Hardcopy in the Office Workflow

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In doing research for developing future digital products, we have analyzed worldwide management data at our disposal that pertains to analog plain paper copiers (PPCs). According to our copy volume data, average monthly copy volume is proportional to the square of the speed (copies per minute) of PPCs. The result of our analysis of the copy volume data provides new information relating to such factors as the scale of offices and the workflow within them (factors influencing average monthly copy volume). The shift in the information infrastructure from a copy-and-distribute to a distribute-and-print model is discussed. According to our field service data, mean copies between service visits is proportional to the half power of the average monthly copy volume. The result of our analysis of the field service data provides new information relating to such factors as the level of technology represented by each PPC series (influencing mean copies between service visits). The copy volume business with field service in the copy market is discussed in light of our new knowledge about both copy volume and product reliability.

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Introduction

The purpose of this study is to investigate monthly copy volume and product reliability of plain paper copiers. Our analysis is based on available worldwide market data.

In analog PPCs, we found that the average monthly copy volume is proportional to the square of the speed (copies per minute). We supposed that this relationship must originate in the scale of the office and its workflow. Office workflow is undergoing a shift from a copy-and-distribute to a distribute-and-print model.[1] At the same time, larger offices are expected to undergo a transition to smaller size, with the result that high copy volume environments may not be viable in the future. Further, the number of electronic documents that serve their purpose without being printed out as hardcopy will increase. The possibility of a declining need for hardcopy in the distribute-and-print office is a matter of primary concern for the hardcopy industry.[2]

We found that the mean copies between service visits is proportional to the half power of the average monthly copy volume. Product reliability is achieved by means of a high level of service quality. We looked at how copy volume (CV) and product reliability affect profit in the overall copy market. In developing new digital products, it is extremely important that the new technologies and systems maintain or even exceed the profit levels (based on copy and print volumes) and the product reliability (based on field service) already achieved with existing analog products.

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TABLE I. Speed of Earlier and Later Generation PPC Series in Copies Per Minute (cpm)

The earlier series	The later generation series
76 (cpm)	81 (cpm)*
60	60
40	45
30	35
23	25
17	18

* An 81 cpm machine has just been marketed.

Monthly Copy Volume and Office Workflow

Average Monthly Copy Volume. The purpose of our management data analysis was to help us understand the general profile of the copy market. In this discussion, two analog PPC series are discussed: an earlier PPC series (marketed around 1990), and a later generation PPC series (CS-PRO series, marketed around 1994), as shown in Table I.

One example of CV management data for a particular PPC model is shown in Fig. 1. The average monthly copy volume for any model in either series can be obtained from histograms of this kind. The relationship between average monthly copy volume (AMCV) and copies per minute (CPM) in the Japanese copy market is shown in Fig. 2. We found a strong correlation between AMCV and CPM. The slope is about 2 on the log–log plot, meaning that the AMCV is proportional to the square of the CPM. This is shown in Eq. 1, where AMCV is equal to a coefficient **a** multiplied by the square of the CPM.

$$AMCV = \mathbf{a} \cdot (CPM)^2 \quad (1)$$

According to our worldwide CV management data, the shape of Eq. 1 is the same for the United States and European markets as it is for Japan, although the coefficient **a** is different.

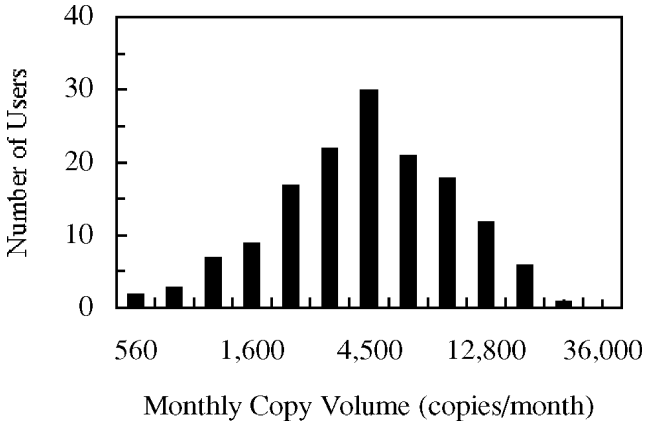

Figure 1. One example of CV management data for a model in a PPC series.

