San Fernando Valley State College

LEARNING CURVE WAGE INCENTIVES

A theoretical Study

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in Business Administration

by

James Andrew Broadston

June, 1967
The thesis of James Andrew Broadston is approved:

Committee Chairman

San Fernando Valley State College

June, 1967
DEDICATION

This thesis is dedicated to
my charming and lovely wife

ELIZABETH

and to our three children
Don, Sue, and LoAnne

whose understanding, patience and encouragement
have made it possible for me to complete
the work required for a

Master of Science
degree in
Business Administration
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Existing wage incentive systems based on fixed time standards do not fully meet the needs of a work force made up of people who show wide differences in their abilities to learn and to perform repetitive tasks.

Managements have historically had difficulty in administering such systems because they are rigid and cannot be readily adapted to a work force having variable needs. It has always been found difficult to motivate people toward maximum productivity.

In recent years, managements have also discovered that with our "new freedoms," it is also becoming increasingly important that management consider the needs of the "whole person" in the industrial environment.

While wage incentive systems have been in use since the early 1880's, when Frederick Taylor's principles of scientific management provided the first effective impetus to the effective utilization of labor, a new discovery having a direct bearing upon the ability of workers to do work and the time required for them to acquire new skills was discovered by Wright in 1936. This new concept, the improvement phenomenon, was first successfully applied to the mass production of military
aircraft during World War II, largely a hand assembly operation by hundreds of people. After an engineer had plotted the total man-hours required to mass produce a series of military aircraft on log-log paper he found, to his surprise, that the points fell in a straight line. This straight line, which later became known as a learning curve, provided a mathematical model of a basic human trait; man's ability to learn and to improve his performance through repetition. It has since been found that the "improvement phenomenon" is a fundamental characteristic of all people.

This study proposes that these two fundamentally human disciplines be brought together in a new discipline that will provide management with an improved tool that is more flexible and adaptable to human needs than past wage incentive systems have been. This new discipline will provide learning curve wage incentives that can be adapted to not only a wide range of capability in any given work force, but to also be responsive to the varying ability of any given individual to perform effectively. This would depend, of course, upon his ability to learn as well as the opportunities he has had to become more proficient by actually performing a repetitive task.

The study reviews the fundamental concepts and
history behind both older disciplines and shows, by actual examples, how they may be merged to provide the improvement delineated above.
ABSTRACT

LEARNING CURVE WAGE INCENTIVES

A Theoretical Study

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This study anticipates the merging of two separate and heretofore unrelated disciplines into a new one that provides a basis for the development of learning curve wage incentives. These new incentive systems will provide a means for accommodating rewards for improvement in productive performance, as classic systems have in the past, and in addition be able to allow for a sensitive evaluation of differences in the needs of individuals in the work force who have different talents. Individuals, having varied social and ego-humanistic needs that must be considered have not been accommodated by past incentive systems. This lack has brought a large measure of difficulty into their administration.

Improved incentive systems which allow for the
influence of the "improvement phenomenon" and other vital factors and still meet management's need to produce high quality products, on time, and at a profit, can be obtained by merging these two disciplines.

The study provides an introduction to the fundamentals and theory behind both basic disciplines, one on wage incentives and the other on learning curve theory, the mathematical model of the improvement phenomenon, and shows how they may be brought together for benefit. While it touches lightly upon the boundless possibilities of such an approach, it limits itself to the application of learning curve theory in providing meaningful motivation for the new worker who enters an already incentivized work-force for the first time. Such methods, while impractical a decade ago because of the complexity of the computations involved, can now be administered with dispatch as a result of advances in modern computer technology.
CHAPTER I

AN INTRODUCTION TO SOME OF THE HUMAN
PROBLEMS OF MOTIVATING PEOPLE
IN REPETITIVE PRODUCTION

This theoretical study proposes the merger of two separate disciplines which apply to the human aspects of motivating people to perform repetitive production as practiced in modern industry.

The first discipline is that of wage incentives which serve as management tools in motivating people to do more work in a given span of time. This motivation results in increased production, the benefits of which are then shared on the basis of some mutually agreed formula, by both the employee and the employer.

The second discipline concerns the improvement phenomenon wherein it is found that people, performing repetitive tasks, improve their skills and speed through learning. Tasks then become easier and can be accomplished more quickly resulting in improved productivity which brings on similar problems of sharing benefits equitably.

