pt 217
11/3/66

AEC RESEARCH AND DEVELOPMENT REPORT

MASTER

Y-1557
Engineering and
Equipment

POST AUDITING MACHINE TOOL INVESTMENTS

J. L. Williams
A. M. Christman

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT Contract W-7405 eng 26**

**UNION
CARBIDE**

OAK RIDGE Y-12 PLANT
P. O. Box Y
OAK RIDGE, TENNESSEE 37830

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in USA. Price \$1.00 . Available from the Clearinghouse for Federal
Scientific and Technical Information, National Bureau of Standards,
U.S. Department of Commerce, Springfield, Virginia 22151

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

H.C. \$ 1.00; MIN .50

Date Issued: October 31, 1966

Report Number Y-1557

Engineering and Equipment
TID-4500

UNION CARBIDE CORPORATION
Nuclear Division

Y-12 PLANT

Contract W-7405-eng-26
With the US Atomic Energy Commission

POST AUDITING MACHINE TOOL INVESTMENTS

J. L. Williams
A. M. Christman

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Oak Ridge, Tennessee

Report Number Y-1557Engineering and Equipment
TID-4500

Distribution:

Ackerson, R. D.	(AFSC)	McLendon, J. D.	
Bailey, E. W.		Meeks, E. J.	(AFSC)
Ballenger, H. F.	(2)	Miskell, R. V.	
Bernander, N. K.		Mitchel, G. W.	
Burkhart, L. E.		O'Hara, M. E.	
Center, C. E.	(ORGDP)	Perry, A. E.	
Christman, A. M.	(5)	Rader, D. H.	
Ebert, J. W.		Schwenn, M. F.	
Evans, G. W.		Smith, H. F.	
Foulk, D. L.		Sommerfeld, K. W.	
Fortenbery, M. J.		Stoner, H. H.	
Fowler, A. H.		Thomas, F. W.	
Gilliam, J. L.		Tilson, F. V.	
Gritzner, V. B.		Trotter, T. C.	
Hamby, N. E.		Waters, J. L.	
Harding, J. E.		Wesley, R. L.	
Harwell, W. L.	(ORGDP) (5)	Whitson, W. K.	
Hemphill, L. F.		Wilson, C. W.	
Hensley, C. E.		Winkel, R. A.	(Paducah)
Huber, A. P.	(ORGDP)	Wood, D. C.	
Jennings, D. A.		Yaggi, W. J.	
Keller, C. A.	(AEC-ORO) (4)	Zurcher, E.	
Little, J. C.		Y-12 Central Files	(5)
McDonald, F. B.		Y-12 Central Files	(Y-12RC)

In addition, this report is distributed in accordance with the category Engineering and Equipment as given in the "USAEC Standard Distribution Lists for Unclassified Scientific and Technical Reports", TID-4500.

ABSTRACT

Post auditing is that part of the investment analysis system which takes a retrospective look at investments to compare actual with predicted benefits for the purpose of improving future analyses. Ten tape-controlled machine tools at the Oak Ridge Y-12 Plant have been subjected to a post-audit review. Results show that some of the machines were better investments economically than others.

CONTENTS

SUMMARY	5
INTRODUCTION	6
INVESTMENT ANALYSIS.	7
Investment Methods	7
MAPI System	7
Post Auditing	9
Post-Audit Examples	10
Turning and Boring Machines (TBM)	10
Engine Lathes (EL)	10
Vertical Turret Lathes (VTL)	10
CONCLUSIONS	15

SUMMARY

Tape-controlled machine tools represent a substantial investment for any company, large or small. Currently, many companies are using some method of investment analysis as a means of improving their judgment on such large investments. The Machinery and Applied Products Institute (MAPI) system is being used at Y-12 to obtain information that is essential to a successful machine tool investment program. Post auditing is a necessary part of the investment analysis system since it provides information which tends to improve future analyses.

Ten tape-controlled machine investments were analyzed from the post-audit viewpoint. The average rate of return was found to be 27 percent, with individual investments varying from 1.5 to 57 percent. The data collected to accomplish the post audit reveal that the most important factors in a successful tape-controlled machine investment are: savings in time per part and the extent of utilization.

