here again Pareto's relationship emerges. Establishing standards for 300 clerical tasks would be extremely expensive and time-consuming. However, examination of the graph shows that approximately 70 per cent of the work load can be covered by establishing standards for only 10 per cent of the tasks.

Since the manpower available to develop the standards was limited and the time was short, standards were set on only the small number of tasks that consumed the major portion of the clerical time.

Careful evaluation of the remaining work load revealed that it varied directly with the basic office work load which was to be covered by standards. Once this was demonstrated a percentage allowance to cover this work was developed by the use of special time and task reports. These reports were completed by each clerk for a period of time that included the complete clerical operation cycle.

The clerical staff requirements

EXHIBIT 4



were calculated by taking the number of transactions covered by standards (i.e., the number of invoices processed, number of receiving reports processed, etc.) multiplied by the standard time for each task. This calculation provided the hours required for the work covered by standards. To this figure the percentage allowance for work not covered by standards was added to calculate the total work load requirement. Finally, a percentage was added to allow for such factors as personal time, errors, fatigue, etc., to calculate the total clerical hours required to staff a given office adequately.

This example demonstrates that if the tasks to be covered by standards are properly chosen a great majority of the man-hours can be covered by establishing standards on a relatively small number of tasks. Thus, Pareto's Law provides a sound basis for allocating effort in time standards development and maintenance so that maximum benefit can be realized from minimum effort.

If the time standards had been developed for a machine shop, perhaps an attempt would have been made to use engineered standards for the 20 per cent of the tasks that account for 85 per cent of the total hours. The remaining tasks might then be covered by analyzing historical data. Specifically, if we take historical data on the last three runs of a particular operation and have the shop foreman and an industrial engineer evaluate them briefly, and adjust the historical data if necessary, we have some inexpensive but sound approximate standards to apply to the 80 per cent of the jobs that represent only 15 per cent of the shop man-hours.

Thus, as previously discussed, we have again directed the majority of our management attention and effort toward the most significant area of the project in question while minimizing the effort directed toward the less significant area of the project. This provides a maximum return on a minimum expenditure of our management resources.

Auditing

In order to form an opinion on a client's financial statements the auditor must test many of the client's records. The areas that must be tested include accounts payable, accounts receivable inventories, prepaid expenses, capital assets, and many others. In most of these areas we can expect the relationship represented by Pareto's Law to exist. When it does exist the auditor can concentrate his testing efforts on the high-dollar-value area and test the relatively insignificant area on a statistical sampling basis. This allows him to determine that the accounts are accurate within the limits of materiality while minimizing his client's audit cost.

For example, the graph in Exhibit 5 on page 59 shows a cumulative distribution of receivable dollars versus the number of receivable accounts for a small manufacturer of specialized industrial equipment.

Recognition of this relationship allows the auditor to make specific major tests (such as circularization) of 96 per cent of the dollar amount of accounts receivable by reference to only 20 per cent of the accounts. The remaining 80 per cent of the accounts may be tested but do not warrant the time and effort on each account that are justified by the larger accounts.

The use of this technique allows the auditor to minimize the client's audit cost without compromising the accuracy or quality of his audit.

Cost reduction

A large industrial valve manufacturer found itself in an increasingly competitive market and consequently launched a drastic cost reduction program.

One of the areas selected for a concentrated cost saving effort was product design. Most of the designs used by the firm were many years old and had been developed when materials and labor were cheap. Therefore, almost all of the product lines had excesses of material and unnecessarily expensive machining requirements. However, a line design change would be expensive since it required engineering for each size valve in the line, new patterns for the cast parts of each size, and new shop tooling to cover each size valve in the redesigned line. In addition, there were the ever-present problems of the limited available engineering time and limited capital for new patterns and tooling.

Redesign of the company's 129 different lines with limited resources was obviously impossible. Here again Pareto's Law became a valuable tool to use in the solution of the problem.

The cumulative curve shown in Exhibit 6 on page 59 was plotted and 10 per cent (thirteen) of the product lines were found to account for 87 per cent of the total unit sales.

Studies were then made by the engineering group to determine the expected unit savings on each of the thirteen high-volume lines. The average unit savings on each line, extended by the number of units sold per year, provided the total estimated savings that could be expected from the redesign of the line. Given this information and the estimated cost of the alterations required by each line, redesign priorities were readily established.

This procedure eliminated the temptation to redesign only those valves with high unit savings. For example, use of the above analysis emphasizes the fact that a \$2-per-unit saving on a valve with sales of 90,000 units per year is much more worthwhile than a \$100-per-unit saving on a valve with sales of 250 units.

The cost reduction effort discussed in this example not only improved the company's profit picture, but also improved its products. As each valve was redesigned it was possible to incorporate all of the minor design improvements that previously by themselves could not justify new patterns, new tooling, etc.

Wide application

The examples and distribution curves that have been discussed illustrate just a few of the many possible applications of Pareto's Law to industrial problems. Many cases involving Pareto's Law and its application to marketing, purchasing, accounting, systems and procedures, data processing, and virtually any other phase of industrial management can be cited.

