Economic principles for interactive graphic applications

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BACKGROUND

With the continuing national economic malaise, there is a steadily increasing consciousness of the need to understand cost/benefits relationships which will result from the use of additional or alternative technical tools. This is particularly true in the consideration of interactive computer graphics (ICG) as a viable and valuable adjunct to our technical options. Although much potential exists to enhance our understanding of the economics of ICG, very little hard data has been forthcoming for a variety of reasons. There are a number of attributes which have been applied to ICG and which represent implied or intangible value. The oft-stated advantages of lead time reduction, reduction of the number of evaluation cycles, improved product quality, better training and comprehension, etc., have various degrees of economic benefit equivalence, but such benefits are difficult to quantify and they depend heavily on both the nature of the application and of the graphic user. For example, if time savings are manifest for tasks which lie on or close to the “critical path” of a multi-task project, cost benefits as a function of time saved might be easily verified and easily computed. On the other hand, savings of time on non “critical path” tasks may have little or no economic value whatsoever. Generally, however, the attributes stated above imply economic advantages on primarily qualitative terms. The problem of determining economic benefits is exacerbated by the method by which graphic facilities are charged. Prorated costs for additional systems and support are quite varied from institution to institution and opportunities for a variety of lease or buy options will impact the computation of cost effectiveness. It should be recognized that an appropriate console use charge for ICG most decidedly impacts ICG utilization and the level of utilization feeds back to affect the charge. Thus, early potential users of a start-up and low-use ICG system may be deterred for budgetary reasons. Therefore, maximum development of cost-effective operations would be possible if ICG use charges were predicted on an “expected” level of use over a reasonable time frame. An appropriate charge can be established as follows. First, determine use charge based on use of graphics of all applications where graphics could show any benefits potential. The resulting charge would then be based on a maximum operation of the system. This charge would then be studied in light of the prospective potential applications to eliminate those for which this “minimum” charge would be too great for cost effective ICG use. With the smaller set of potential applications, an amended use charge would be computed, remaining applications would be studied in light of the modified charge, and the iterative cycle would be continued until there is convergence on charges and applications which will use the system. If there is no convergence, then there would be no application set for which graphics is cost effective. The charge should be subsidized or put into overhead initially to give ample opportunities for ICG applications to reach their potential. Subsequently, the charge to users would be periodically reviewed and modified. This approach to ICG charges can yield the optimum number of graphic scopes. This will be described later in more detail.

Another problem in determining cost effectiveness or benefits for ICG is characteristic of people and of their organizations. In general there seems to be little or no funding mechanism to make serious studies and to perform needed controlled comparative experimentation to derive hard data to clearly set forth the advantages of ICG. Without such a mechanism there is no eagerness on the part of each potential user to spend his own budget to perform modest research on the cost effectiveness for his application. Where good benefits data have been developed, most ICG users have no particular motivation to publicize it. Thus, we note the continued expanded use of ICG (which implies cost benefits), but good factual data is very difficult to find. The most prevalent data have been developed using the hard data liberally augmented by the “educated” estimates of experts in various application areas for ICG. The thoroughness, the method of assessment, and indeed the reliability of such estimates will vary among users. The important point is that most institutions come out with similar benefit expectations for similar applications.

In spite of the lack of large quantities of accessible hard data on ICG economics, there have been some data developed in the past, some data is being developed, and there is a considerable amount of unexploited potential in this area. In 1969, for example, the Lockheed-Georgia Company documented a savings of $250,000 for the first nine months of use of the 3-scope IBM 2250 and 360/50 system as applied to 2-D structural analysis. This cost reduction was recorded as Lockheed Report CRR#68-12-266-G-01 under the DOD cost reduction program. It was a net value after subtracting appropriate costs for additional hardware, for system mainte-
nance, and for system implementation. It did not reflect earlier costs for research and development. It is interesting to note that the largest portion of cost reduction was achieved in the data evaluation and documentation phases. Net computer costs, including graphics charges, were increased, although that may not necessarily be the case for certain other applications.