INTRODUCTION

It is a responsibility of the Union Carbide Corporation to apply the best possible business principles to the management of the physical facilities which it operates. This policy applies not only to the utilization of existing facilities, but also to the acquisition of new assets. Since the Y-12 Plant is a major fabrication facility in the AEC weapons complex, management of the machine tool inventory is an important responsibility.

Methods of internal plant organization for conducting a management program will not be discussed here. There are many variations of such systems and the particular one used by an individual company will depend upon many things, including the management philosophy of the company and the kind of personnel available for assignment to the activity.

A component of the management function, which is common to all systems regardless of the degree of formality of the particular program, is analysis. The analytical methods used by industrial concerns in judging investment proposals for machine tools are often formal and sometimes highly complex, but one of the facets of these systems that is often neglected is the collection of data on actual performance in order to conduct a post audit of the original investment and to provide a means for improving future analyses. The purpose of this paper is to examine the principle of investment analysis and to illustrate the use of the MAPI system^(a) in post auditing a group of numerically controlled machine tools purchased by the Y-12 Plant.

(a) The MAPI system was devised by George Terborgh, Research Director of the Machinery and Allied Products Institute. The system, which takes its name from the initials of the institute, is described in detail in Terborgh's book, "Business Investment Policy"; Port City Press (1958).

INVESTMENT ANALYSIS

INVESTMENT METHODS

Many of the most important decisions made by business management involve investment proposals. These decisions which normally involve large amounts of money and are usually irreversible, may have a long-term effect on the business. As a result, most large companies now employ a more or less formal method of investment analysis. Many methods are available and the selection of a specific method is probably less important than the concept of using a systematic approach rather than the intuitive or "seat of the pants" technique.

Investment methods available include: payout time, rate of return, annual cost, cash flowback (also known as present worth, incremental present worth, and venture worth), cash discount flow (also known as profitability index, investors method, interest rate of return, and internal rate of return), and MAPI. Some of the requirements for a good replacement formula are:

1. It should solve the right problem. Many formulas base the analysis on a comparison of costs between a present and a proposed machine over the estimated service life of the latter. Thus, if the machine is given a life of ten years, it is assumed that the old one will be kept ten years longer. However, in most cases, the question is not whether the replacement should occur this year or in ten years, but whether the replacement should occur this year or next year.
2. The formula should measure how profitable the investment is instead of how rapidly the investment cost will be liquidated. Adjustments should be made for projects having different lives.
3. It should consider the time value of money and the time shape of the earnings. For example, a dollar returned in the first year is worth more than a dollar returned in subsequent years.
4. It should be easy to use and capable of projecting future deterioration and obsolescence.
5. In addition to allowing for present and future salvage values, the formula should provide a consistent ranking procedure.

MAPI SYSTEM

Based on the criteria just listed, the MAPI system was selected for use in the Y-12 Plant. The MAPI formula, as used at Y-12 (modified somewhat to eliminate considerations such as income tax), is as follows:

$$\text{Rate of Return} = \frac{(2) + (3) - (4)}{(1)},$$

where:

(1) represents the net investment.

This investment is the installed cost of the project, less any investment released or avoided by it. The released investment equals the present disposal value of the assets that would be retired by the project. The avoided investment is the amount of capital additions that would be required in the absence of the proposed project.

(2) represents the next-year operating advantage.

This advantage is the reduction in operating costs resulting from the project, compared with the operating cost for producing the required product by the best available alternative.

(3) the next-year capital consumption avoided.

This amount is the loss of the disposal value from holding for another year the assets that would be retired by the project, plus the next-year allocation of capital additions required in its absence. This cost is avoided by acquiring the asset represented by the project under consideration.

(4) the next-year capital consumption incurred.

This amount is the consumption of the project investment itself. It is the amount by which the remaining use value of the project at the end of the year is below its cost. In other words, it is the amount by which the use value runs off during the year (the cost of the project being taken as its initial value). The MAPI chart provides this value.