We considered what might underlie the relationship between average monthly copy volume and copies per minute, seeking to understand why AMCV is proportional to the square of the CPM. The AMCV can be expressed as

$$AMCV = ACS \cdot AMCO \tag{2}$$

where ACS is the average copies made per copy operation and AMCO is the average monthly copy operations, that is, the number of times an operator pushes the start button. We found the following empirical relationship according to another management data:

$$ACS = \alpha \cdot CPM \tag{3}$$

The CV management data shown in Fig. 2 were replotted in Fig. 3 as the relationship between the ACS and the AMCO. Assuming $\alpha = 0.1$, the ACS and AMCO were obtained from Eqs. 2 and 3. We found a meaning relationship between ACS and AMCO, as expressed in the following equation:

$$ACS = 1 + \beta \cdot AMCO \tag{4}$$

where, for the Japanese copy market $\beta = 1.4 \times 10^{-3}$. Substituting terms from Eq. 3 into Eq. 4 allows us to restate the relationship as follows:

$$AMCO = (\alpha \cdot CPM - 1) / \beta \tag{5}$$

Substituting terms derived in Eqs. 3 and 5 into Eq. 2 yields the following equation:

$$AMCV = (\alpha \cdot CPM)^2/\beta - \alpha \cdot CPM/\beta \tag{6}$$

Figure 4 shows this analytical relationship when $\alpha = 0.1$ and $\beta = 1.4 \times 10^{-3}$. Close agreement between observed (Fig. 2) and calculated (Eq. 6) values was obtained. The coefficients α and β differ in the United States, European and Japanese markets.

Segmentation Strategy. We considered what dynamics of mutual interference might account for the fact that each model covers the appropriate area of the overall average monthly CV as shown in Fig. 4. One factor is copy productivity (copy speed) and another is list price. High copy volume users need higher copy productivity,

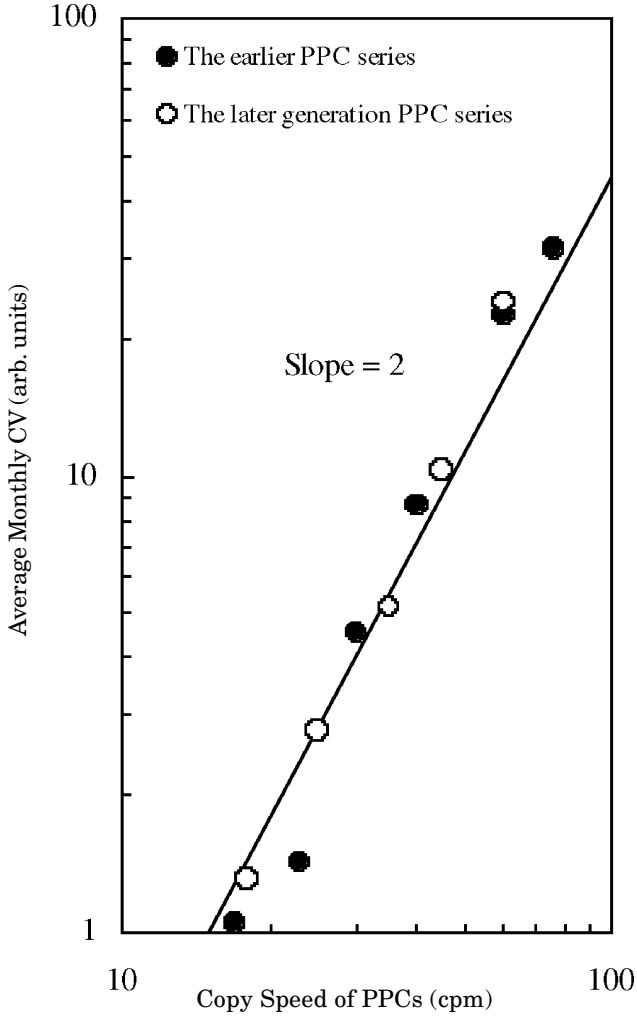

Figure 2. Relationship between the average monthly CV (AMCV) and the copy speed of PPCs (cpm) for the earlier and later generation PPC series in the Japanese copy market. Slope 2 was obtained.