The well-publicized numerical control part programming application at Lockheed-Georgia did not improve manpower productivity as much as initial estimates of six to one had predicted. The actual increase of productivity by a factor of three (one man hour at the graphic console would produce the equivalence of three man hours of conventional N/C work) was estimated to defray the additional costs associated with the utilization of graphics for N/C programming. The other benefits of time, product quality, better utilization of scarce manpower skills, etc., tipped the scales in favor of graphics for N/C part programming. The use of the Lockheed-Burbank developed CADAM, Computer Augmented Design and Manufacturing, further enhanced the value of N/C graphics since CADAM produces the geometry (on which N/C cutter paths are derived) at an earlier stage of design—in the detailed drafting phase via graphics. CADAM itself has received very heavy use at both Lockheed-Burbank and Lockheed-Sunnyvale. It increases productivity over a range of values depending on the application type. Its heavy utilization and a Lockheed-Burbank software development which operates many terminals within a single core partition have teamed to lower costs to operate graphic consoles and to make CADAM cost effective. Efforts to reduce hardware costs through consideration of alternative displays and of mini computers promise to further enhance CADAM for design drafting, N/C, and other applications.

There are many relatively simple tests and analyses that could be assessed, in the light of potential applications, that would indicate the potential economics of various graphic system options. For applications which require analysis, multiple parameters, iterations, and plotted results, it may suffice to affix a direct view storage display directly to a time share system. It should be very easy, in most cases, to show cost effectiveness with this very low cost addition. Of course, the level of sophistication of interactive graphics that will produce the maximum benefit is a function of many factors and is, therefore, difficult to determine. Among the ICG options are: stand alone single display systems, stand alone multiple display systems, multiple display and other consoles within a stand alone system, non-stand alone host/satellite ICG systems, and systems that can operate either in stand alone or host/satellite mode. In most modern and future options of this sort, mini computers will play a prominent role. Thus, mini computer characteristics, display type and facilities, communication options, peripheral devices, applications mix, available software, organizational considerations, and many other factors must be weighed in a veritable infinitude of combinations and permutations.

Although costs are continually falling for both hardware and software, it will be asserted without proof that most ICG applications of substance will require a graphic console and peripherals ranging in equivalent purchase price from approximately $75K to about $200K and even higher (excluding the case of the direct linkage between the computer and a storage tube described earlier). Of course, multiple consoles can be implemented at lower costs per console, in general. (Special CPU requirements and system support will increase the unit cost, as is the case for CADAM.) Although such costs would be contested by some, the figures are intended as more or less an all-inclusive range and are an attempt to put vastly differing systems on a common basis.

To interpret this range in cost/hour for the system, one may consider a variety of lease/buy/accounting alternatives. These options will not be discussed. However, nominal values will be assumed here to put matters into perspective. Suppose, for example, the ICG system is to be amortized over five years. The number of work hours in a standard work year is taken, for convenience, to be 2000 hours. Thus, amortization is taken, in this example, over a period of 10,000 hours. This translates the console purchase price range from above to $7.50 through $30 per hour for a standard eight hour work day, five days each week, for 50 weeks each year. To this figure one should add a reasonable level of maintenance and support which is particular to graphics such as, for example, $5 to $10 per hour per console. (Obviously this figure will not rise proportionally to the number of consoles; but an estimate for maintenance and support is needed for the number of consoles that may be projected.) These latter estimates increase the hourly rates to a range from $12.50 to $30. This resultant can, of course, be easily modified contingent upon other assumptions for utilization, amortization schedule, maintenance and support, and other particular hardware/software options. It is now convenient to consider the wage rate (including fringe benefits, overhead, etc.) for the principal ICG user. This is another parameter. As an example, assume that it is $20/hour. Then the increased cost of $12.50 to $30 per hour associated with the provision of ICG services can be ratioed with respect to wage rate to produce a figure of "productivity increase" necessary to defray costs of the ICG system. That is $12.50/$20 through $30/$20 or 0.625 through 1.5 increase in productivity. Put another way, the graphic console user would have to produce 1.625 to 2.5 his normal output (productivity ratio) to defray additional system costs. This range depends on factors described earlier but are put forth as "reasonable" figures of merit to delineate the principal cost components. It is important to note at this juncture that trends toward lower costs of hardware and software and higher costs of manpower lead to a decreased range of productivity ratios which are necessary to defray ICG systems cost. However, even present productivity requirements favor the widespread use of ICG. This is because experience has indicated, in somewhat qualitative terms, that most applications have shown a minimum productivity ratio of three. Therefore, an application with sustained utilization should show a cost benefit based on the statistics set forth here. Again, one should be cautioned that such statistics and judgments might well have detractors. The experiences and judgments of practitioners of ICG vary widely as might be expected. There is no doubt that the amount of hard data on the subject is quite inadequate. Somewhat more potential exists than has been.
exploited to evaluate the expected cost benefits in employing ICG for a particular application.