The success or failure of the MAPI system, like any other system, hinges upon the reliability of the data utilized. Items (1), (3), and (4) are either available numbers or they can be standardized; however, this is not the case in Item (2). Deriving the next-year operating advantage requires the most thought and effort, and the accuracy of this value essentially determines the accuracy of the analysis.

MAPI can be applied uniformly to a wide variety of investment proposals; and, its result not only provides an absolute feel for the individual proposal, but also a priority ranking, by comparing rates of return, for all proposals analyzed.

POST AUDITING

To discuss post audits as a part of investment analysis, it is first necessary to establish a frame of reference. To do this, the basic principles of machine tool management will be defined even though no attempt will be made to discuss management methods.

All systems of machine tool management have three things in common: planning, analysis, and action.

In the planning function, advantage is taken of all the long-range information available, including management intuition, to arrive at the detailed plan which defines what the basic capital asset acquisition program will be.

In the analysis phase, each of the individual projects in the plan is subjected to a critical analytical study to insure that it really is what is needed, and that it is a sound business investment.

After completion of the analysis phase, the program then culminates in action; that is, the expenditure of funds for a new investment.

It can be seen that this program is very much like a tape-controlled machine tool. The planning function is similar to the preparation of a tape, the analysis function is like the work of the computer section of the control system, and the action function is the same as the movement of the slides as a result of servo impulses.

But it will be recognized that this is not a very good tape-controlled machine, because it is an open-loop system. The slides can be directed where to move, but there is no way of assuring that they respond correctly. To obtain real precision, a vital element is required—feedback. When it is provided, the loop is closed and the tape machine can now monitor itself and make corrections if it finds itself inaccurate.

The corresponding feedback function in the machine tool management program is post auditing. It can be defined as comparing predicted with actual performance for the purpose of improving future estimates. In other words, it is the "proof of the pudding" insofar as investment analysis is concerned. A good post audit should result in a definite conclusion as to whether or not the purchase was economically justified. In addition, it should identify those factors which significantly affect the return on the investment. If it does these things well, it may not only be beneficial to the investment analysis program, but it may also help the shop operator by revealing areas where additional savings may be realized by implementing simple changes in operating methods.

The MAPI system is used for post auditing as well as for the preinvestment analysis and thereby provides a direct comparison. This comparison is now being made at the Y-12 Plant. However, comparisons are not shown in this report since the tools under consideration were purchased prior to the installation of the MAPI system.

Post-Audit Examples

As an example of its application, post-audit data are presented on ten tape-controlled machine tools which have been purchased at Y-12 during the past three-year period. These tools are divided into three types:

Turning and Boring Machines (TBM) - The installed cost of these machines is about \$120,000 each. The post-audit example shows four of these machines used in one shop and two used in another.

Engine Lathes (EL) - These tools cost about \$110,000 installed. The post-audit shows two of these machines.

Vertical Turret Lathes (VTL) - These cost \$240,000 as installed and equipped for use. The post-audit example covers two of these machines.

Pertinent figures from the MAPI analysis of the post audit of these investments are presented in Table 1.

Table 1
MAPI POST AUDIT OF TEN TAPE-CONTROLLED MACHINE TOOLS

Machine Type	Shop	Number of Machines	Net Investment Required (\$)	Return on Investment (\$)	Rate of Return (%)
TBM	A	4	386,000	6,000	1.5
TBM	B	2	173,000	42,000	24
EL	C	2	157,000	36,000	23
VTL	D	2	368,000	208,000	57

The net investment, as shown, is lower than the purchase price because the MAPI formula allows credit for the disposal value of the alternate machines (that is, the machines which would have been used if the new investment had not been made). In each of the cases shown in Table 1, the alternate machines were considered to be tracer-controlled lathes. Also, it was considered that the tape machines were replacing existing tracer lathes rather than adding extra capacity, which is a more conservative approach for the analysis.