In establishing an overall matrix for this study, the following hypotheses are proposed:
1. No concerted effort has been made to bring wage incentive theory and improvement phenomenon theory together.

2. As both theories deal with human values and the characteristics of workers performing repetitive tasks, they may be brought together with benefit.

3. All past wage incentive plans use fixed time standards as if they were designed for machines rather than for people.

4. Attempts to adapt fixed time standards to people, who vary from each other, as well as individually, result in administrative problems that often cannot be solved by management.

5. The rate at which a machine can perform a repetitive task is relatively constant because machines do not learn.

6. The rate at which an individual person can perform a repetitive task will improve with experience and practice because people do learn by doing.

7. Different individuals exhibit wide differences in their ability to learn and to perform comparable repetitive tasks.

8. Existing wage incentive systems, using fixed time standards, do not fit the needs of people who are widely variable in their learning and doing capacities.

9. The improvement phenomenon and its mathematical model, the learning curve, can be used to generate variable time standards that will match human characteristics of learning and performing.

10. Wage incentive systems can be designed to have variable time allowances to accommodate both the differences in people on the work force as well as differences in the ability of any given individual to learn and to perform repetitive tasks.
11. New theoretical disciplines, as required for the generation of learning curve wage incentives, though complex, can be made practical through the use of modern computer technology.

12. No individual innovation in the field can be expected to provide a solution to all of the problems of managing a wage incentive system.

This study tests the above hypotheses by reviewing primary and secondary data pertaining to both disciplines, by discussing many of the fundamental human characteristics involved in matters of motivation and learning, by delineating some of the problems and shortcomings of past experience with wage incentive systems and by suggesting that improved wage incentive plans can be created by adapting the fundamentals of the human improvement phenomenon to such plans. To support this belief this study concludes by showing how variable time standards, generated through the use of improvement phenomenon theory, can be used to more effectively match human performance than the old fixed time standards used in the past.

Human Factors in Motivating People

Any study of the problems involved in motivating people must include consideration of their individual differences as well as certain common traits that exist to a greater or lesser degree in the personality of each one.
Paul Goodman refers to "human nature" and the organized system and observes that present day sociologists and anthropologists have little to say about the process by which a human being assimilates a culture, grows in strength and acquires habits in its environment which round it out into a complete being. Since people can be taught almost anything if the right techniques of "socializing" or "communicating" are used, the essence of "human nature," as he sees it, is to be pretty indefinitely malleable.\(^1\)

We find, however, an astonishingly different opinion on the part of experts who deal with human beings in a more raw, less highly processed state. Those who have to cope with people individually or in small groups, rather than statistically, attending to them as individuals rather than toward some broad far-off goals (parents, teachers, physicians, policemen, wardens, shop foremen, and grievance committees)--these experts are likely to hold stubbornly that there is a "human nature."\(^2\) With this view we do not need to be able to say what human nature \textit{is} in order to be able to say that something is "against human nature" and one persists in


\(^2\)Ibid., p. 5.
it at peril.

In the discussions which follow, certain habit patterns and human characteristics are ascribed to people; hence, in the absence of a more suitable term, these traits are referred to as "human nature" since they seem to be rather widely distributed throughout the population.

Because of human nature, which has often resulted in poor management, poor administration, and poor maintenance, many wage incentive and profit sharing plans designed to increase the overall productivity of groups of employees have not fared well in the long run. While there are some exceptions, of course, as well as a wide range of beliefs regarding their advantages and disadvantages, it has been observed that whenever rules are established that are contrary to basic requirements and drives of human nature, trouble will eventually result.

It appears that work incentives are only effective when the individual himself experiences a sustained improvement over that which he has experienced in the past. He must feel, and it must be true, that this gain was the result of his own individual effort, and not the result of the efforts of others or the "system," if it is to really motivate him.

A new generation, when born into a communal society, that does not experience the privations which
prompted its ancestors to join forces by creating such a plan for their overall mutual well-being, experiences little or no incentive to do more than a minimum share of the community effort. For this reason their standards of living have remained as they were many years ago, at the time of their founding.

In similar fashion, in our industrial organizations, unless methods are devised to bring obvious and tangible benefit to all new workers who enter the work force, and this benefit is proportional to their individual effort, past experience by others in attaining this improvement is of little consequence in motivating the new workers.