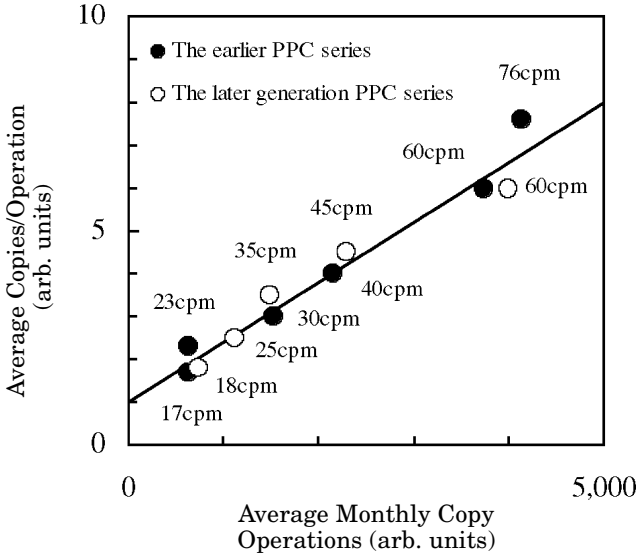

Figure 3. Average copies per copy operation (ACS) as a function of average monthly copy operations (AMCO).

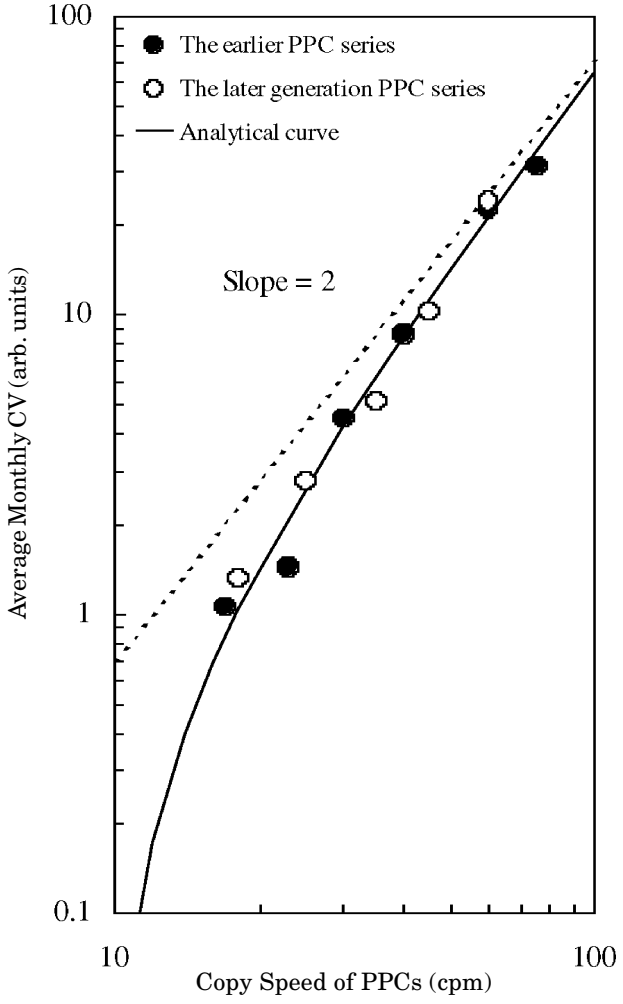

Figure 4. Analytical curve calculated from Eq. 6 with $\alpha = 0.1$ and $\beta = 1.4 \times 10^{-3}$ for the average monthly CV (AMCV) as a function of the copy speed of PPCs (cpm).

so higher-speed copiers are installed. Because list prices of copying machines are approximately proportional to their copy speeds, faster copiers are relatively expensive. Low-volume users are compelled to settle for lower-speed copiers for reasons of cost.

The aim of a segmentation strategy[3–4] is to cover a wide market efficiently with a limited number of products. Key to the success of this strategy is an appropriate basis for segmentation. In the case of copying machines, copy speed has been the prevalent means for determining segmentation. Among the models in our PPC series, copy speeds are distributed at regular intervals on the log scale, as shown in Fig. 4, with copy speeds increasing by a factor of about 1.35 from one model to the next. Therefore each model covers the same size segment on the log scale. If the differences between models were too great, we might lose users whose requirements placed them "between two models." If the differences were too narrow, conflicts could occur between models in adjacent segments.