As a brief illustration of this point some other possible applications of the graphs contained in this article are as follows:

The parts usage graph would be very meaningful to a purchasing agent in directing his efforts to the high-dollar-usage items when considering cost reduction through alternative supply source development or when attempting to reduce costs through price negotiations.

This parts usage graph would also be quite useful to a value analysis staff in directing its studies toward the high-dollar-usage parts. The units sold graph would also be useful to the value analysts in pointing out the relative number of items manufactured and sold, to help direct their design evaluation efforts.

The clerical work distribution graph would be valuable to a systems group to indicate which systems have large concentrations of clerical work hours. These are the areas in which systems effort can develop the most spectacular savings.

The unit sales graph would be quite useful to a cost accounting group in developing a standard cost system. Accurate standard costs could be developed for the large-volume items at the left of Pareto's curve while less accurate standards or even historical costs could be used for those relatively insignificant items at the right of the curve. This will provide a sound cost accounting system without allowing the standard-setting group to become bogged down developing precise standards for the trivial items at the right of the curve.

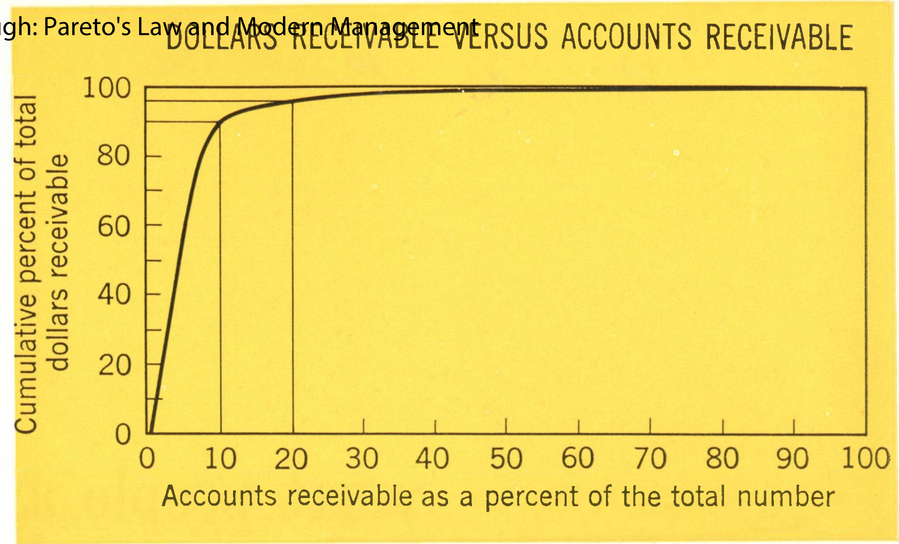


EXHIBIT 5

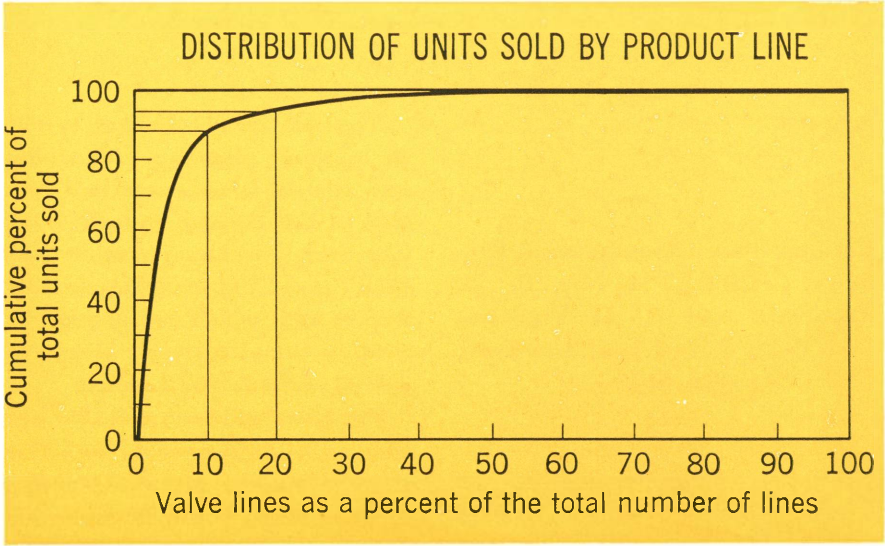


EXHIBIT 6

The accounts receivable graph can be used by credit and collections groups as a tool to help direct their efforts in limiting credit losses.

The examples discussed illustrate some of the numerous possible applications of Pareto's Law. Many more cases involving this relationship and its application to virtually every phase of management could be cited. Many examples of management failure, resulting from the failure of managers to recognize this relationship, could also be cited. Each of us has seen managers fail because they allowed themselves and their subordinates to become bogged down in trivia.

Pareto's Law cannot be applied to every management system, but it can be applied often enough so that the manager should always look for it. When it does exist, he should use it to help him allocate the majority of his management resources, including his own time, to those areas of his operation that will provide the maximum economic return.

Efficient management exists when the amount of management effort and cost applied varies in direct relationship to the importance of the item being managed.