This study seeks to show that the effectiveness of wage incentive plans can be improved in the long run by the application of learning curve theory. By the application of such theory it will be shown that each new worker will be able to experience the same thrill of personal accomplishment and benefit from his own sustained effort and talent as did his predecessors.

**Some Basic Observations on Human Nature**

Before proceeding with this study it appears that since human nature plays such a large role in both the improvement phenomenon (upon which the learning curve
level again. The span of time varies with the nature of the matter—it may take only hours for a child to return to bad habits like thumb sucking or fingernail chewing, yet it may take six months for an adult to resume bad chain-smoking habits after a scare like the Surgeon General's recent report on the deleterious effects of tobacco. New Year's resolutions provide almost universal evidence of the widespread recognition of this human frailty.

2. Up to a point, people learn through practice and experience to perform certain repetitive tasks more efficiently, more expertly and more quickly. Experience has often been called the great teacher. If, for example, a person installs a screen door for the first time it would require several hours of hard work—measuring, finding the right tools, sawing, fitting, installing, and removing, to check latch and hinge positions, and finally mounting the door and adjusting it for proper operation.

If the same person were to repeat the job, it would be much easier to do a better
job in less time because of the "improvement phenomenon." Repetition of the job many times over would result in much improved proficiency because the learning process improves the method as effective habit patterns are established.

It is interesting to observe that there is a rather amazing correlation or similarity between the two basic human factors just described: the first of "forgetting" or slacking off of discipline and the second of "learning" or becoming more capable and proficient with experience. While these two factors are not the same, they can be plotted for comparison and show similar characteristics:

\[ 
\begin{array}{c}
\text{LEVEL OF SELF DISCIPLINE} \\
\text{FORGETTING} \\
\text{UNITS OF TIME PER OPERATION} \\
\text{LEARNING} \\
\text{No. of Operations} \\
\text{Similarity of Two Different "Human" Traits}
\end{array} \]
The important point that must be stressed in these two observations, however, is that these performance characteristics, while typical of the entire human race, are strictly individual characteristics and relate to the experience of a specific individual only. Similar experiences by a friend, a neighbor, a co-worker, a parent, or the experiences of society in general, are of no significance insofar as an individual member of society himself is concerned. The individual himself must experience both the forgetting and the learning. Others cannot do it for him, nor can anyone predict with any certainty how an individual will perform in any given situation.

These characteristics are strictly a personal matter, but can be influenced appreciably by motivators that appeal to the individual and that will bring him individual benefits that are somewhat proportional to the effort he expends.

3. Our capitalistic society provides each individual an opportunity to prosper or be poor, to succeed or to fail somewhat in
proportion to his individual contribution.

Because we live in a relatively free society, workers feel that they have a perfect right to criticize management, or, through labor unions, bring pressures to bear which will force the correction of practices which they do not like. Unless the job motivates them to work effectively, they may become dissatisfied and become sensitized to their environment and find fault.

Employees work more effectively when they have a challenging job which allows a feeling of achievement, responsibility, growth, advancement, enjoyment of the work itself and earned recognition.3

The opportunity to progress on a job within the industrial society depends directly upon the worker's individual ability to acquire skills (learning capacity) and to apply them constructively (produce). Each individual citizen's accomplishment, or progress made, depends primarily upon his own

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contribution to society and this, in turn, is incentivized by the rewards attainable by such performance and the individual appeal these incentives have for him. Such freedom, catering as it does to basic human traits, brings about a greater overall progress than can be accomplished by direction in a controlled state or dictatorship where people are told what to do and both incentives and payoffs are strictly limited. Performance under such conditions suffers accordingly.

**Wage Incentive Plans Can Motivate or Restrict**

Industrial organizations, like governments, can either provide wholesome constructive incentives for progress, or they can be severely restrictive, like oppressive dictatorships, and be subject to alteration or abolishment by the people in the same fashion as governments.

Herzberg observes that "In the last hundred years there has been a growing realization of sickness in our society and that one source of that sickness is the relationship of people to their work."[4]

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Many of the failures of past wage incentive systems have been due to the fact that they operated more nearly like dictatorships under strict rules and limits, and on strictly short-range considerations for large groups rather than with full consideration for their long-range effects on individuals with their human idiosyncracies, which are sensitive to long-range motivation. If wage incentive plans can be modified to give long-range goals and incentives to individuals for growth rather than be designed for average mediocrity, with little or no incentive to excel, they can be made more successful.