TECHNIQUES FOR DETERMINING COST REDUCTION

The preceding discussion has dealt primarily with background principles which impact cost benefits determinations. The sequel will describe more specific techniques for determining cost reduction and the number of graphic consoles that will support multiple graphic applications.

Any application under consideration might be classified into cost components. For example, suppose $T_1$ represents the total cost to accomplish a particular application using current technology. Suppose further that $T_1$ is partitioned into costs as follows:

- $A_1 = \text{Planning and Scheduling}$
- $B_1 = \text{Set Up}$
- $C_1 = \text{Key Punch and Data Preparation}$
- $D_1 = \text{Computing}$
- $E_1 = \text{Data Analysis and Evaluation}$
- $F_1 = \text{Documentation and Administration}$
- $G_1 = \text{Correlated functions unaffected by the introduction of ICG.}$

Here $A_1$ through $F_1$ represent component tasks whose costs will be affected (either increased or decreased) by the introduction of ICG. The element, $G_1$, represents components unaffected by ICG. Similarly $T_2$ is composed of the same components $A_2, B_2, \ldots, G_2$ after ICG has been introduced. Of course, one may choose whatever classification components that fit the application. If desired, classification can be somewhat more detailed. For the present example, the two costs, $T_1$ and $T_2$, might be represented by two bars as follows:

In the example, keypunching is eliminated, computing costs are actually increased, and other costs (except for G) are decreased. Then,

Cost Reduction $= \Delta T = T_1 - T_2 = (A_1 - A_2) + (B_1 - B_2) + (C_1 - C_2) + (D_1 - D_2) + (E_1 - E_2) + (F_1 - F_2)$

where $G_1 - G_2 = 0$ since the G's are defined as those tasks unaffected by ICG.

It should be noted that the two primary parameters that influence the value of $\Delta T$ are man hour rate of the ICG console user and the cost per hour rate for the use of the ICG system. Thus,

$\Delta T = F(R_M, R_C)$

where $R_M = \text{Man Hour Rate}$ and $R_C = \text{Console Rate}$

Both $T_1$ and $T_2$ and hence $\Delta T$ will be affected by the choice of $R_M$ and $R_C$. More specifically, $\Delta T$ may be expressed as:

$\Delta T = K + R_M (H_1 - H_2) - R_M H_3 - R_C H_4$

where: $K = \text{The cumulative cost effects (gains and/or losses) resulting from the use of ICG but not directly a function of the graphic system or of the graphic console user, per se.}$

$H_1 = \text{The hours the potential graphics user would employ in the conventional task where cost is defined earlier as } T_1.$

$H_2 = \text{The hours (expected to be less than } H_1, \text{ in general) that the user would expend after the interjection of ICG, but not in the use of the graphic console, per se.}$

$H_3 = \text{The hours that the ICG user spends at the console.}$

The parameter, $K$, could include such effects as material or weight reduction, decreased inspection requirements, decreased batch or other nongraphic computation, different technician and administrative support, and other factors with varying degrees of direct cost effects. Since $K$ would normally be expected to be positive, on balance, the required console user productivity gain needed to defray ICG systems costs would be decreased. If it is assumed that $R_M$ and $R_C$ are measured in $$/hour, then $H_3$ and $H_4$ are measured in hours.

The preceding equation for $\Delta T$ encompasses all gains and losses that result from ICG use. This equation is rewritten as:

$\Delta T = K + (H_1 - H_2 - H_3) R_M - H_4 R_C$ (1)

Here it is clear that $\Delta T$ is a linear function of $R_C$ and that for any $R_M$, the slope of the line is $-H_4$ For an application under consideration to use some form of ICG, $\Delta T$ can be plotted as in Figure 2.

Using algebra on equation (1), it can be shown that

$\Delta R_C = (H_1 - H_2 - H_3) \Delta R_M / H_4$ (2)

Where the line, for a particular $R_M$, crosses the abscissa, that will be the highest console rate (threshold) to achieve cost effectiveness. Either the plot for $\Delta T$ or equation (2) may...
be used to relate the change in the threshold graphic console rate to alternative man hour rates.

