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A Method For Determining What Effect CAD Has on Productivity in Gage Design of the Process and Tool Department at the John Deere Component Works

Dan Rae Teel
University of Northern Iowa

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Abstract

The purpose of this study was to develop a method for determining what effect CAD has on productivity in the Gage Design area of the Process and Tool Department of the John Deere Component Works.

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Gage Design of the Process and Tool
Department at the John Deere
Component Works

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Dan Rae Teel
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Approved by:

(James P. LaRue)	Advisor	12/18/86 Date
(Ron Bro)	Faculty Member	12/18/86 Date
(Bruce Rogers)	Faculty Member	12/18/86 Date

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Introduction

Background of the Problem

Continually throughout history man has tried to produce more, at faster rates, in shorter time periods. Man has often found he spent a great deal of time in the initial design of his product, however, he has also found that he spends an almost equal amount of time in designing new ways to produce his product faster. Today, this common practice is known as productivity. Productivity, the ratio of output to some measure of input, has always had some effect on everyone. "Within any economic system, whether pure capitalism or out-and-out state control, the real wealth of the economy is going to depend upon the productivity of the economy" (Gettelman, 1976, p.5). As our country has grown to become one of the strongest countries in the world, productivity has become much more than a word tossed around by some industrialist. The idea of productivity has become a very serious matter for our country.

Because of the recent importance put on productivity, more and more time is being spent on the question of how to improve productivity. "Congressional hearings have been held on the subject, and I venture to say that there isn't a chief executive of any company in this nation who isn't giving considerable time to the question of how to improve his organization's productivity" (Burnham, 1972, p.13). This unquenchable desire to increase the ratio of the output to the input has become the main goal of many of today's industries.

> Historically, two thirds of the nation's economic growth has come from gains in productivity. But as more workers spend their time lawyering, repairing, healing, etc. (by 1985, it is estimated that approximately three-fourths of the U.S. economy will be service-oriented) productivity gains will be increasingly hard to come by (Forbes, 1977, p.137).

Management is continually seeking new and different methods of procedure in an attempt to improve their company's productivity. "Getting better results by productivity improvements is the most important task of all managers, whatever their level in the company" (Ross, 1977, p.2). Management generally attributes increases in productivity to improved efficiency of some specific resources such as capital, material, or technology. Therefore, management must look to these areas to find the answer to the question of how to improve an organization's productivity. The one area, of those mentioned above, that management has begun to focus a great deal of its attention on has been that of new technology. Management is always looking for new paths to explore which might hold new secrets to increasing productivity by continually making changes in their company's procedures with the latest in new technology. "The only way you can get continuous, cumulative productivity improvements is through changes in methods of operation" (Burnham, 1972, p.19). Over the last few years, industries have experimented with making changes in their procedures using computers, in the hope of improving productivity. "The integration ofcomputers into manufacturing is having a profound impact on industrial productivity" (Evans, 1978, p.1). "In addition, Barcus indicates that the application of computers or automated systems assures cost-effective manufacturing and quality products, and is becoming an ever increasing significant method to achieve high performance results" (Barcus, 1977, p.2). One industrial area that has seen the impact of computers is the process and tool area of manufacturing. The use of Computer-Aided Drafting (CAD) has become a common tool with which to try to increase productivity in this area.

The need for man to have drawings and layouts to aid him in his development of designs has been around for hundreds and hundreds of years.

Drafting is one of the oldest occupations. It has been practiced since humankind first felt the need to design, invent, build, or manufacture to better its lot on earth. In fact, the famous artist and inventor Leonardo daVinci was himself an accomplished drafter. Some of his most famous works are intricately detailed plans for his numerous inventions (Goetsch, 1983, p.65-66).

Over the past hundreds of years drafting tools and equipment have been developed in response to the need. Early drafting equipment consisted of a flat board called a "Drawing Board", some type of a straight edge often called a "T-square", a pencil and eraser, triangle, and a rule or scale. Such equipment, used for many years, was gradually replaced by new drafting machines, templates, and electric erasers. Modern drafting facilities in industry include the necessary equipment to produce CAD.

The first attempt at some form of CAD system was thought to be in the early 1950's at the Massachusetts Institute of Technology(MIT). A Cathrode Ray Tube was connected to the Whirlwind 1 computer and used to generate simple pictures. The military, however, probably played the most important role in the origin and early development of CAD.

> The military/aerospace sector has played an important role over the years, particularly in the United States. Thus the first technological breakthrough for CAD - that is, the refresh graphics screen plus light-pen, which allowed for an interactive relationship between the screen and the operator was developed for the SAGE(Semi-Automatic Ground Environment) early warning radar system in the 1950's. Later, in the 1960's the United States Department of Defense played an important role in disseminating the virtues of CAD (Kaplinsky, 1982, p.41).

However, many people point to Ivan Sutherland's, Ph.D work at MIT as the real breakthrough in the history of CAD.

> Computer Graphics made little progress until 1962, when Ivan Sutherland at MIT published his Ph.D thesis entitled "Sketchpad: a Man-Machine Graphical Communication System." This document is generally considered the starting point for computer graphics" (House, 1982, p.29).

The 1960's was a period of real growth and development for CAD because of the large amount of research done by both educational and corporate institutions. As technology in the computer field grew so did the technology of CAD systems. There were several important breakthroughs in both software and hardware in the late 1960's and early 1970's which led to the present day CAD systems.

Today, a typical CAD configuration consists of a cathode ray tube (CRT), keyboard, electronic inputting device (digitizing device) and tablet or menu board, plotter, and printer. The combination of one or more of these devices together is called a CAD Workstation.

The CRT or "terminal" is a TV-like display screen which is used as an output device. This device displays both text (alphanumeric) and graphic data in monochrome (white on black), green on black, or in color. These vary in display quality or "resolution". Resolution is the number of picture elements (pixels) that are contained on a screen. Often they will be rated such as 1024 x 1024 resolution. Which means a rectangular arragement (matrix) that contains 1024 pixels across and 1024 pixels down. The higher the matrix of pixels, the higher the resolution. The cost also increases with the higher resolution. The design of CAD terminals vary somewhat from manufacturer to manufacturer.

The keyboard is a set of keys attached directly or indirectly to the terminal. The keyboard is used for inputting alphanumeric characters or symbols into the computer. These characters will be either displayed on the terminal or used to input instructions to the Central Processing Unit (CPU). The keyboard also varies in design according to the manufacturer.

The digitizer is another device used for inputting information into the computer. Digitizing is the process by which graphic data is converted into a form that the computer knows as binary. The digitizing device when touched to a tablet or screen sends electrical impulses known as the "binary signal" to the CPU. This tablet or menu is a flat surface device, representing the face of the screen. The digitizing device is moved over the tablet to place graphic data on the screen.

The digitizing device is usually in the form of a stylus pen, mouse, or puck. The puck is a small box which contains a set of cross hairs that triggers a signal that is picked up by the screen or tablet. Buttons on the puck are used to issue function commands to the graphics system.

When the CAD operator wants a hardcopy (paper) of the drawing he has created on the system he must use a plotter. The plotter uses the binary signal created by the computer and turns it into a a set of numbers (X-Y coordinates) used to specify the location of a point along a line, on a surface, or in space. These coordinates are then used to drive the plotter. The plotter has a pen and paper attached to it which when driven by the coordinates cause the pen to draw on the paper. These plotters can come in a large variety of sizes .

The final device usually associated with the CAD workstation is called a printer. The printer is used to output alphanumeric characters onto paper. These printers are rated by the quality of the character and speed at which they can print. Printers are available to produce either black or colored alphanumeric characters.

There are three basic types of computers which are used to run today's CAD software: Mainframe, Minicomputer, and Microcomputer. The Mainframe computer is the largest of the family of computers. This type of computer is usually characterized by being physically large and having the capabilities to perform applications requiring large amounts of data. These systems are able to handle large numbers of CAD Workstations with very quick response times to the users. However, there are some drawbacks with this type of system. These Mainframe computers are very expensive, require many operators to maintain the system, and require closely controlled environmental conditions. There are several well-known CAD programs (software) that are available for mainframe computers such as Lockheed's CADAM software, McDonnell Douglas's Mc-auto software, and General Motor's CGS(Corporate Graphics System) software.

> The power of mainframe computers provides two major advantages to users. The first is that these systems are powerful enough to undertake the more taxing requirements of particular software applications (e.g., finite element modelling in mechanical engineering) as well as to process data bases (e.g., parts lists, payrolls, etc) for which minicomputers are not suitable. And second, the power of the mainframes allows large users (or those using them on a time-sharing basis) to reap economies of scale in unit terminal costs (Kaplinsky, 1982, p.39).