Lincoln believes that "Money earned as a direct reward for outstanding individual performance is a reinforcement of the motivators of recognition and achievement." 5

As is shown in Chapter II, the problem with previous wage incentive plans lies in the fact that they consider shop workers only as "hands" and reward them solely on the basis of productivity relative to a fixed, machine-like time standard without consideration of the human factors.

This study is built upon the foundations established by earlier wage incentive practices, as

5 Ibid., p. 117.
summarized in Chapter II, backed up by Appendix A, and upon learning curve theory outlined in Chapter III, and supported by Appendix B. It presents a new concept, one not yet attempted, i.e., the merging of these two disciplines, in forming a new one which will provide the base upon which learning-curve wage incentives can be designed.

The method will evolve in Chapter IV after the reader has had the opportunity to become familiar with the basic theories and philosophies behind the two disciplines. As will be shown, this study will be limited to the application of the new theory to the problem of the new worker entering the wage incentivized work force for the first time (or that of the old worker in changing from one job to a new one he has not performed before).

Even though the new discipline can be applied to other work situations, to accommodate various degrees of talent by individuals in the work force in terms of learning speed, innovative ability, monotony tolerance, ability to show sustained effort, native dexterity and other factors beyond purely productive output, and to reward them accordingly, such effort is beyond the scope of this study.

The terms in this study are taken from the established disciplines described in Appendices A and B,
Opinions regarding wage incentive systems vary widely. Much has been said about wage incentive plans since the inception of work time standards by Taylor\(^1\) and Fayol,\(^2\) in the early 1880's. These range from outstanding success, as reported by Lincoln Electric to the very conservative view of our late and eminent behavioral scientist, Douglas McGregor. There is controversial literature on the subject.

A private publication, *Incentive Compensation, The Way to Industrial Democracy*, by Lincoln Electric Company is favorable:

> The principle of incentive compensation as a stimulus to better work, higher production, and industrial peace is the finest contribution that has been made to American enterprise. The results achieved by applying it are literally amazing when contrasted to the old pattern of pay by the hour to men who have little or no sense of partnership in the success of the company for which they work.

Incentive compensation pays a man for what he


It recaps the advantages that incentive compensation has brought to their company between 1933 and 1951, in this manner:

1. Production per man increased seven times.
2. Take home annual wages increased over four times.
3. Dividends increased three times.
4. People employed increased four times.
5. Prices reduced 50 per cent.
6. There has never been a strike.
7. Employees are highest paid factory workers in the world, in terms of dollars.
8. Measured in units of work produced per man, they are the lowest cost workers in the world in a similar line.
9. Incentive Compensation has waked the sleeping giant--has brought the self-interest of workers into the management of the success of the enterprise.
10. Wherever the principle of incentive compensation is applied properly and sincerely, it leads to industrial peace, contented workers, lower costs, higher production--It is the golden key--Release that power and the work that will be done in this confused, hate-split world is beyond our gaze.

Their record of achievement through those

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eighteen years stands as testimony to the obvious benefit of a wage incentive system that was made to work through active participation by both management and labor.

In contrast, Douglas McGregor, the late eminently respected past president of Antioch College and past board member of the Foundation for Research on Human Behavior, one of the best known men in the field of behavioral sciences, and author of Theories X and Y, expressed his concern on wage incentive plans as follows:

Individual incentive plans provide a good example of an attempt to control behavior which fails to take sufficient account of "natural law"—in this case, human behavior in the industrial setting.

The practical logic of incentives is that people want money, and that they will work harder to get more of it. In accord with this logic, we measure jobs, establish standards for a "fair day's work," and determine a scale of incentive pay which provides a bonus for productivity above the standard.

Incentive plans do not, however, take account of several other well-demonstrated characteristics of behavior in the organizational setting: (1) that most people also want the approval of their fellow workers and that, if necessary, they will forego increased pay to obtain this approval; (2) that no managerial assurances can persuade workers that incentive rates will remain inviolate regardless of how much they produce; (3) that the ingenuity of the average worker is sufficient to outwit any system of controls devised by management.