The y-intercepts of equation (1) show the maximum cost reduction, ΔT_{\text{MAX}}, that would be achieved for a given man hour rate. This would be the value of ΔT for a zero console rate. The formula for ΔT_{\text{MAX}} is:

\[ \Delta T_{\text{MAX}} = K + (H_1 - H_2 - H_3)R_M \]

It should be noted that ICG becomes increasingly cost effective as graphic rates decrease and as man hour rates increase. Thus, present economic trends of lower computer costs and higher wages tend toward the increased value of ICG. The higher ΔT for higher R_M at a particular R_C means that the introduction of a labor saving system such as ICG is worth more when it increases the productivity of high-priced labor. In the example, the threshold for cost reduction for a $20/hour manpower rate is about $62/console hour. In other words, ICG can benefit application X, in pure cost, for a total graphic rate as high as $62/hour which would imply that application X can support a fairly sophisticated ICG system. The $10/hr. R_M crosses the axis at a console rate of about $37/hr. This means that if application X uses principal manpower at a rate of $10/hr, then the ICG system would have to be somewhat less expensive if it is to be a paying proposition in purely monetary terms.

**EXAMPLE OF GRAPHIC/NON-GRAPHIC COMPARISON**

To illustrate the preceding discussion of cost reduction, a candidate application in the Lockheed-Georgia CADAM evaluation for potential contract work will be described.

The following chart is a breakdown of tasks for both conventional and CADAM processing of a particular numerical control tape development task, Figure 3.

From the chart, it can be observed that tasks 1, 4, 5, 10, and 13 are unaltered. They would fall into the classification, “G,” in the earlier discussion of cost reduction. All other tasks are altered because of graphics and would be treated similar to classifications “A” through “F.”

In reference to the equation for ΔT in terms of K, H_1, H_2, H_3, R_M and R_C, it is noted for this example that K is zero (although there are certainly other related effects, like inspection, that are not included in the chart).

The formula, \[ \Delta T = K + (H_1 - H_2 - H_3)R_M - H_3R_C \]
gives \[ \Delta T = 0 + (40.55 - 6.10 - 9.26)20 - 9.26(40) \]
Based on a 4-scope CADAM system with a $40/hr console rate, R_C, and a $20/hr manpower rate, R_M.

Thus \[ \Delta T = $133.40 \text{ (cost reduction)} \]

Since tasks 1, 4, 10, and 13 are unaffected by graphics (classification “G”), they need not necessarily have been included in the chart. Their inclusion does help set forth all the elements of the example N/C application. If they had been deleted from the chart, then both H_1 and H_2 would be 6.10 hours less. That is, they would be 34.45 and 0 respectively. As discussed before, this would not alter the cost reduction value of $133.40 because cost reduction is independent of tasks classified as “G.”

**CONSOLE RATES**

The applications and system costs of a projected Lockheed-Georgia CADAM system relate directly to the earlier discussion on the optimum charging mechanism and on the opti-
### APPROPRIATE IBM 360/65 SYSTEM COSTS (IN THOUSANDS OF DOLLARS)

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<tr>
<th>Number of Scopes</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
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<td>CPU &amp; Associated Peripherals</td>
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<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
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<td>Scopes (Includes 10% 2nd Shift Charge)</td>
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<td>5.1</td>
<td>5.1</td>
<td>10.1</td>
<td>10.1</td>
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<tr>
<td><strong>Scope Control, Selector Channel, MPX Sel. Sub Channel</strong></td>
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<td>44.9</td>
<td>47.4</td>
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<td>59.8</td>
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<td><strong>Programming, Operator Support</strong></td>
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<td>8.6</td>
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<td><strong>Total Monthly Cost</strong></td>
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<td>36.8</td>
<td>51.4</td>
<td>53.5</td>
<td>56.0</td>
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<td>65.3</td>
<td>67.4</td>
<td>70.0</td>
<td>77.1</td>
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<td><strong>Hours of Use/Month, (2 Shifts, 5 Days/Wk., 80% Utilization)</strong></td>
<td>554</td>
<td>831</td>
<td>1108</td>
<td>1385</td>
<td>1662</td>
<td>1939</td>
<td>2216</td>
<td>2493</td>
<td>2770</td>
<td>3047</td>
<td>3324</td>
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<tr>
<td><strong>Cost, $/Scope Hour</strong></td>
<td>58</td>
<td>41</td>
<td>33.5</td>
<td>37</td>
<td>32</td>
<td>29</td>
<td>28.5</td>
<td>26</td>
<td>24</td>
<td>23</td>
<td>23</td>
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<td><strong>Cost Adjustment/Scope for Errors in Estimates, Assumptions, Unanticipated Costs</strong></td>
<td>10</td>
<td>8.0</td>
<td>6.5</td>
<td>5.5</td>
<td>5</td>
<td>4.5</td>
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<tr>
<td><strong>Total Cost, $/Scope Hour</strong></td>
<td>68</td>
<td>59</td>
<td>40</td>
<td>42.5</td>
<td>37</td>
<td>33.5</td>
<td>32.5</td>
<td>29.5</td>
<td>27</td>
<td>25.5</td>
<td>25.2</td>
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</table>