The concept of equal segmentation on the log scale can be explained on the basis of the Weber–Fechner Law. According to the Weber–Fechner Law,[5] the psychological magnitude of a property is proportional to the logarithm of its physical energy. For example, the

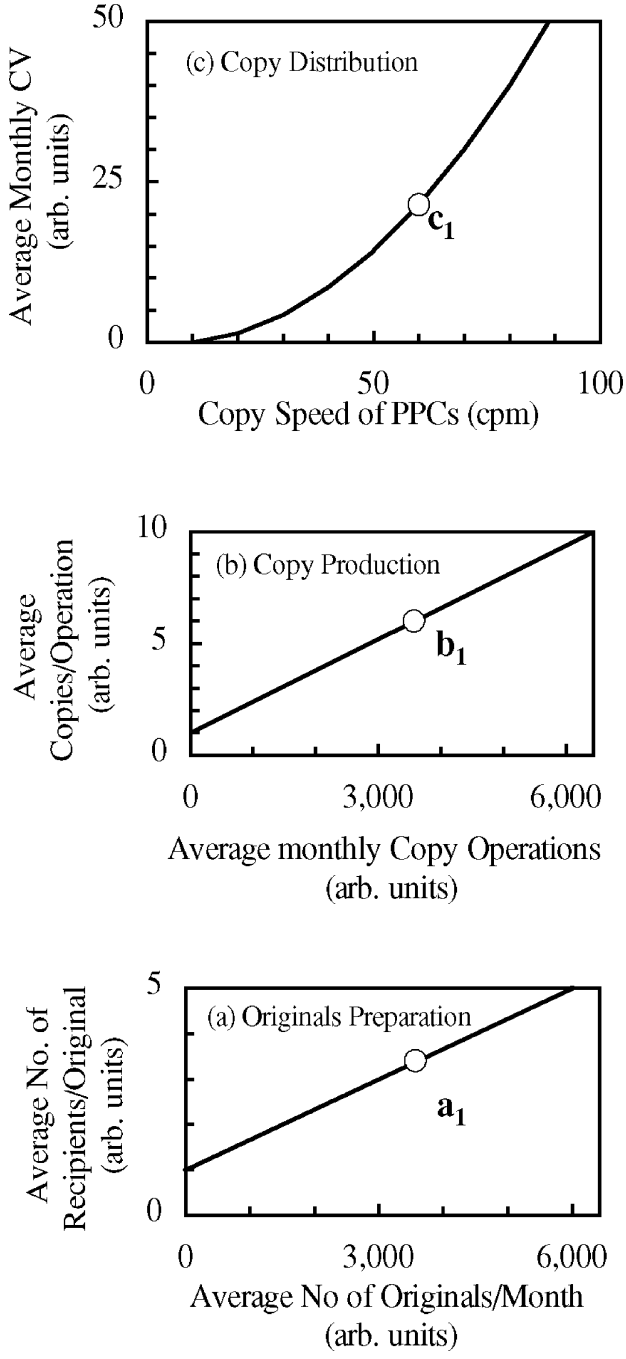

Figure 5. The office workflow for copy-and-distribute. Information passes through (a) originals preparation, (b) copy production and (c) copy distribution. For a given office size, $\mathbf{a}_1$, $\mathbf{b}_1$, and $\mathbf{c}_1$ correspond at the positions shown.

psychological magnitude of brightness is proportional to the logarithm of illuminance. In the case of copying machines, this theory can be expanded to say that psychological copy productivity is proportional to the logarithm of the copy speed in copies per minute (cpm).

Office Workflow. Based on our new insight into the significance of copy volume in the office, we took another look at office workflow. We assumed that office workflow as represented by hardcopy is determined by (a) originals preparation, (b) copy production and (c) copy distribution, as shown in Fig. 5. For a given office size,

$\mathbf{a}_1$, $\mathbf{b}_1$ and $\mathbf{c}_1$ correspond at the positions shown. The plot at the bottom of the figure (a) shows that as the scale of the office grows, the average number of originals per month and the average number of recipients per original both increase. The plot in the middle (b) shows that average monthly copy operations and average copies per copy operation also increase (see Eq. 4). Likewise, the plot at the top (c) shows that average monthly copy volume increases in proportion to the square of the copy speed (see Eq. 6).