A "good" individual incentive plan may bring about a moderate increase in productivity (perhaps 15 per cent), but it also may bring a considerable
variety of protective behaviors—deliberate restriction of output, hidden jigs and fixtures, hidden production, fudged records, grievances over rates and standards, et cetera. In addition, it generally creates attitudes which are the opposite of those desired—antagonism toward those who administer the plan, cynicism with respect to management's integrity and fairness, indifference to the importance of collaboration with other parts of the organization (except for collusive efforts to defeat the incentive system).

All of these results are costly, and so are the managerial countermeasures which must be established to combat them (staff effort, elaborate control procedures, closer supervision, concessions with respect to rates, down-time provisions, setup arrangements, et cetera). If the total costs of administering the incentive program—both direct and indirect—were calculated, it would often turn out that they add up to more than the total gains from increased productivity. Certainly the typical incentive plan is of limited effectiveness as a method of control if the purpose is to motivate human beings to direct their efforts toward organizational objectives.5

With such wide differences in viewpoint and opinion between a qualified industrial leader and an authoritative academician there must exist both facts and fallacies that upon examination will reveal reasons for success or failure as well as illuminate our hypotheses.

A given plan may succeed or fail.—John Cox picked two firms of a similar type in the middle west, one of which was very successful in applying its wage incentive

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system and another that turned out to be a complete and total failure; yet both plans were similar and, in fact, were set up by many of the same men—"if anything," he says, "the one that failed was more precise, accurate and provable." 6

What were the reasons for these differences? John Cox explains them this way:

The plan used at plant A was a success because it satisfied both workers and management and resulted in better than ordinary performance. Its main theme was psychological. The plan was "sold from the top down"—management had an open book policy, it promised and published the system in some detail—the workers and the company felt that things were done fairly.

The similar plan used at plant B was a failure. It failed to please the workers and management was very unhappy with the poor performance and trouble. This plan spent little time on whys. It concentrated on how to make out time tickets and how to use the method instruction cards. The plan was strictly manipulative.

In both plants it was pointed out that performance on one job did not affect the others. Each job was guaranteed at base pay—there was a weekly "cap" (Maximum allowance) on earnings of 20%.

Cox concludes that it would seem reasonable to say that:

1. Companies need to update their labor standards

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continually if they hope to keep them in line.

2. Having a union through which to deal is a good method of communicating with workers; better than letters and bulletin boards.

3. An incentive cap indicates lack of confidence on the part of management in the basic quality of labor standards.

4. Methods time measurement and time study are both workable from a technical standpoint.

5. A daily guarantee does not encourage cheating as much as a job guarantee.

6. A time ticket that an operator can make out is easier for him to understand than is one that must be made out by a special time clerk.

7. It is important that operators understand all the technical information necessary to an incentive plan if they are to support the plan.

8. Politics in a company contribute to the probability of an incentive system failure.

9. Operators trust their own people more than they trust management people.

10. Operators like to know that rates will not be tightened just because an operator performs well on a particular job.

11. Apparent unstability of labor conditions is not necessarily proportional to the probability of success or failure of an incentive system.

12. Line supervisors need to be in accord with the incentive plan and must be qualified to handle the administrative job for which they are held responsible.

Information given on wage incentive theory and
practice, in Appendix A, describing many of the incentive plans that have stood the test of time show beyond any doubt that all such plans have but one common denominator. They all incentivize productivity only against a fixed time standard; hence they can all be easily represented by the "earning curves" prepared by Lytle in his outstanding text, as shown in Figures 1 and 2.  

From these data it appears obvious to the writer that the only criteria for determining pay is the amount of production, just that and nothing more. Men are considered as "hands" or as machines and no consideration is given to any other factor, leaving nothing but the deadening monotony of production. All other considerations fade into insignificance. Herein lies a basic wage incentive problem that is common to all existing methods. While position descriptions and experience curves are used in setting pay ranges for higher level and supervisory people, such methods do not appear to have been used appreciably for production assembly line people who do routine repetitive work.

Whereas much has been said about such matters as the human and sociological side of the working force, C. W. Lytle, Wage Incentive Methods (New York: Ronald Press, 1942), p. 130.
In all of the above plans the amount of compensation can be plotted directly with respect to quantity of production as a percentage of a fixed time standard. No other factor has any influence upon take-home pay. With variable learning curve time standards such a plot could not be made because each operator's time allowance and pay would be different.