The next type of computer that the CAD software runs on is the Minicomputer. This computer is physically much smaller than the Mainframe and does not have the capabilities to handle large numbers of CAD workstations. The system is usually characterized with small memory and a limited amount of input/output (I/O) channeling. This type of system has some very attractive features over the mainframe computer such as cost, less need for the expensive environmental equipment and less overhead for operators to maintain the system. This type of computer, also, offers some advantages over the smaller micro systems in the form of power and flexibility.

> The minicomputer-driven systems are more powerful and more flexible. These form the basic processing capability for all of the existing turnkey systems. Their strength relative to the small dedicated system is that they are powerful enough to be able to undertake a large number of applications programs as well as to drive between three and eight terminals,depending upon the particular suppliers' software and the use made of it by the user (Kaplinsky, 1982, p.39).

Again, there are several well known CAD software products that run on Minicomputer systems such as Computervision's CADDS software, Applicon's BRAVO software and Intergraph's IGDS(Interactive Graphics Design Software) software.

The final type of computer system that CAD Software runs on is known as the Microcomputer or Personal Computer. This computer is physically very small and usually fits on or under a desk and acts as a single or stand-alone CAD workstation. This system is usually limited to CAD software that has much less flexibility to perform some of the more powerful commands and the ability to handle only small CAD models. These systems usually are much slower than either the Mainframe or Minicomputer systems. These systems however are usually quite inexpensive, need not be in an environmentally controlled room, and requires no "systems" people to operate it.

> Microcomputers are microprocessor-driven dedicated terminals, which are small and not very powerful. Basically they are suitable as pure drafting aids - a sort of draftperson's word processor - although some are able to undertake elementary processing programs such as laying out the circuits on a printed circuit board (Kaplinsky, 1982, p.39).

The Gage department in the Process and Tool area of the John Deere Component Works has used a CAD system since it was introduced to Deere in 1979. This system is the Computervision System and falls in the class of the Minicomputers. The system is a 16 bit, 1 Megabyte of main memory, minicomputer. Bit is short for binary digit which can have only two possible values 0 or 1. A byte is a sequence of eight adjacent bits used to represent a character in the computer. A Megabyte is 1 million bytes or 8 million bits. This system contains 6 CAD workstations with each workstation comprised of a 512 X 512 raster terminal, digitizing pen and menu, keyboard, and termal-paper hardcopy unit. The system also has a magnetic tape drive, three 300 megabyte disc drives, and a 42" electrostatic plotter. The system runs Computervison's own "CADDS" (Computer-Aided Design and Drafting Software) software package. This system is used by four of the manufacturing groups at the John Deere Component Works. These areas are the Tool and Gage Design, Plant Engineering, Manufacturing Engineering Services, and Foundry Pattern Development. There is a total of 65 trained users for the system. Users who use the system 6 hours or more a day, five days a week, are classified as a dedicated users. Anyone who uses the system less is considered a casual user. The system is used by both dedicated and casual users. The system is used by all the areas on a split shift basis which covers a 12 hour time period. There is a system operator who maintains the system and runs backups.

Statement of the Problem

The purpose of this study was to develop a method for determining what effect CAD has on productivity in the Gage Design area of the Process and Tool Department of the John Deere Component Works.

Significance of the Study

Our lagging growth rate of productivity is a serious problem especially because nations such as Japan and West Germany have had annual growth rates which surpass that of the U.S., recently" (Gerhardt and Krass, 1980, p.891). United States industries have to look to ways to gain back some of this ground lost to countries such as Japan and West Germany by finding ways to improve productivity.

This study may be of significant interest to many companies that are either already using, or are considering using CAD. It should help management determine when and if a CAD system might be more productive than manually producing drawings on drafting boards using conventional drafting equipment.

Definition of Terms

CAD(Computer-Aided Drafting): The use of computers to assist gineering design in developing, producing, and evaluating design, data, and drawings (Computervision, 1982).

Computer: A device that can input, store, manipulate, and output data. It can automatically follow a program, a detailed step-by-step set of directions (Billings, 1979).

CPU(Central Processing Unit):	It is the brain center of the computer system. The CPU actually directs all the other components in a system. It contains a control section and a logic section (Goestch, 1983).
Digitizing Device:	Inputting location data by creating electronic contact between the pen and the tablet (Computervision, 1982).
Dump:	To write the contents of a storage or a part of storage, from an internal storage to an external medium (Computervision, 1982).
Gage Design:	Gages are related to quality by providing a rapid undisputable means of checking parts for being dimensionally correct (Andersen, 1984).
Mainframe:	A computer that is physically large

and provides the capability to perform applications requiring large amounts of data. These computers are much more expensive than Microcomputers or Minicomputers (Computervision, 1982).

Microcomputer: The so-called "computer-on-a-chip" in which the CPU, memory, and I/O control are packaged onto a single circuit card (Computervision, 1982).

Minicomputer: A type of computer whose physical size is smaller than a mainframe. Generally, a 16 bit computer which has small word size, small memory, and limited I/O channeling (Computervision, 1982).

Pixel: Picture element, a term used to describe the information contained in one unit of display surface (Computervision, 1982).

Software: Computer programs, procedures, rules, and associated documentation which directs the operation of a computer (Computervision, 1982).

X,Y Coordinates: Coordinates are determined by measuring the distance to a given point from each of two reference lines that intersect at right angles. The horizontal reference line is called the x-axis, the vertical line is called the y-axis, and the point of intersection, or origin, is the zero point. (Time-Life Book, 1986).

Limitations of the Study

Since only one CAD system (Computervision) was available at the time of the study, the results reflect only the one type of system. The results could vary from one system to another because some systems are designed to do certain applications better than others. Also because of a limited number of CAD operators and the time restriction of the study, only a relatively small number of sample designs were collected. The results could be different because of the difference in operators' knowledge of the function or knowledge of the system. Therefore, all conclusions and recommendations were based on the above limitations.

There might be intangible benefits that could be gained from the use of a CAD system that were not considered in this study. Such factors as increased creative output levels, increased employee motivation, and job enrichment, are areas that also might be affected but were not considered in this study. Rather, comparison was made of manual vs CAD.

Review of Related Literature

The effect CAD has on productivity has been one of the major concerns of managers throughout the country for some time. However, the search for related literature has shown that very few studies have been done on this subject. A computer search performed at the University of Northern Iowa Library uncovered very little research done in the past on this subject, therefore, very little supportive evidence was available. Many articles make statements to the effect that CAD systems are having a significantly positive effect on productivity. Some state various ratios of affect. However, no articles were found that indicated how productivity impact through CAD was measured. In some personal conversations with peers in the CAD business as to how they measure the effect of CAD on productivity, it was often found that "data" based on "best guesses". These best guesses were generally made by their own CAD operators, and were based on how the operator felt they could do the same job on the drafting board.

Methodology

The Process and Tool Department of the John Deere Component Works consists of several different departments such as Tool Design, Process Planning, Tool Procurement, and Methods Set-up. The Tool Design department can be broken into two majors areas, Tool Design and Gage Design. This study will be concentrating on the area of Gage Design. This area was picked over the other areas in Process and Tool because in this area all forms of Gage designs are being put on the CAD system, whereas, the Tool Design area picks only designs which have elements that tend to lend themselves towards CAD.

Determining what effect CAD has on productivity, could be found by determining the time it takes to perform a design manually and comparing that time, to the time it takes to perform the same design done on CAD. "The normal measure of CAD/CAM system productivity is the ratio of the hours to do a given task on the system, to the hours required to do the job by hand" (Cummings, 1980, p.351). However, in a time when there is so much competitiveness between industries, the extra cost involved in drawing the design manually and then repeating the design on the CAD system would be difficult to justify. In view of this, the best approach may be to do the design only once on CAD and compare that time to an estimated manual time provided by the expert schedulers.

These schedulers have the responsibility to estimate the time it takes to manually perform a design and then assign on an equitable basis evenly among the department designers. These expert schedulers are people who have between 15 and 25 years of experience in drafting and design and know these fields quite well. Because of this past experience and vast knowledge of these fields, they have developed the expertise enabling them make estimations which are quite accurate. Because of this ability the company uses their expertise for determining the cost to "design new tools outside vs inside and also for determining design and build" schedules. Historical data from past reports was used to check the accuracy of the experts' estimations to actual recorded manual times. These reports reflected the credibility and accuracy of the expert schedulers.