A widespread convention of business management has been to concentrate in the same area those responsible for a given type of occupation and to maintain proximity among groups in charge of related organizations. This approach has been effective for decision making, intention notification and sharing of information through face-to-face communication. Therefore, as office size increases, the average number of originals (proposals, minutes, reports and the like) per month and recipients per original also increases, confirming Eq. 4. Equations 4 and 6 are the result of how principles of business management are reflected in copy operations: decision making, intention notification and information sharing flow through the trunk line of hardcopy.

Document Digitalization. As noted, the information infrastructure is shifting from copy-and-distribute to distribute-and-print. To understand the forces at work, we must closely monitor changes in the scale of the office and its workflow.

First, larger offices will experience significant downsizing, a transition already in evidence in some markets. Traditional principles of business management will be severely tested by the rapid spread of networks. However, in the office of the future, decision making, intention notification and information sharing will continue to be the main mission. Therefore, we can expect groups that are physically dispersed but tightly connected by networks to operate as larger offices for some time into the future.

Secondly, with downsizing and increased network connectedness, the paradigm will shift from copy-and-distribute to distribute-and-print, and hence from average monthly copy operations to average distribution operations per month. The number of electronic documents that will serve their purpose without being printed out as hardcopy can be expected to increase. An important question is, how will this affect paper usage? Summing up several specialists' opinions of the value of paper, two points stand out: first, paper is easy to read and work with; and second, it is a reliable medium for preservation. Electronic storage media have changed frequently over time, and the means for reproducing digital files are sometimes lost as technology moves on. Further, technological improvements such as digitalization and colorization will make paper an even more useful and flexible medium by offering high processing speeds, high image quality, on-demand and personalized printing, sophisticated hardcopy finishing and capabilities such as electronic sorting, duplexing and booklet-making. In the end, it will be necessary to develop methods that allow for both more effective use of hardcopy and conservation of paper.

Product Reliability and CV Business

Mean Copies between Service Visits. A high level of product reliability of PPCs is maintained by high quality field service. Field service visits include both preventative maintenance and repairs by highly skilled service personnel. Product reliability in the copy market can be measured by mean copies between service visits (MCBV). MCBV can be defined by the following equation:

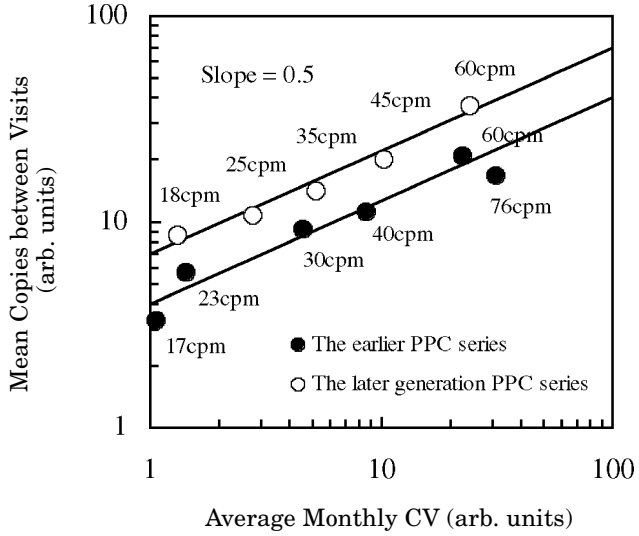

Figure 6. Relationship between average monthly CV (AMCV) and mean copies between service visits (MCBV) for the earlier and later generation PPC series in the Japanese copy market. Slope = 0.5 was obtained.

$$MCBV = Total\ CV\ /\ Total\ Number\ of\ Visits \qquad (7)$$

The relationship between MCBV and AMCV for our two PPC series in the Japanese copy market is shown in Fig. 6. We can see an unexpected relationship between the MCBV and the AMCV. That is, the slope is about 0.5 on the log–log plot, meaning that the MCBV is proportional to the half power of the AMCV, as expressed by the following equation:

$$MCBV \propto (AMCV)^{0.5} \qquad (8)$$

Further consideration of this relationship, seeking to understand why the MCBV is proportional to the half power of AMCV, showed that MCBV can be expressed as in Eq. 9:

$$MCBV = ACS \cdot ACOV \qquad (9)$$

where ACOV is the average copy operations between service visits.