Figure 2.--Earning Curves--Class III Plans, Employer and Employee Sharing Savings*

These plans are more sophisticated but they also use productive performance against a fixed time standard as the sole criteria for additional wage incentive payments.

and a few authors' views will be quoted to emphasize the point, all of these plans make absolutely no allowance for the differences in people—their dexterity, their ability to learn easily and quickly, their tolerance for monotony, and their desire to be recognized in other ways than by merely daily productive capacity.

Probably one of the most comprehensive overall studies of the broad sociological impact of incentive payment systems throughout the world was made by R. Marriott for the British Medical Research Council's Joint Committee on Human Relations in Industry. This effort was for the purpose of assuring rapid progress toward the British goal of doubling their standard of living within 25 years. Such a goal would require an increase in national productivity of about three percent per year, compounded. The British knew that such an increase would place heavy demands on both the technical ingenuity and the skill of "work people" as well as management. "Incentive Payment Systems" were recognized as one of the major forms of motivation traditional in industry.¹⁰

After appraising all of the literature available,

Beach reports that inadequate study of the administration of human problems has caused many a technically sound incentive system to founder.\(^{13}\)

While Weber's thesis has not been widely accepted, he observes that managements often make assumptions that are not necessarily characteristic of all workers. For example, many believe that all workers will work as hard as they can to maximize earnings; that hard work, self-denial of worldly and social pleasures, thrift, and the acquisition of more and more money, as characterized by the Protestant ethic, apply in all cases.\(^{14}\) Weber asks that a new framework be considered for viewing work and workers.

Beach supports this thought with the observation that many workers do not respond in the way management expects—more money? yes—but not at the sacrifice of other values in life that the workers judge more important. Many workers, he finds:

1. are not motivated by competition (with their friends).
2. seek the cooperation, friendship and esteem of their fellow workers.

\(^{13}\)Dale S. Beach, "Wage Incentives and Human Relations," *Journal of Industrial Engineering*, XII, No. 5 (September–October, 1961), 349.

3. find loyalty to their friends (on the same work force, of course) is important.

4. want to belong and to be accepted by the group, hence will consciously restrict production, below limits of fatigue, because of social motives.

5. find it is important to have time to talk and socialize during the work day.

6. want to go home at the end of the working day with plenty of energy left to have a good night of bowling with the team, or to spend the evening at a fraternal lodge to make life worth living.

7. feel that unrestrained production by a few individuals is the quickest and surest way of bringing out the industrial engineer for a re-examination of the job, even if management promises no rate cutting.

8. feel that it is always the jobs with high earnings that are re-studied.

9. believe that if they all produce about the same percentage above standard, then none of them will stand out in management's eyes and nothing will happen.

10. have the fear of rate-cutting ingrained in their culture, hence are always suspicious of management's motives in this respect.

To emphasize the importance of the humanistic, i.e., the social side of the industrial environment, it is valid to observe that in 1955 nearly 25% of all grievances handled by the American Arbitration Association were caused by disputes over job standards.
wage incentives and time studies. In five years, between 1951 and 1956, more than 25 per cent of all manhours lost from work stoppages were caused by disputes over workloads and work measurement. 16

In summary it can be said that as a management tool, wage incentives have been successful in some cases and complete failures in others. It appears that success or failure depends largely upon how well management really enters into the operation of the system and how well it meets the basic needs of the employee. Unless the employee feels comfortable about it, unless his human needs as an individual are met in some fashion, by either pay or recognition or understanding or a combination of these, the plan will fail. Anything that will aid in compensating him for his varied talents so that he will be honored by his associates for his skills, will assist management in meeting his overall needs and increase the probability of success.

16*Time Magazine*, March 26, 1956, p. 94.
CHAPTER III

LEARNING CURVES AS A MANAGEMENT TOOL

The improvement phenomenon can be translated into learning curves which are also known as cost reduction curves, time reduction curves, or experience curves. Knowledge of the properties of these curves provides management with a very simple and useful tool for estimating futures or analyzing the past. A thorough understanding of this phenomenon, the curves, and their fundamental properties, which are derived from basic human traits, can add a new and very useful perspective to the judgment, appraisal, and estimation of many factors within management's concern. Much has been written about the wide variety of their applications but their use is still far from universal. References to many of these applications are given by the books and articles in the bibliography.