The first step of this study was to randomly select a Gage design to be done on the CAD system and obtain an estimate of the time it would take to do this same design manually. This was accomplished by selecting three department expert schedulers to estimate the time it would take to do the design manually. The same three experts were used for the duration of the study to control this important variable. The estimated time includeds only that time used for actually creating the drawing. Such things as coffee breaks, phone calls, and design preparation were not a part of the estimation, nor were they included on the CAD time. The schedulers were not to be shown one another's estimations to ensure that each estimate was not affected by the other's estimations.

The next step was to fill out the "Productivity Study Worksheet" with the appropriate information (See appendix A). The operator began by filling the name of the operator performing the work on the CAD system (See appendix B - letter A). The operator would complete the blanklabeled "Experience", with the amount of experience the operator had on the system (See appendix B - letter C&D). The operator should fill out the gage number assigned to this design (See appendix B - letter E).

John Deere has developed a special numbering system (See appendix C) which provides valuable information in determining what type of gage it is. This special 8 digit number system identifies the type of gage that the engineer is working with. The first two digits of a "gage" number are always 29. The next two digits tell the type of gage. The last five digits are taken from the sequence number book found in the Gage Department. For example, in assigning a number for a radius gage design, the first two digits would be 29, followed by a hyphen, the second two digits would be 30 (which is used for Radius gages) followed by a hyphen, and the last five digits would be the next number in sequence taken from the gage number assignment book (example 29-30-12345).

The operator would then enter the John Deere part number of the particular part that this gage will check. The operator will also complete the blanks labeled "Dec. No" and "file" (See appendix B - letter G&H) at this time. The Dec. No is the decision file developed by process planning which determines the need for a gage to check a particular operation or sequence in the production of a part. After the operator has completed filling out those blanks on the Productivity Worksheet, he is ready to start the actual design on the graphics system. The CAD system has an exact method for recording the amount of time that was spent on a particular job. This information is kept in the computer on an accounting software package. When the system operating software is loaded there is a file that is called "System Authorize" (See appendix D) which can be edited to track individual user time spent on certain jobs. Each line in this file contains five columns of information that must be setup for each individual user. The first column contains a combination company unit identifier and employee number which identifies each John Deere employee. For example in the number "RX37179" the "RX" would stand for the John Deere Component Works and The "37179' would be the CAD users John Deere clock number. The second column contains a number or an "*". This column allows the CAD user to log on to that specified number or if that column contains an * he can log on to any number he wants. The third column on this file either contains the word "admin" or "basic". This tells the system what level of file authorization that this user has. The "admin" level allows the user access to any of the files contained in the system. Most of the individual users will not need this level of authorization therefore the word "basic" should be put into the column. Basic allows only access to personal files. The fourth level is the protection level of the job he is working on. A user may want the other users to have the capability to only view the drawing and not have the ability to make changes to the drawing. This is the column where that information is added. The final column is for the password for that user. The system automatically scrambles the password column so that someone cannot go into the system unless they are authorized. This file contains all the users who will log on the system. When the user tries to log on the system he will receive a message "Type Name and Number". The user then must type in a valid name and number which corresponds with the one found in the file, System.Authorize. The system will respond with the word "password" for which the user must respond with his proper password. After the system check to make sure that the user enters the proper password the system will log him on. The system will then record the time the user was logged on to that name and number. The system will even record all the times that the users logs on and sum them together. This file can then be compiled and the contents wrote to some form of external medium (dumped) so there is an accurate tracking of the time spent on each drawing (See appendix E). A cost can also be associated to each minute the user is logged on, from which the system can automatically calculate total cost to each of the users. This file, also, contains the dates the user was logged onto a particular file, the time he or she logged on, the duration of the work session, the terminal that the work was done on and finally the cost of the work session, if a cost has been established (See appendix

E). The operator should only record the time spent working on that particular design to insure accurate recordings of the time spent doing that design on the CAD system. After the design is completed and the operator has totalled the time spent to complete the design, this time should be recorded on the Productivity Study Worksheet in the column labeled "Actual CAD Time" (See appendix B - letter M). After the design is completed on the CAD system and the actual time recorded, the operator should obtain a hardcopy plot of the new design to be used later for the next step of determining the estimated manual time.

In order to establish an estimated manual time the operator will take the hardcopy plot to the expert schedulers for them to establish a manual time. The operator will not let the schedulers know how much time it took on the system so that he will not be influenced by the actual time. The operator will record the estimated time of the experts on the Productivity Worksheet in the column labeled "Expert A" (appendix B - letter I+K+J). The experts should not be shown or told what the other expert's estimation is so that he is not influenced by the other expert's time. These three estimated times are then added together and divided by three to establish a mean estimation time which should be quite accurate. This averaged estimated time should be recorded on the Productivity Worksheet in the column labeled "Avg. Est. Time"(See appendix B - letter L). The final step in order to obtain a productivity ratio is to divide the "Avg Est Time" by the "actual CAD time". The number should then be put in a ratio form, such as (3:1) and recorded in the column labeled "Productivity Ratio"(See appendix B - letter N). These steps described above should be followed for each new gage design until a random sample has been established.

For this project, the user assigned a certain number to each drawing so that when he was working on that job he would log on to the CAD system under that number. The user was asked to guard against working on other drawings when logged onto a number assigned to a particular job. The user was asked to sign-off his terminal if he left the terminal for any length of time. These were all measures taken to ensure that the time recorded by the system was indeed time spent on that drawing.

Results

In order to compile the results of this research several steps were taken to complete the job. After the user had finished all his Gage design jobs to be used in this research paper, the accounting program was dumped and compiled on the Computervision system which tracked all the time for those jobs.

After the accounting file is dumped from Computervision, this data is to be transferred manually into a program which resides on the John Deere host system, which is the main computer system for all of John Deere.

The John Deere host system is capable of running many different types of host based software such as TSO (Time Share Option), SAS (Statical Analysis System), IMS (Information Management Systems), GT (Group Technology), CADAM (Computer Augmented Design and Manufacturing), and GMCS (Generalized Machine Cell Simulator). This host based system is capable of running a large number of terminals which are located throughout the United States and Overseas. This type of system contains Accounting, Production, Manufacturing, Design, and Service information which is accessible by any Deere Unit in the world.

To compile the information for this paper a combination of programs was used. First, the information was taken from the Productivity Study Worksheet and accounting file found on Computervision and placed into a TSO data set which is located on the host system (See appendix F). The first set of eight numbers found in the data set is automatically assigned by the TSO program and used for identifying line numbers. The second set of four numbers is the project number assigned by the CAD User to keep track of time spent on that drawing and is found in the accounting file. The next set of 10 numbers is the John Deere Gage number assigned by the CAD User. The next set of 4 numbers is taken from the Computervison Accounting File which is the total actual time that it took to draw the Gage on the CAD system. The following 3 sets of 4 numbers are the the three manual estimates that were given for that job by the three expert estimators. The final set of 4 numbers is the average estimation of the three estimators which is the average of the three previous set of numbers. An entry is made in the TSO data set for each Gage that is to be used in this paper.

After an entry for each job was placed in the data set a SAS program (See appendix G) was run against this data set. This high level statistical program allows the user to compile and arrange the data found in a data set, in any way that is desired. The following results were created (See appendix H) when the SAS program was run against the TSO data set.

These results show that the first column labeled "JOB TYPE" breaks down the Gages into specific types and groups them together. This can be very useful in gathering specific information about each type of gage. This could help to identify which types of Gages are more suited for CAD and which types are not. The column which is labeled "JOB" is the four digit job number assigned by the CAD designer and was used on the Computervision system accounting file to identify a certain gage. The column labeled "GAGE" contains the 8 digit code number assigned by John Deere to describe that a part is a gage and tell the type of gage that it is. The next column labeled "SYSTEM HOURS" records how much time it took to do that Gage on the Computervision system. The next three columns labeled "EST A, EST B, EST C" contain the three manual estimates made by the three expert estimators for each job. The column labeled "AVE. EST." contains the average of the three experts' schedulers. The column labeled "DES ENGR." is a number given to each CAD designer to identify the designer that created the gage on the system. This number could be of great significance if you had several CAD designers working on the system. The SAS program could be run against individuals to check each CAD designers' work. Management could use this to check individuals progress on the CAD system. Management could also decide which types of Gages each individual is most productive at designing on the CAD system. This could also show which CAD designers produce certain types of gages and which produce them the fastest. The next column which is labeled "Savings" is the amount of time difference found between the manual estimate and the time it took on the CAD system which is achieved by substracting the column labeled "SYSTEM HOURS" from the column labeled "AVE. EST.". If this is a positive number, this means that the CAD system took less time to produce the gage. If this number is negative, it took the CAD system more time to produce it than it would have taken manually. The final column labeled "PROD. RATIO" is the Productivity Ratio or the "SAVINGS" put in ratio form. This Productivity Ratio has become a national standard for measuring CAD systems and their effectiveness in the user's environment. The program also gives a total on all gages that are of the same type. The results finally give information such as the "MEAN" and "STANDARD DEVIATION" of each type or category of gage.