Figure 4—Console rate versus number of scopes

The minimum number of scopes to support the applications. Data are being compiled within the framework of an on-site CADAM system. It is assumed that a dedicated IBM 360/65 configuration will be acquired to service the appropriate number of scopes. Based on the potential of driving "N" scopes two shifts each day, five days each week and with 80 percent utilization, the hourly console rate as a function of "N" has been computed, as shown in the preceding tabulation, Figure 4. The hourly console rate for this particular system is high for up to three consoles (in comparison to ranges set forth earlier) because of the cost of the assumed graphic dedicated IBM 360/65 which is predicated on multiple-scope use, because third shift CPU operation is not assumed, and because substantial support is to be given initially.

**PRODUCTIVITY RATIO DEFINITION**

One of the more valuable measures of effectiveness for graphics is productivity ratio defined by:

\[
\text{Productivity Ratio} = \frac{R_M + R_C}{R_M}
\]

For a \( R_M \) of 20 and a \( R_C \) of 40, as in the example above, this ratio would be 3. In other words, one hour at the console would have to produce the equivalent of three hours of non-graphic work to defray the extra cost of the console. From the chart of Figure 3, the conventional hours on which graphics have an effect are 40.55-6.10 = 34.45. This work can be accomplished, according to the chart, with 9.26 hours at the console. Thus (34.45/9.26) = 3.7 is the productivity ratio for the example. This compares favorably to the 3.0 threshold or "breakeven" ratio. In computing ratios of hours as exemplified here, it is essential to consider only graphic-affected tasks if the ratio is to have meaning. That is why 6.10 was excluded from the calculation of the ratio of 3.7. That is, 6.10 was subtracted from both the total CADAM hours and the conventional hours. Had this not been done, the ratio would have been (40.55/15.36) = 2.6 which would have falsely indicated that the increased productivity did not reach the "breakeven" value of 3.0. Furthermore, had the unaffected hours been much greater, say for example 106.10 instead of 6.10, the ratio would have been (140.55/115.36) = 1.2. This illustrates that if the constant hours (same for both conventional and graphics) are not subtracted out before calculating...
Figure 5—Average productivity ratio for applications using \( N \) scopes

<table>
<thead>
<tr>
<th>Task</th>
<th>Conventional Hours</th>
<th>Cumulative Conv. Hours</th>
<th>Scope Hours</th>
<th>Cumulative Scope Hrs.</th>
<th>Productivity Ratio</th>
<th>Cum. Prod. Ratio</th>
<th># Scopes (2770 Hours/Scope)</th>
</tr>
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<tbody>
<tr>
<td>1. Stock Drawings</td>
<td>632</td>
<td>632</td>
<td>146</td>
<td>146</td>
<td>4.3</td>
<td>4.3</td>
<td>1</td>
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<tr>
<td>2. Assemblies, Detail Drawings</td>
<td>18940</td>
<td>19572</td>
<td>5167</td>
<td>5313</td>
<td>3.7</td>
<td>3.7</td>
<td>2</td>
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<tr>
<td>3. Sheet Metal Drawings</td>
<td>7975</td>
<td>27547</td>
<td>2175</td>
<td>7488</td>
<td>3.7</td>
<td>3.7</td>
<td>3*</td>
</tr>
<tr>
<td>4. Extrusion Drawings</td>
<td>1873</td>
<td>29420</td>
<td>577</td>
<td>8065</td>
<td>3.2</td>
<td>3.6</td>
<td>3</td>
</tr>
<tr>
<td>5. N/C (Tapes)</td>
<td>1780</td>
<td>31200</td>
<td>668</td>
<td>8733</td>
<td>2.7</td>
<td>3.6</td>
<td>3*</td>
</tr>
<tr>
<td>6. Detail Drawings (Another Project)</td>
<td>5502</td>
<td>36702</td>
<td>2267</td>
<td>11000</td>
<td>2.4</td>
<td>3.3</td>
<td>4</td>
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<tr>
<td>7. *Other Tasks</td>
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<td>2.3</td>
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</table>

* See following discussion in text.

the ratio, then the ratio would be a function of the number of unaffected hours which are listed and would, therefore, obviate the meaning of the ratio as a measure of effectiveness.