This study, however, is limited in its concept. It is primarily concerned with the use of learning curve theory for establishing variable time standards and the techniques for using these standards in improving wage incentive methods. These are to be more responsive to differences displayed by various individuals in the work.
force than past wage incentive plans that have considered only productivity as compared to fixed time standards as the criterion for extra pay. Familiarization with time standards, the foundation upon which all wage incentive plans are built, is essential to an understanding of this new concept.

Barnes' text demonstrates basic concepts related to the approach suggested in this paper.\(^1\) From it the basic facts can be seen as they are developed in an actual training and/or factory situation, rather than building the concept on artificial data that might not have the fundamental human touch.

Such an analysis allows one to become quickly acquainted with the effect of the improvement phenomenon in reducing the time required to perform certain repetitive tasks while the worker is either in training or at the production task.

In his text, Barnes describes in great detail the task, the work-place conditions, and the learning process involved in generating a learning curve from an actual punch-press operation.\(^2\) This curve is reproduced as Figure 3 of this study.


\(^2\)Ibid., p. 565.
A similar learning curve, showing the improvement phenomenon in a simple pin-board learning experience by a human operator is also reproduced, from Barnes, as Figure 4.3

These two learning curves represent real-life learning experiences; hence it would be normal to expect, as the fundamental improvement phenomenon learning curve theory predicts, that when the data from these two curves (both plotted arithmetically on simple coordinated graph paper by Barnes) are plotted on log-log paper, they would generate straight lines. This has been done, Figures 6 and 7, and, as predicted, the data is so near perfect that no deviation can be seen in either case.

For the same purpose, two other learning curves from Barnes have been reproduced as source material for purposes of illustration.4 These also provide convenient, real-life curves generated in a factory situation where a standard time had been established for the operation. In this case the operator went through both the learning period to the point where the assembly could be done within the standard time of 0.175 minute, and then continued well into the production phase.

3Ibid., p. 566.
4Ibid., pp. 560-568.
TYPICAL LEARNING CURVES
PLOTTED LOGARITHMICALLY

FIG. 6
LOG-LOG LEARNING CURVE
PUNCH PRESS OPERATION

FIG. 7
LOG-LOG LEARNING CURVE
PIN BOARD LEARNING EXPERIENCE

FIG. 8
LOG-LOG LEARNING CURVE
MECHANICAL PENCIL MECHANISM ASSEMBLY

REFERENCE: BARNES, P. 565, 566, 568.
The first of these curves represents the learning results for a mechanical pencil mechanism assembly operation and is reproduced as Figure 5. The second, taken from the same operation, shown as Figure 9, extends the production phase beyond the 180,000 cycles of the first curve, to 590,000 cycles.

At the outset it is encouraging to find that the data from all four curves, when plotted on log-log paper, produce straight lines; hence they must have been generated by people with human characteristics. (Note: At this point, unless the reader is thoroughly familiar with the fundamental theory behind the improvement phenomenon and its mathematical model, the learning curve, it is recommended that Appendix B be referred to before proceeding.)

In analyzing the pertinent characteristics of these learning curves reference is first made to the log-log plots of the first two, Figures 6 and 7. It is found that the slopes (N values) are .154 and .088 respectively, which, when compared with the N values of Table 3, page 120, indicate that these are 90% and 94% learning curves respectively. While it is simple to determine the learning curve percentage from the log-log slope, either by interpolation from Table 3, or by computation, using equation 2, page 114, it would be quite a laborious task.
to determine the percentage from the arithmetical plot.

These data certainly support the belief, expressed on page 107 that the learning curve concept truly depicts a basic fundamental characteristic of the human improvement phenomenon.

It is very doubtful if any thought was given to the percentage learning rate by those who conducted these tests. At that time no one was probably aware of the mathematical model of the improvement phenomenon nor what it could do for them as it had probably not been discovered. It is also unlikely that the data had ever been plotted on log-log paper. If this had been done, it is probable that Professor Barnes would have emphasized this concept in the text. Such information provides a further index to the learning capacity of an operator for rating, ranking, and motivating through incentive plans, the subject of this study.