The purpose of this study is to determine how to measure the productivity of the computer graphics system, not whether it is more productive then doing the work manually. However, the productivity results produced by the SAS program are very easy to read and analyze. For example if we wanted to know the results of designing Alignment Plugs (29-14) on the system we could simply look at the results of the Productivity Study (See appendix H). The Productivity Study shows that there were 12 jobs in this gage type completed by three different designers. The Productivity Study results show that the jobs range from a .44:1 productivity ratio, which would mean that it took almost twice as long on the system as it would have taken to draw manually, to a 2.65:1 productivity ratio. The 2.65:1 productivity ratio means that it was 2.65 times faster do it on the computer graphics system as it would have taken do the job manually. The results also show that the overall productivity ratio for all Alignment Plug gages is 1.46:1. The SAS program allows a lot of flexibility on how the results are displayed.

Conclusion

The purpose of this study was to develop a method for determining what effect CAD has on productivity. In order for U.S. industries to keep up with the Foreign countries, they must continue to implement the latest technology. The implementation of this technology can be very costly and time consuming. Therefore, after this new technology has been implemented it is very important that it be used to its fullest potential. Most industries in this country do not have the time or money to bring a CAD system "in-house" to determine if it can be justified. Often these systems are implemented without ever really knowing if they will meet the needs of the company. Knowing how productive the system is, can be especially beneficial for managers of CAD areas. This information can be useful for a number of things, such as scheduling future and present man-power workloads, justifying present and future CAD equipment, or the scheduling of new product design releases.

Such information is vital to a company, but must be gained with as little interruption as possible to the normal workflow. In the past, CAD managers have had to rely on their users for information pertaining to how productive the system was compared to the manual method. They could not afford to study a system in a controlled environment where a drawing was made manually and then drawn again using CAD. Not only is this type of method costly, but it is very time consuming. In today's fast paced society, the survival of a company often depends on who's the first to market a new product.

This study does avoided many of the problems of a controlled study. It was very easy to implement and made use of many of the resources already available to the company, therefore avoiding much of the cost associated with other controlled studies. Older engineers sometimes are resistant to change and feel threatened by new technology. This study gets them involved with the project by utilizing their expertise, which is their knowledge of manual drafting rather than segregate them. "The decision to invest or not to invest requires judgement on the part of Management. Judgment is typically based on prediction of 'performance measures' provided by experts" (Jacobson, 1983, p.370). This is especially important for the estimating because most CAD operators found in industries have not had the experience doing manual drawings that the older designer has. This study was much cheaper than a controlled study because the job is only completed once. With the use of the average of the estimates from the three experts, it compares with a more controlled study in accuracy. This study is setup to conform more closely to the workflow that already exist. Except for the additional small amount of time used for the manual estimating and recording, this study does not add a lot time to the the normal workflow of a job. Which means it does not add a lot of cost to the job.

This system can also provide a very good historical data base for examining present and past trends. Statistically, this study allows the CAD manager much flexibility in examining his data. This study allows him the ability to determine certain types of gage designs that are found to be more productive, thus utilizing the system to its fullest capabilities. The manager can use the data in the results to track progress of a CAD user,s learning curve or productivity.

This study provides an inexpensive, yet accurate, option for determining what effect CAD has on productivity.

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PRODUCTIVITY STUDY

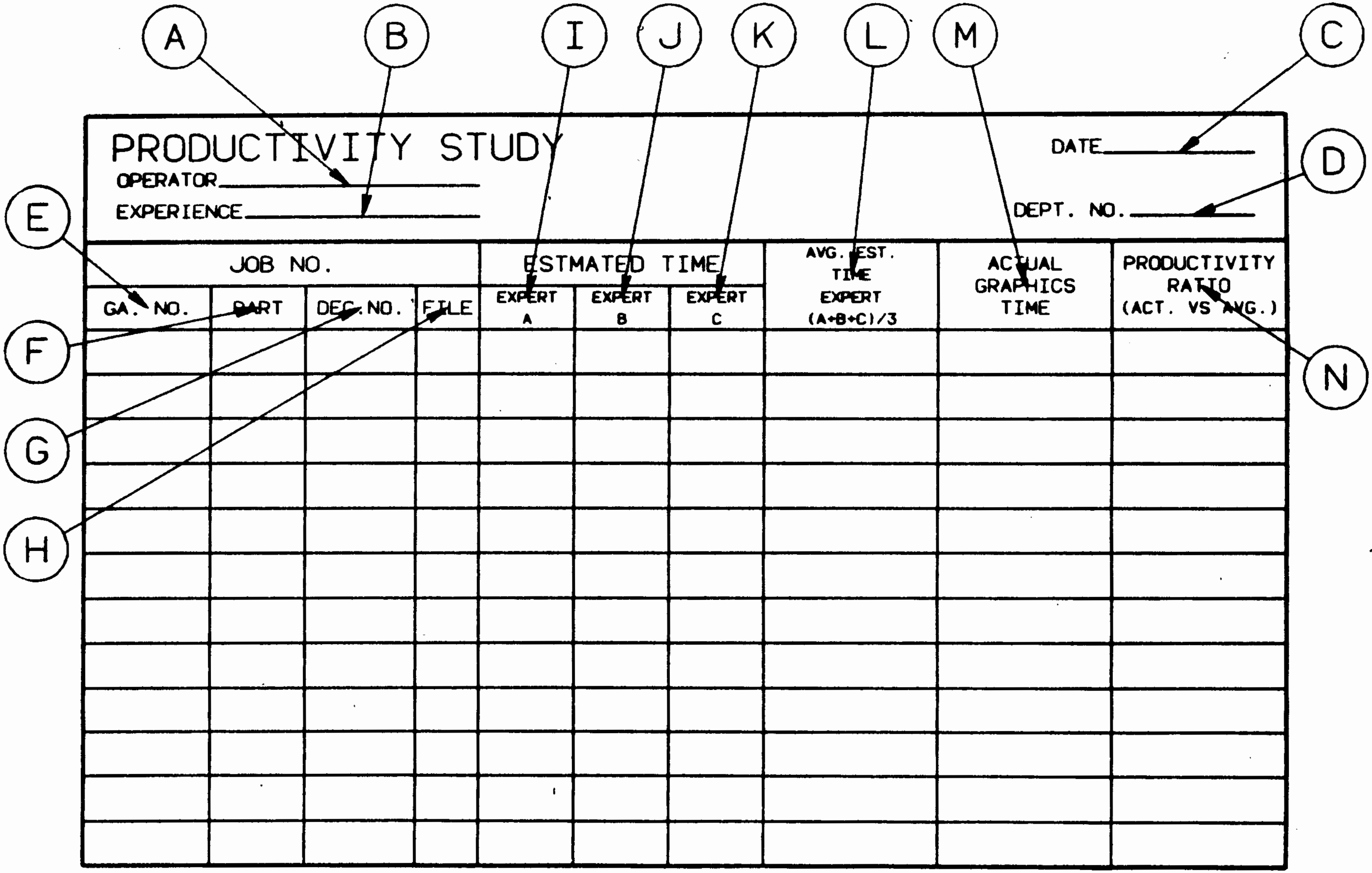
DATE____________

OPERATOR____________________

EXPERIENCE____________________

DEPT. NO.____________

JOB NO.				ESTMATED TIME			AVG. EST. TIME EXPERT (A+B+C)/3	ACTUAL GRAPHICS TIME	PRODUCTIVITY RATIO (ACT. VS AVG.)
GA. NO.	PART	DEC.NO.	FILE	EXPERT A	EXPERT B	EXPERT C			



A
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PRODUCTIVITY STUDY
OPERATOR
EXPERIENCE
DATE
DEPT. NO.
JOB NO.
GA. NO.
PART
DEC. NO.
FILE
ESTMATED TIME
EXPERT A
EXPERT B
EXPERT C
AVG. EST. TIME EXPERT (A+B+C)/3
ACTUAL GRAPHICS TIME
PRODUCTIVITY RATIO (ACT. VS AVG.)