The console rates from Figure 4 are used in Equation 3 (with \( R_m = 20 \)) to determine productivity ratios for each “\( N \).”

These productivity ratios, as a function of \( N \), are the “breakeven” ratios required for “\( N \)” scopes. The plot of this ratio as a function of “\( N \)” is depicted as function A on the graph, Figure 6.

APPLICATIONS AND PRODUCTIVITY RATIOS FOR CADAM

The current Lockheed-Georgia mix of potential applications for CADAM has been initially identified as follows:

* Engineering Drawings
  - Layouts
  - Assemblies, Details
  - Machined Parts
  - Sheet Metal Parts
  - Extrusions
  - Stock Drawings

* Tool Design
  - Interference Layouts
  - Small Fab and Assembly Tools

* N/C (Tapes)
  - Lay-up Blocks
  - Production Machined Parts

For several specific tasks, the productivity ratio has been computed based on studies, experimentation, and judgment. The ratios are believed to have been conservatively established. It is assumed that the first scopes will be applied to the most productive of the potential application tasks. Therefore, as a larger number of scopes (\( N \)) are contemplated, applications with less productivity are brought into consideration and thus the cumulative productivity ratio will decline as a function of “\( N \).” These potential applications are listed in order of decreasing productivity ratio in the preceding tabulation, Figure 5.

It should be noted that the application set beyond four scope utilization has not been determined as of this writing. Therefore, for the purpose of showing the complete technique for ascertaining the “optimum” number of scopes, estimates of ratios are inserted on the basis of an average ratio for complete utilization of each additional scope. Subsequent studies may very well show additional applications with relatively high ratios. However, at any assessment
time, the applications should be added to the set in descending order of ratios—as exemplified in the tabulation.

The CADAM operational use was studied for a projected 10-month period, from initiation on March 1, 1975, through the end of 1975. Therefore, the hours of use to determine the number of scopes (last column of Figure 5) is obtained by multiplying the monthly use (lower part of the tabulation on Figure 4) by 10.

ANALYSIS OF GRAPH OF PRODUCTIVITY RATIOS

Curve B, Figure 6, of productivity ratio versus “N” results from plotting the data from the table of Figure 5. It is interesting to note that both functions A and B decline, in general, with increasing “N.” Function A is erratic because of the introduction of certain specific hardware, like controllers, drums, etc., at specific values of “N.” Thus, function A is more or less a step function. Similarly, function B depends on the mix of application ratios which is not homogeneous in this case. Therefore, function B is erratic.

If function B remained below function A for all “N,” then there would be no number of scopes that would make CADAM cost effective for the considered applications.

The crossover between “N” equals three and four, illustrates the hypothetical point where savings (increase in productivity) exactly defray the cost of the scopes. The differential productivities between “B” and “A” is a maximum for “N” equal to four. This means that the increase in productivity obtained by going to four scopes more than offsets the additional systems costs. From then on, increasing “N” yields a decreasing difference. Where the functions cross again, between 8 and 9, all cost benefits are wiped out. Thus, the optimum for the particular application mix considered and for the assumed configuration costs is four scopes. Naturally, any shift in either the “A” or “B” functions would, in general, change the optimum number of scopes in the purely cost benefits sense.

POSITIVE AND NEGATIVE INTANGIBLES

The data that is used to develop function B is somewhat more subjective than that used for function A. Although the methodology for evaluating cost effectiveness, as set forth here, is an attempt to blend the maximum amount of both objective and experienced subjective data, there must remain some level of error—both positive and negative error. To those intangible benefits cited in the opening remarks of the maximum for cost benefits, all cost benefits are wiped out. Thus, the optimum for the particular application mix considered and for the assumed configuration costs is four scopes.

Naturally, any shift in either the “A” or “B” functions would, in general, change the optimum number of scopes in the purely cost benefits sense.

It is not common practice for most organizations to know the breakdown of costs for conventional tasks not to mention the breakdown for tasks using advanced technology. This is not to say that such data could not or should not be sought. On the contrary, in an era where increased productivity is becoming so very important, it would seem that organizational growth or even survival might well depend on the intelligent appraisal of present costs of operation and of alternative costs as a function of the incorporation of new technology.

As pointed out earlier, although cost benefits are by no means the only benefits, they undoubtedly play a major role in the decision processes of most establishments. Even with this constraint, interactive computer graphics is now coming of age.

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BIBLIOGRAPHY