The amount available for return on the investment is the difference between the total operating cost savings for the first year and the capital consumption which was incurred with the new investment. The capital consumption figure is actually the heart of the MAPI system and it is analogous to a depreciation or amortization figure for the first year of use. For example, the actual first-year savings for the turning and boring machines for Shop A was found to be \$65,000. The capital consumption incurred, however, was \$59,000, leaving a difference of \$6,000 which is the return on the investment.

The rate of return then is the percentage of the net investment which was returned in the first year of use. As stated earlier, an adjustment was made to the MAPI formula to account for the absence of income tax in Y-12's operation and to make the rates of return comparable with private industry. On this basis, private industry usually experiences a rate of return of about 15 percent. Therefore, three of Y-12's investments will compare favorably and one will not. The weighted average of the four investments, however, shows a \$292,000 return on a net investment of \$1,084,000, for an overall percentage rate of return of 27 percent.

The next phase of the analysis was to determine why the Shop A machines did not pay off as well as the others. The following discussion will show the effect on the rate of return of varying some of the factors which are important to the post-audit analysis.

Figure 1 shows the effect of rework labor and rework inspection. The rate of return is plotted along the ordinate and the percentage difference between the tape and duplicator (tracer controlled lathe) in acceptance on first inspection is plotted along the abscissa. The circled point is the base case and is the percent difference found in actual experience and used in the post audit. Each curve was then derived by mathematically varying the factor under consideration, in this case the difference between tape and duplicators on first-inspection acceptance. This method allows an estimation of what the rate of return would have been if the rework labor were more or less. As can be seen, these curves are so flat that even an improvement of almost nine percent, as experienced with the Shop A machines, has very little overall effect on the rate of return.

Figure 2 shows the effect of difference in the scrap rate. Again, in this example, the rate of return has been plotted on the ordinate and the percent difference in scrapped parts between duplicators and tape on the abscissa. Again, the circled point is the actual experience and the curve is derived mathematically. It can be observed that the high cost of material worked in Shop D has a profound effect on the rate of return for the VTL machines.

Figure 3 shows the effect of utilization. These curves show that even the Shop B machines would have been an unsatisfactory investment if they had been used for only one shift per day.

The final graph (Figure 4) shows the effect of the savings in direct labor; that is, the

Figure 1. RATE OF RETURN AS A FUNCTION OF REWORKING.

Figure 2. RATE OF RETURN AS A FUNCTION OF THE KILL RATE.

Figure 3. RATE OF RETURN AS A FUNCTION OF TOOL UTILIZATION.

Figure 4. RATE OF RETURN AS A FUNCTION OF THE MACHINING TIME PER PART.

"time-per-part" relationship. It can be seen that the actual experience varied from 20 percent in the case of the Shop A machines to over 75 percent for those used in Shop D. A generalization may be inferred from these data, namely: a tape machine will not be a good buy unless it can show at least a 30-percent saving in direct labor when compared to duplicators. This variable is certainly the most important factor that was found, and for this case it shows very clearly why the Shop A machines did not show as high a pay-off percent as the others. To follow up on this, an analysis of the part types involved showed that the Shop A parts were very simple and the duplicator operations were producing them initially at extremely low unit times.

As a result of the low rate of return on the Shop A machines, certain changes have been made to improve the situation. These changes include moving two of the machines to an area where they will be better utilized on more complex parts. Also, some minor changes in the machines have been made which increase their capacity and which allows the scheduling of more complex parts on the machines that were left in Shop A.

The fundamental question, however, relates to why these two variables, utilization and time per part, should have such an overriding effect on the rates of return for these investments. The answer is twofold: these variables directly affect the total number of machines needed for a given job, and the initial cost of the tape machines is very high.

CONCLUSIONS

The results of this study indicate that:

1. Machine tool management is becoming more and more important as the dollar value of the machine tool inventory increases.
2. A machine management program that does not post audit at least some of its investments is like an open-loop tape machine—it cannot prove where it has been and does not know for sure where it is going.
3. A good post-audit system is one which gives positive results. It should provide information to improve the next estimate and it should also tell whether or not the last investment was profitable. Also, post auditing should identify the factors which have significantly influenced the return on the investment.