JDCW STANDARD GAGE #'S

29-04-XXXXX	STANDARD SEIBERT TOOL SET GAGES
29-10-XXXXX	PROGRESSIVE PLUG GAGES
29-11-XXXXX	D.E. PLUG GAGES
29-12-XXXXX	FLAT PLUG GAGES
29-13-XXXXX	DUBO AND RELATED GAGES
29-14-XXXXX	ALIGNMENT AND SPECIAL PLUG GAGES
29-15-XXXXX	TAPER PLUG AND RING GAGES
29-16-XXXXX	STANDARD ADJ. "C" SNAP GAGES
29-17-XXXXX	BAR SNAP GAGES
29-18-XXXXX	SPECIAL SNAP GAGES
29-19-XXXXX	SAW LENGTH GAGES
29-20-XXXXX	FORM TEMPLATE AND TARGET GAGES
29-21-XXXXX	SETUP HEIGHT AND SETUP BLOCK GAGES
29-22-XXXXX	ARBORS
29-23-XXXXX	BAR GAGES
29-24-XXXXX	FEELERS, KEYWAY AND SLOT WIDTH GAGES
29-25-XXXXX	KEYWAY DEPTH GAGES
29-26-XXXXX	DEPTH GAGES
29-27-XXXXX	DISTANCE AND LENGTH GAGES
29-28-XXXXX	RELATION GAGES
29-29-XXXXX	CHECKING FIXTURES
29-30-XXXXX	RADIUS GAGES
29-31-XXXXX	SPECIAL DESIGN GAGES
29-33-XXXXX	ARNOLD AND RELATION TYPE GAGES
29-34-XXXXX	DIAL BORE GAGES
29-35-XXXXX	DIAL SNAP GAGES
29-36-XXXXX	GROOVE DIAMETER GAGES
29-37-XXXXX	MASTER RING GAGES
29-38-XXXXX	MASTER DISC GAGES
29-39-XXXXX	AIR GAGES
29-40-XXXXX	PLANNING CHART
29-41-XXXXX	GLEASON ARBOR AND SETUP GAGES
29-42-XXXXX	B&S SETUP GAGES
29-43-XXXXX	B&S BUSHINGS
29-44-XXXXX	B&S ARBORS, SPUDS AND SPECIAL EQUIPMENT
29-45-XXXXX	LEAD CHECK AND PROFILE GAGES
29-46-XXXXX	MASTER GAGES
29-47-XXXXX	BASE CIRCLE GAGES
29-48-XXXXX	SPLINED P.D. GAGES
29-49-XXXXX	CHECK PINS
29-50-XXXXX	INVOLUTE SPLINE RELATION GAGES, MALE AND FEMALE
29-51-XXXXX	TAPER SPLINE RELATION GAGES, MALE AND FEMALE
29-52-XXXXX	STRAIGHT SPLINE RELATION GAGES, MALE AND FEMALE
29-53-XXXXX	SERRATION SPLINE GAGES, MALE AND FEMALE
29-54-XXXXX	TAPER INVOLUTE SPL RELATION GAGES, MALE AND FEMALE
29-55-XXXXX	K-CHARTS
29-56-XXXXX	INDICATORS, MAGNETIC GAGES
29-58-XXXXX	UNIVERSAL TEST EQUIPMENT
29-59-XXXXX	HARDNESS AND SURFACE FINISH
29-60-XXXXX	BALANCE WEIGHTS
29-61-XXXXX	MASTER THREAD SETTING PLUGS
29-62-XXXXX	OPTICAL CHARTS AND ADAPTORS
29-63-XXXXX	MALE THREAD GAGES
29-64-XXXXX	FEMALE THREAD GAGES