The following equation was obtained from Eqs. 2 and 4:

$$AMCV = (ACS)^2/\beta - ACS/\beta \qquad (10)$$

Solving for ACS then gives the following equation:

$$ACS = 0.5 \cdot (1 + (1 + 4\,\beta \cdot AMCV)^{0.5}) \qquad (11)$$

The field service management data shown in Fig. 6 were replotted in Fig. 7 to show the relationship between the ACS and the ACOV, assuming $\beta = 1.4 \times 10^{-3}$ and with ACS and ACOV obtained from Eqs. 11 and 9. Figure 7 shows that the average ACOV in each series, that is, $(ACOV)_{avg.}$, is nearly constant regardless of the copy speed of the machines.

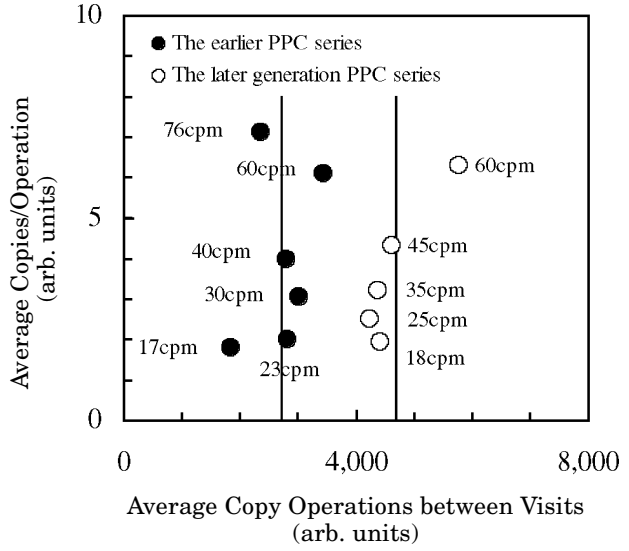

Figure 7. Average number of copy operations between service visits (ACOV) for the earlier and later generation PPC series.

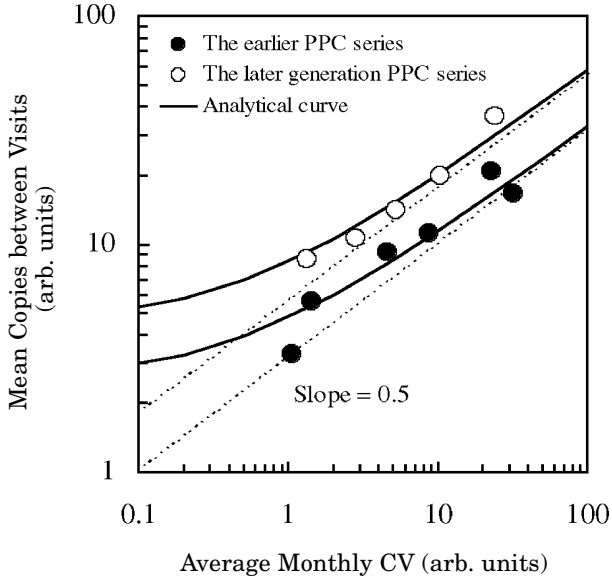

Figure 8. Analytical curves were calculated from Eq. 12 with $\alpha = 0.1$ and $\beta = 1.4 \times 10^{-3}$ for the mean copies between service visits (MCBV) as a function of the average monthly CV (AMCV).

We can now obtain the following equation from Eqs. 9 and 11:

$$MCBV = 0.5 \cdot (ACOV)_{avg.} \cdot (1 + (1 + 4\,\beta \cdot AMCV)^{0.5}) \quad (12)$$

Assuming $\beta = 1.4 \times 10^{-3}$, MCBV as a function of AMCV was calculated from Eq. 12. The results are shown in Fig. 8. Close agreement between observed (Fig. 6) and calculated (Eq. 12) values was obtained.