XXXXX-THESE ARE SEQUENICAL NUMBERS TAKING FROM GAGE NUMBERING BOOK

T

```
0>
0>EDIT SYSTEM.AUTHORIZE
#T
      1!CGOS200,10,ADMIN,0000,HwHwHw
      2!RF19656,*,BASIC,0000,WSCB\w
      3!RF22016,*,BASIC,0000,MBECoE
      4!RF25201,*,BASIC,0000,P`6}]M
      5!RF27710,*,BASIC,0000,]ZSJBu
      6!RF28530,*,BASIC,0000,YBM[e|
      7!RF31053,*,BASIC,0000,SIXuzv
      8!RF31065,*,BASIC,0000,W__ObI
      9!RF36889,*,BASIC,0000,ZuZYND
     15!RX21854,PE0003,BASIC,0000,|IU}F^
     16!RX23177,12,BASIC,0000,VonkTB
     17!RX25297,*,BASIC,0000,`U|[uR
     18!RX25550,PE0036,BASIC,0000,fEHRS
     19!RX28881,PE0001,BASIC,0000,BsSNaH
     20!RX28933,9,BASIC,0000,inTJ
     21!RX30077,PE0039,BASIC,0000,`@sE\N
     22!RX30155,PE0013,BASIC,0000,I[PcQK
     23!RX30199,PE0016,BASIC,0000,PhPhOk
     24!RX31075,PE0035,BASIC,0000,GyVuQ
     25!RX31871,PE0011,BASIC,0000,X|MbTW
     26!RX32441,PE0021,BASIC,0000,AYFMEG
     27!RX33339,PE0017,BASIC,0000,AIDCv
     28!RX33545,PE0006,BASIC,0000,QrhFN[
     29!RX3628,PE0015,BASIC,0000,\GRDW
     30!RX33683,PE0012,BASIC,0000,]AiQJn
     31!RX33741,PE0004,BASIC,0000,RJH]~W
     32!RX33831,*,BASIC,0000,{a}v^A
     33!RX33841,PE0029,BASIC,0000,fwPyYI
     34!RX33931,PE0038,BASIC,0000,\o{}Ai
     74!RX28507,*,ADMIN,0000,TyTvaA
     75!RX535,4,BASIC,0000,uWUQVJ
#Q
0>AUTHRIZ
0>
```

```
T
 1!0>
 2!0>DPLOG
 3!TYPE COMMAND
 4!COMPLOG
 5!TYPE COMMAND
 6!SUMCHARG
 7!TYPE COMMAND
 8!DUMPLOG
 9!
10!PE0038          $    52.38
11!10              $   100.67
12!20000           $     8.39
13!19              $    15.59
14!723             $    10.89
15!20              $    31.62
16!9               $    10.47
17!4               $    35.27
18!841             $     3.45
19!11              $     4.12
20!121             $    22.85
21!100             $     6.63
22!101             $      .93
23!PE0006          $      .92
24!2               $      .27
25!122             $      .28
26!
27!NAME:                NUMBER:        DATE:    TIME: DURA: TASK: COST:
28!
29!CGDS200              10             05/01/85 05:27 00:13 00    $    .22
30!RX36359              723            05/01/85 05:50 00:59 02    $    .98
31!CGDS200              10             05/01/85 06:49 00:16 00    $    .27
32!RX28933              9              05/01/85 06:51 01:06 01    $   1.10
33!RX33931              PE0038         05/01/85 07:02 00:02 04    $    .03
34!RX33931              PE0038         05/01/85 07:13 02:45 04    $   2.75
35!RX36360              20000          05/01/85 07:16 02:42 05    $   2.70
36!RX36359              723            05/01/85 07:21 02:37 02    $   2.62
37!RF31053              19             05/01/85 07:39 02:10 03    $   2.17
38!RF31065              20             05/01/85 08:19 01:29 06    $   1.48
39!RX33931              PE0038         05/01/85 09:50 00:08 01    $    .13
40!CGDS200              10             05/01/85 09:50 00:08 00    $    .13
41!CGDS200              10             05/01/85 09:58 05:18 00    $   5.30
42!RX33931              PE0038         05/01/85 10:02 05:10 01    $   5.17
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1000	29-31-6887	03.12	02.50	03.00	02.00	02.50	01.00
1002	29-55-1562	00.83	01.00	00.50	00.50	00.66	01.00
1003	29-55-1566	00.47	01.00	00.50	00.50	00.66	01.00
1004	29-55-1568	00.37	01.00	00.50	00.50	00.66	01.00
1005	29-55-1571	00.27	01.00	00.50	00.50	00.66	01.00
1006	29-31-6917	03.16	04.00	06.00	03.00	04.33	01.00
1007	29-31-6923	03.20	05.00	06.00	03.00	04.66	01.00
1010	29-26-5138	02.43	05.00	07.00	05.00	05.66	02.00
1011	29-14-1645	00.77	01.00	00.42	01.00	00.81	01.00
1012	29-14-1650	02.30	02.50	00.50	01.00	01.33	03.00
1013	29-24-1322	01.23	00.67	00.33	00.75	00.58	02.00
1014	29-21-1932	00.32	00.25	00.16	00.16	00.19	01.00
1015	29-21-1930	00.50	00.25	00.16	00.16	00.19	01.00
1017	29-31-6934	01.88	01.00	02.00	00.75	01.25	02.00
1018	29-23-0272	07.62	04.00	04.00	02.50	03.50	01.00
1019	29-26-5137	18.52	06.00	10.00	16.00	10.66	02.00
1020	29-27-6507	02.72	04.00	04.00	03.00	03.67	03.00
1021	29-31-7033	01.72	02.00	01.50	01.00	01.50	03.00
1022	29-55-1583	00.68	01.00	00.50	00.50	00.67	01.00
1023	29-55-1585	00.80	01.00	00.50	00.50	00.67	01.00
1024	29-40-1348	01.40	01.00	01.00	01.00	01.00	02.00
1025	29-55-1553	00.25	01.00	00.50	00.50	00.67	01.00
1026	29-55-1551	00.37	01.00	00.50	00.50	00.67	01.00
1027	29-11-4460	00.25	00.50	00.16	00.50	00.38	02.00
1028	29-11-4461	00.08	00.50	00.16	00.50	00.38	02.00
1029	29-14-1644	00.33	00.50	01.00	01.00	00.83	02.00
1030	29-18-3161	00.75	01.50	02.50	01.00	01.67	02.00
1031	29-18-3162	00.47	00.16	00.25	01.00	00.08	02.00
1032	29-18-3163	00.25	00.25	00.25	00.50	00.33	02.00
1033	29-18-3164	00.08	00.25	00.25	00.50	00.33	02.00
1034	29-24-1304	01.00	00.25	00.25	00.50	00.33	02.00
1035	29-24-1305	00.08	00.25	00.25	00.50	00.33	02.00
1036	29-27-4349	16.00	24.00	17.00	27.00	18.00	02.00
1037	29-40-1332	00.42	00.50	00.25	01.00	00.58	02.00
1038	29-18-3196	00.25	00.25	00.25	00.50	00.33	02.00
1039	29-18-3202	00.08	00.25	00.25	00.50	00.33	02.00
1040	29-18-3185	00.25	00.25	00.25	00.50	00.33	02.00
1041	29-27-6354	24.00	10.00	17.00	12.00	13.00	02.00
1042	29-31-6875	02.50	06.00	03.00	04.00	04.55	02.00
1043	29-31-6876	01.00	01.00	00.50	01.00	00.83	02.00
1044	29-40-1340	01.00	01.00	01.00	01.50	01.16	02.00
1045	29-22-0794	01.75	02.00	03.50	02.00	02.50	02.00
1046	29-26-5025	01.83	02.50	03.00	01.00	02.28	01.00
1047	29-14-1628	03.00	01.00	02.00	01.00	01.55	01.00
1048	29-14-1633	01.00	01.00	01.50	01.00	01.28	01.00
1049	29-14-1621	00.83	02.50	01.00	01.00	01.50	01.00
1050	29-14-1634	00.83	02.50	01.00	01.00	01.50	01.00

1051	29-31-6862	01.33	03.00	01.50	02.00	02.28	01.00
1052	29-26-5056	00.33	03.00	01.50	02.00	02.28	01.00
1053	29-14-1639	03.50	02.00	01.00	01.00	01.55	01.00
1054	29-27-6328	08.87	03.50	04.00	03.00	03.50	01.00
1055	29-14-1643	01.80	01.00	02.00	01.00	01.28	01.00
1056	29-31-7215	01.95	01.50	04.00	01.50	02.33	01.00
1057	29-31-7228	01.03	05.00	04.00	07.50	05.50	01.00
1058	29-31-7245	00.65	02.00	03.00	00.50	01.83	01.00
1059	29-31-7244	01.33	02.00	02.50	00.50	01.66	01.00
1060	29-55-1678	00.33	01.00	00.50	00.50	00.67	01.00
1061	29-31-7249	01.70	02.00	02.00	00.50	01.50	01.00
1062	29-26-0305	05.28	04.00	02.00	03.50	03.17	02.00
1063	29-14-1727	00.97	02.00	03.00	00.50	01.83	01.00
1064	29-14-1722	00.68	02.00	02.00	01.00	01.66	01.00
1065	29-14-1725	00.82	02.00	02.00	02.50	02.17	01.00
1066	29-29-1318	31.50	20.00	16.00	20.00	18.66	02.00
1067	29-31-7277	35.83	08.00	12.00	16.00	12.00	01.00
1068	29-40-1517	01.98	02.00	03.00	03.00	02.66	02.00
1069	29-31-7284	02.10	02.00	02.00	00.50	01.50	02.00
1070	29-40-1527	01.38	01.00	01.00	00.17	00.72	02.00
1071	29-31-7289	00.97	02.00	02.00	00.50	01.50	02.00
1072	29-40-1392	04.23	03.00	03.00	03.00	03.00	02.00
1073	29-40-1528	02.85	01.00	03.00	01.00	01.66	02.00
1074	29-27-6812	26.14	00.00	00.00	00.00	00.00	02.00
1075	29-27 6298	12.80	00.00	00.00	00.00	00.00	01.00
1076	29-14-1669	02.32	00.00	00.00	00.00	00.00	01.00
1077	29-40-1517	00.37	00.00	00.00	00.00	00.00	02.00
1078	29-31-7348	13.40	00.00	00.00	00.00	00.00	02.00
1079	29-27-6857	23.88	00.00	00.00	00.00	00.00	02.00
1080	29-40-1340	00.68	00.00	00.00	00.00	00.00	02.00
1081	29-18-3430	08.37	00.00	00.00	00.00	00.00	02.00

```
//RXTEEL   JOB (RX55ST,X55S,BJA000,RX0000,34663),'D. TEEL 55S  ',
//  MSGCLASS=T,PRTY=02,NOTIFY=RX34663,TIME=5,MSGLEVEL=(2,0)
//*MAIN  ORG=RXR4,CLASS=TSO30
//*FORMAT PR,DDNAME=FT12F001,DEST=RXR4,COPIES=1
//*FORMAT PR,DDNAME=,DEST=RXR4,COPIES=1
/*
/*****************************************************************
/***  THIS SAS PROGRAM PRINTS A SUMMARY REPORT OF PRODUCTIVITY **
/***  IMPROVEMENT DUE TO COMPUTER GRAPHICS.                    **
/***        DELIVER TO   DAN TEEL , 55S                        **
/***         PROGRAM IS LOCATED IN RX34663.SAS.CNTL(TEEL)      **
/*****************************************************************
//STEP1 EXEC SAS,REGN=2048K
//FILE1     DD DSN=RX37179.PRODGAGE.DATA,DISP=SHR
//SYSIN   DD *,DCB=BLKSIZE=80
OPTIONS MISSING=' ' NOSOURCE LINESIZE=80;
DATA ONE;
INFILE FILE1;
INPUT @1 JOB 4.  @6 GAGE $10. @18 ACT_HRS 5.2 @24 A_EST 5.2
      @30 B_EST 5.2 @36 C_EST 5.2 @42 EST_AVG 5.2 @48 DESIGNER 2.
      @9 JOB_TYPE $2. @1 ACC $1.;
IF EST_AVG=0 THEN DELETE;
SAVINGS=EST_AVG - ACT_HRS;
PRATIO= EST_AVG / ACT_HRS;

PROC MEANS MAXDEC=2 N MEAN SUM;
VAR ACT_HRS EST_AVG PRATIO;
TITLE COMPUTER GRAPHICS PRODUCTIVITY STUDY;

PROC SORT;
  BY JOB_TYPE;
PROC PRINT UNIFORM SPLIT=*;
  BY JOB_TYPE;
  ID JOB_TYPE;
  VAR JOB GAGE ACT_HRS A_EST B_EST C_EST EST_AVG DESIGNER SAVINGS
      PRATIO;
  SUM ACT_HRS EST_AVG PRATIO SAVINGS;
  FORMAT ACT_HRS A_EST B_EST C_EST EST_AVG SAVINGS PRATIO 5.2;
  FORMAT JOB 4. DESIGNER 2.;
  LABEL PRATIO=PROD.*RATIO;
  LABEL JOB_TYPE=JOB*TYPE;
  LABEL ACT_HRS=SYSTEM*HOURS;
  LABEL A_EST=EST A;
  LABEL B_EST=EST B;
  LABEL C_EST=EST C;
  LABEL DESIGNER=DES.*ENGR.;
  LABEL EST_AVG=AVE.*EST.;
  TITLE COMPUTER GRAPHICS PRODUCTIVITY STUDY;

PROC MEANS MAXDEC=2;
  BY JOB_TYPE;
  VAR   ACT_HRS A_EST B_EST C_EST EST_AVG SAVINGS PRATIO;
  LABEL JOB_TYPE=JOB TYPE;
```

COMPUTER GRAPHICS PRODUCTIVITY STUDY

JOB TYPE	JOB	GAGE	SYSTEM HOURS	EST A	EST B	EST C	AVE. EST.	DES. ENGR.	SAVINGS	PROD. RATIO
11	1027	29-11-4460	0.25	0.50	0.16	0.50	0.38	1	0.13	1.52
	1028	29-11-4461	0.08	0.50	0.16	0.50	0.38	1	0.30	4.75
--			-----				-----		-----	-----
11			0.33				0.76		0.43	6.27
14	1011	29-14-1645	0.77	1.00	0.42	1.00	0.81	1	0.04	1.05
	1012	29-14-1650	2.30	2.50	0.50	1.00	1.33	1	-0.97	0.58
	1029	29-14-1644	0.33	0.50	1.00	1.00	0.83	1	0.50	2.52
	1047	29-14-1628	3.00	1.00	2.00	1.00	1.55	1	-1.45	0.52
	1048	29-14-1633	1.00	1.00	1.50	1.00	1.28	1	0.28	1.28
	1049	29-14-1621	0.83	2.50	1.00	1.00	1.50	1	0.67	1.81
	1050	29-14-1634	0.83	2.50	1.00	1.00	1.50	1	0.67	1.81
	1053	29-14-1639	3.50	2.00	1.00	1.00	1.55	1	-1.95	0.44
	1055	29-14-1643	1.80	1.00	2.00	1.00	1.28	1	-0.52	0.71
	1063	29-14-1727	0.97	2.00	3.00	0.50	1.83	1	0.86	1.89
	1064	29-14-1722	0.68	2.00	2.00	1.00	1.66	1	0.98	2.44
	1065	29-14-1725	0.82	2.00	2.00	2.50	2.17	1	1.35	2.65
	1070	29-14-1669	2.32	4.00	3.00	3.50	3.50	1	1.18	1.51
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			19.15				20.79		1.64	19.19
18	1030	29-18-3161	0.75	1.50	2.50	1.00	1.67	1	0.92	2.23
	1031	29-18-3162	0.47	0.16	0.25	1.00	0.08	1	-0.39	0.17
	1032	29-18-3163	0.25	0.25	0.25	0.50	0.33	1	0.08	1.32
	1033	29-18-3164	0.08	0.25	0.25	0.50	0.33	1	0.25	4.13
	1038	29-18-3196	0.25	0.25	0.25	0.50	0.33	1	0.08	1.32
	1039	29-18-3202	0.08	0.25	0.25	0.50	0.33	1	0.25	4.13
	1040	29-18-3185	0.25	0.25	0.25	0.50	0.33	1	0.08	1.32
	1061	29-18-3430	8.37	12.00	10.00	9.00	10.33	1	1.96	1.23
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18			10.50				13.73		3.23	15.84
21	1014	29-21-1932	0.32	0.25	0.16	0.16	0.19	1	-0.13	0.59
	1015	29-21-1930	0.50	0.25	0.16	0.16	0.19	1	-0.31	0.38
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21			0.82				0.38		-0.44	0.97
22	1045	29-22-0794	1.75	2.00	3.50	2.00	2.50	1	0.75	1.43
23	1016	29-23-0272	7.62	4.00	4.00	2.50	3.50	1	-4.12	0.46
24	1013	29-24-1322	1.23	0.67	0.33	0.75	0.58	1	-0.65	0.47
	1034	29-24-1304	1.00	0.25	0.25	0.50	0.33	1	-0.67	0.33
	1035	29-24-1305	0.08	0.25	0.25	0.50	0.33	1	0.25	4.13
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24			2.31				1.24		-1.07	4.93

COMPUTER GRAPHICS PRODUCTIVITY STUDY

JOB TYPE	JOB	GAGE	SYSTEM HOURS	EST A	EST B	EST C	AVE. EST.	DES. ENGR.	SAVINGS	PROD. RATIO
26	1010	29-26-5138	2.43	5.00	7.00	5.00	5.66	1	3.23	2.33
	1019	29-26-5137	18.52	6.00	10.00	16.00	10.66	1	-7.86	0.58
	1040	29-26-5025	1.83	2.50	3.00	1.00	2.28	1	0.45	1.25
	1052	29-26-5056	0.33	3.00	1.50	2.00	2.26	1	1.95	6.91
	1062	29-26-0305	5.26	4.00	2.00	3.50	3.17	1	-2.11	0.60
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26			28.39				24.05		-4.34	11.66
27	1020	29-27-6507	2.72	4.00	4.00	3.00	3.67	1	0.95	1.35
	1036	29-27-4349	16.00	24.00	17.00	27.00	18.00	1	2.00	1.13
	1041	29-27-6354	24.00	10.00	17.00	12.00	13.00	1	-11	0.54
	1054	29-27-6328	8.87	3.50	4.00	3.00	3.50	1	-5.37	0.39
	1074	29-27-6812	26.14	32.00	32.00	30.00	31.33	1	5.19	1.20
	1075	29-27 6298	12.80	16.00	16.00	15.00	16.33	1	3.53	1.28
	1079	29-27-6857	23.88	24.00	24.00	24.00	24.00	1	0.12	1.01
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27			114.4				109.8		-4.58	6.89
29	1066	29-29-1318	31.50	20.00	16.00	20.00	18.66	1	-12.8	0.59
31	1000	29-31-6887	3.12	2.50	3.00	2.00	2.50	1	-0.62	0.80
	1006	29-31-6917	3.16	4.00	6.00	3.00	4.33	1	1.17	1.37
	1007	29-31-6923	3.20	5.00	6.00	3.00	4.66	1	1.46	1.46
	1017	29-31-6934	1.88	1.00	2.00	0.75	1.25	1	-0.63	0.66
	1021	29-31-7033	1.72	2.00	1.50	1.00	1.50	1	-0.22	0.87
	1042	29-31-6875	2.50	6.00	3.00	4.00	4.55	1	2.05	1.82
	1043	29-31-6876	1.00	1.00	0.50	1.00	0.83	1	-0.17	0.83
	1051	29-31-6862	1.33	3.00	1.50	2.00	2.26	1	0.95	1.71
	1056	29-31-7215	1.95	1.50	4.00	1.50	2.33	1	0.38	1.19
	1057	29-31-7228	1.03	5.00	4.00	7.50	5.50	1	4.47	5.34
	1058	29-31-7245	0.65	2.00	3.00	0.50	1.83	1	1.18	2.82
	1059	29-31-7244	1.33	2.00	2.50	0.50	1.66	1	0.33	1.25
	1061	29-31-7249	1.70	2.00	2.00	0.50	1.50	1	-0.20	0.88
	1067	29-31-7277	35.83	8.00	12.00	16.00	12.00	1	-23.8	0.33
	1069	29-31-7284	2.10	2.00	2.00	0.50	1.50	1	-0.60	0.71
	1071	29-31-7289	0.97	2.00	2.00	0.50	1.50	1	0.53	1.55
	1078	29-31-7346	13.40	24.00	22.00	25.00	23.66	1	10.26	1.77
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31			76.87				73.38		-3.49	25.37
40	1024	29-40-1346	1.40	1.00	1.00	1.00	1.00	1	-0.40	0.71
	1037	29-40-1332	0.42	0.50	0.25	1.00	0.58	1	0.16	1.38
	1044	29-40-1340	1.00	1.00	1.00	1.50	1.16	1	0.16	1.16
	1065	29-40-1517	1.98	2.00	3.00	3.00	2.66	1	0.68	1.34
	1070	29-40-1527	1.38	1.00	1.00	0.17	0.72	1	-0.66	0.52