Level of Technology. The value of ACOV is a good indicator of product reliability. The $(ACOV)_{avg.}$ can also be considered an indicator of the level of technology in each series. The levels of technology in a series converge in this way because the models in the series are developed using the same key technologies, the same design policy and the same quality control.

The ACOV relates to the frequency of start/stop cycles, each of which causes machine wear. In copiers and printers in general, it is well known that start/stop cycles cause wear of machine components. In electrophotography in particular, frequent start/stop cycles cause excessive wear in the development, cleaning, fixing and paper feeding subsystems. Assuming that the electrophotographic process as we know it will continue to be used for some time into the future, additional scientific research in tribology, i.e., the fundamentals of friction, wear and lubrication, may lead to improvements in reliability. With digital products, it should be possible to improve reliability still further since the technology makes possible decreases both in the number of original scan operations and the number of start/stop cycles–for example, by storing image data in memory.

In developing our later generation PPC series, we introduced new technologies to reduce preventative maintenance visits, reduce failures and problems, produce high image quality and allow for ease of use. All of these development goals were expected to contribute to improved $(ACOV)_{avg.}$, directly or indirectly.

CV Business. As noted, the CV business was analyzed on the basis of the CV and field service management data at our disposal. The number of machines of a particular model covered by each service person (N_M) is given by:

$$N_M = N_V \cdot MCBV / AMCV \quad (13)$$

where N_V is the number of service visits per month per service person. Total service personnel (N_S) covering total machines of a particular models in the field (MIF) is given by:

$$N_S = MIF / N_M \quad (14)$$

Therefore, the total AMCV for a particular model of MIF can be expressed by the following equations:

$$MIF \cdot AMCV = N_S \cdot N_V \cdot 0.5 \cdot (ACOV)_{avg.} \cdot (1 + (1 + 4\,\beta \cdot AMCV)^{0.5}) \quad (15)$$

Equation 15 describes an important aspect of the CV business: income is proportional to the total AMCV on the left side of the equation, and the service cost is proportional to the number of total service personnel (N_S). Therefore, profit in the CV business increases by improving N_V, $(ACOV)_{avg.}$ and AMCV.

As shown in Fig. 4, the AMCV segments for our PPC series cover a wide market efficiently. This is a result of the models in the series being correctly marketed, using segmentation strategy. From the view point of profit, segmentation of AMCV is more important than segmentation of copy speed.

In order to conserve development investment, it is necessary to use the smallest possible number of base engines. Applying this model, a few engines are developed using the same base technologis (for example, a new imaging process and so on) as a base. Several models are designed from each base engine. Additional variations and successor models are developed from the core group of models. To make this approach viable requires using the same base technologies throughout the product line but allows for differentiation by means of the specifications of individual models. There may seem to be an

element of contradiction here, but important differentiations are easy to identify—copy speed is primary among these, and paper handling and finishing option also make for important distinctions.

Conclusion

Our analysis has shown the following:

Average monthly copy volume (AMCV) is proportional to the square of the speed (copies per minute) of the PPC. A two-dimensional expansion of AMCV (= average copies per copy operation × average monthly copy operations) is the result of how principles of business management are reflected in copy operation data. A traditional principle of business management has been to concentrate in the same neighborhood the persons in charge of a given type of occupation and the groups in charge of related organizations. Based on face-to-face communication, this principle has been effective for decision making, intention notification and sharing of information.

The information workflow model is shifting from copy-and-distribute to distribute-and-print. The number of electronic documents that never need to be printed out as hardcopy will increase, but at the same time, digitalization and colorization of electrophotography will make paper more useful than ever. It will become necessary to develop methods that promote both more effective use of hardcopy and more conservation of paper, that is, that raise the overall quality of hardcopy documents.

Another analysis has shown the following:

Mean copies between service visits (MCBV) is proportional to the half power of the AMCV. We made it clear that MCBV is greatly influenced by the frequency of start/stop cycles between service visits and the average copy operations between service visits (ACOV) is a good indicator for product reliability. The average of ACOV in each series, that is, $(ACOV)_{avg.}$, shows the level of technology in a given PPC series. Profit in the CV business increases by improving $(ACOV)_{avg.}$ and AMCV.

The electrophotographic process as we know will continue to be used for some time into the future, and we believe that tribology is a promising research area that may lead to improvements in reliability for the office machines of the future.

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