	1072	29-40-1392	4.23	3.00	3.00	3.00	3.00	1	-1.23	0.71
	1073	29-40-1526	2.85	1.00	3.00	1.00	1.66	1	-1.19	0.58
	1077	29-40-1517	0.37	4.00	4.00	4.50	4.16	1	3.79	11.24
	1080	29-40-1340	0.68	2.00	2.50	3.00	2.50	1	1.82	3.68
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COMPUTER GRAPHICS PRODUCTIVITY STUDY

JOB TYPE	JOB	GAGE	SYSTEM HOURS	EST A	EST B	EST C	AVE. EST.	DES. ENGR.	SAVINGS	PROD. RATIO
40			14.31				17.44		3.13	21.33
55	1002	29-55-1562	0.83	1.00	0.50	0.50	0.66	1	-0.17	0.80
	1003	29-55-1566	0.47	1.00	0.50	0.50	0.66	1	0.19	1.40
	1004	29-55-1568	0.37	1.00	0.50	0.50	0.66	1	0.29	1.78
	1005	29-55-1571	0.27	1.00	0.50	0.50	0.66	1	0.39	2.44
	1022	29-55-1583	0.66	1.00	0.50	0.50	0.67	1	-0.01	0.99
	1023	29-55-1585	0.80	1.00	0.50	0.50	0.67	1	-0.13	0.84
	1025	29-55-1553	0.25	1.00	0.50	0.50	0.67	1	0.42	2.68
	1026	29-55-1551	0.37	1.00	0.50	0.50	0.67	1	0.30	1.81
	1060	29-55-1678	0.33	1.00	0.50	0.50	0.67	1	0.34	2.03
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55			4.37				5.99		1.62	14.77
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			312.3				292.2		-20.1	129.7

COMPUTER GRAPHICS PRODUCTIVITY STUDY

16:28 THURSDAY, JULY 11, 198

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERRO OF MEAN
JOB TYPE=11						
ACT_HRS	2	0.16	0.12	0.08	0.25	0.0
A_EST	2	0.50	0.00	0.50	0.50	0.0
B_EST	2	0.16	0.00	0.16	0.16	0.0
C_EST	2	0.50	0.00	0.50	0.50	0.0
EST_AVG	2	0.38	0.00	0.38	0.38	0.0
SAVINGS	2	0.21	0.12	0.13	0.30	0.0
PRATIO	2	3.14	2.28	1.52	4.75	1.6
JOB TYPE=14						
ACT_HRS	12	1.40	1.01	0.33	3.50	0.2
A_EST	12	1.67	0.72	0.50	2.50	0.2
B_EST	12	1.45	0.76	0.42	3.00	0.2
C_EST	12	1.08	0.47	0.50	2.50	0.1
EST_AVG	12	1.44	0.38	0.81	2.17	0.1
SAVINGS	12	0.04	1.04	-1.95	1.35	0.3
PRATIO	12	1.47	0.82	0.44	2.65	0.2
JOB TYPE=18						
ACT_HRS	7	0.30	0.24	0.08	0.75	0.0
A_EST	7	0.42	0.48	0.16	1.50	0.1
B_EST	7	0.57	0.85	0.25	2.50	0.3
C_EST	7	0.64	0.24	0.50	1.00	0.0
EST_AVG	7	0.49	0.53	0.08	1.67	0.2
SAVINGS	7	0.18	0.39	-0.39	0.92	0.1
PRATIO	7	2.09	1.51	0.17	4.13	0.5
JOB TYPE=21						
ACT_HRS	2	0.41	0.13	0.32	0.50	0.0
A_EST	2	0.25	0.00	0.25	0.25	0.0
B_EST	2	0.16	0.00	0.16	0.16	0.0
C_EST	2	0.16	0.00	0.16	0.16	0.0
EST_AVG	2	0.19	0.00	0.19	0.19	0.0
SAVINGS	2	-0.22	0.13	-0.31	-0.13	0.0
PRATIO	2	0.49	0.15	0.38	0.59	0.1
JOB TYPE=22						
ACT_HRS	1	1.75	.	1.75	1.75	
A_EST	1	2.00	.	2.00	2.00	
B_EST	1	3.50	.	3.50	3.50	
C_EST	1	2.00	.	2.00	2.00	
EST_AVG	1	2.50	.	2.50	2.50	
SAVINGS	1	0.75	.	0.75	0.75	
PRATIO	1	1.43	.	1.43	1.43	

COMPUTER GRAPHICS PRODUCTIVITY STUDY
16:28 THURSDAY, JULY 11, 198

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERRO OF MEAN
JOB TYPE=23						
ACT_HRS	1	7.62	.	7.62	7.62	
A_EST	1	4.00	.	4.00	4.00	
B_EST	1	4.00	.	4.00	4.00	
C_EST	1	2.50	.	2.50	2.50	
EST_AVG	1	3.50	.	3.50	3.50	
SAVINGS	1	-4.12	.	-4.12	-4.12	
PRATIO	1	0.46	.	0.46	0.46	
JOB TYPE=24						
ACT_HRS	3	0.77	0.61	0.08	1.23	0.3
A_EST	3	0.39	0.24	0.25	0.67	0.1
B_EST	3	0.28	0.05	0.25	0.33	0.0
C_EST	3	0.58	0.14	0.50	0.75	0.0
EST_AVG	3	0.41	0.14	0.33	0.58	0.0
SAVINGS	3	-0.36	0.53	-0.67	0.25	0.3
PRATIO	3	1.64	2.15	0.33	4.13	1.2
JOB TYPE=26						
ACT_HRS	5	5.68	7.40	0.33	18.52	3.3
A_EST	5	4.10	1.43	2.50	6.00	0.6
B_EST	5	4.70	3.67	1.50	10.00	1.6
C_EST	5	5.50	6.06	1.00	16.00	2.7
EST_AVG	5	4.81	3.55	2.28	10.66	1.5
SAVINGS	5	-0.87	4.38	-7.86	3.23	1.9
PRATIO	5	2.33	2.66	0.58	6.91	1.1
JOB TYPE=27						
ACT_HRS	4	12.90	9.18	2.72	24.00	4.5
A_EST	4	10.38	9.55	3.50	24.00	4.7
B_EST	4	10.50	7.51	4.00	17.00	3.7
C_EST	4	11.25	11.32	3.00	27.00	5.6
EST_AVG	4	9.54	7.18	3.50	18.00	3.5
SAVINGS	4	-3.35	6.05	-11.00	2.00	3.0
PRATIO	4	0.85	0.46	0.39	1.35	0.2
JOB TYPE=29						
ACT_HRS	1	31.50	.	31.50	31.50	
A_EST	1	20.00	.	20.00	20.00	
B_EST	1	16.00	.	16.00	16.00	
C_EST	1	20.00	.	20.00	20.00	
EST_AVG	1	18.66	.	18.66	18.66	
SAVINGS	1	-12.84	.	-12.84	-12.84	
PRATIO	1	0.59	.	0.59	0.59	

COMPUTER GRAPHICS PRODUCTIVITY STUDY

16:28 THURSDAY, JULY 11, 198

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERRO OF MEAN
JOB TYPE=31						
ACT_HRS	16	3.97	8.54	0.65	35.83	2.1
A_EST	16	3.06	1.99	1.00	8.00	0.5
B_EST	16	3.44	2.74	0.50	12.00	0.6
C_EST	16	2.77	3.98	0.50	16.00	1.0
EST_AVG	16	3.11	2.77	0.83	12.00	0.6
SAVINGS	16	-0.86	6.26	-23.83	4.47	1.5
PRATIO	16	1.48	1.19	0.33	5.34	0.3
JOB TYPE=40						
ACT_HRS	7	1.89	1.28	0.42	4.23	0.4
A_EST	7	1.36	0.85	0.50	3.00	0.3
B_EST	7	1.75	1.20	0.25	3.00	0.4
C_EST	7	1.52	1.08	0.17	3.00	0.4
EST_AVG	7	1.54	0.95	0.58	3.00	0.3
SAVINGS	7	-0.35	0.73	-1.23	0.68	0.2
PRATIO	7	0.92	0.37	0.52	1.38	0.1
JOB TYPE=55						
ACT_HRS	9	0.49	0.23	0.25	0.83	0.0
A_EST	9	1.00	0.00	1.00	1.00	0.0
B_EST	9	0.50	0.00	0.50	0.50	0.0
C_EST	9	0.50	0.00	0.50	0.50	0.0
EST_AVG	9	0.67	0.01	0.66	0.67	0.0
SAVINGS	9	0.18	0.23	-0.17	0.42	0.0
PRATIO	9	1.04	0.69	0.80	2.68	0.2