A closer look at the log-log plots of the third learning curve, Figure 8, and the fourth, Figure 10, reveals a startling discovery! These curves do not show a single learning rate throughout, as would normally be expected if the theory is basically correct, but two learning rates are shown:

The first learning curve rate, where \( N = .274 \) is, from Table 3, page 120, about 82.5%. The second, where
Fig. 9

Arithmetical Learning Curve
Mechanism Assembly Operation (Barnes, Pg. 560)

Fig. 10

Log-Log Learning Curve
Mechanism Assembly Operation
N = .091, shows a much slower learning rate of 94 percent. This appears contrary to learning curve theory, but upon closer scrutiny, it is noted that the break in the curve coincides with the point where the operator first succeeded in meeting the standard time. It may be that "human" factors now have a greater influence than before.

Up to this point the operator has not received any extra pay, just her standard time during the "learning" period. She may have been trying very hard, in fact, probably working harder than ever to reach the desired proficiency. Now that she has learned to do the job in standard time it would be normal for her to slack off, to not try so hard, and to enjoy collecting her incentive bonus. From this point on there is not so much incentive to improve. Her learning speed hereafter will result from letting human nature take its normal course. She does not have to work as hard to learn and she now gets a bonus!

Without questioning the operator's intent or implying criticism, it is possible to observe and point out for later reference, that such actions do appear to illustrate a perfectly normal human trait. Individuals do not try so hard when they have "arrived" in the eyes of their associates. In this case her accomplishment consists of doing the assembly in standard
time or better. She will now earn a bonus for not trying so hard, and, again, per the "code" of the shop, being careful not to perform the operation too rapidly for fear that the industrial engineer will come out and study the time standard. She also faces the risk that her associates may criticize her for not conforming to the shop view of how fast it should be done.

Just for comparison the 82.5% "learning phase" learning curve of this operator is projected down to the 180,000 cycle point, as shown at the bottom of Figure 8. From this projection it appears that this operator (if motivated equally as well as she was during the learning period and not held to an old-fashioned fixed standard time of 0.175 minute, or social pressure to conform to the shop norm) could probably be producing these assemblies at an average time per cycle of only 0.100 minute! This is quite an improvement when compared with the 0.141 time she actually spent after performing 180,000 assemblies.

This log-log projection has been added back as a dashed line below the arithmetical plot of Figure 5. Even on this arithmetical plot the new learning curve shows a more characteristic, more smooth trend of learning improvement than the original curve which shows a sudden upward break in slope as it crosses below the standard time line.
Reference to Barnes' Figure 321 for additional information shows that approximately 480 hours were expended by the operator in reaching the point of production of assembly 180,000.\textsuperscript{5} A close look at the log-log plot at the bottom of Figure 8 indicates that this proficiency (0.141 minute/assembly) should have been acquired at the 54,000 cycle point, i.e., in 160 hours. It appears therefore that the operator, lacking the previous incentive, did not do so well as she might have done easily with her talent for learning and her dexterity. Of course she gets little credit for her learning ability under the old-fashioned fixed time standard.

From a management point of view, using the learning curves on hand, the 82.5\% possible, as compared with the actual of 94\% which prevailed after the "standard time" was met, it is easy to estimate what the difference has cost the company in hours.

Before proceeding, however, lest it may appear that this is an unfair and unreasonable approach, it would be good to refer back to Barnes' Figure 321 again, and obtain the additional pertinent information that at this point the operator was able to perform the assembly operation at a time of 0.100 minute per piece from

\textsuperscript{5}Ibid., p. 568.
Barne's "Curve B which is the actual time per piece as determined by a time study made of 50 cycles at the end of the day." This indicates that after a full day's work, the operator can still do quite well, but because of factors 7, 8, 9, and 10 of Chapter II, pages 27 and 28, she probably does not choose to do so.

To determine the cost, some rough approximations can be made and some conclusions drawn. From Figure 5 it appears that the "standard time" line was crossed on the 21,200th assembly. The "break" in the learning rate curve came at 28,500 units, where she became aware of her progress. From that point onward, following the slower learning curve it can be seen that 151,500 more units were produced bringing the total to 180,000 where the average assembly time per unit had dropped to 0.141 minute.

If, to prevent confusion, rather than using the log-log plot of Figure 8 with its varying log-time scale, the straightforward arithmetical plot at the bottom of Figure 5 is used, it is possible to see that the time lost is represented by the bent tipped triangle between the two dashed-line learning curves, and extending from an apex at the 28,500 mark to the 180,000 mark. Simple arithmetic permits an estimation of the average "area"

6Ibid., p. 568.
of this triangle, which represents the loss, to be one-half the base times the height. The "base" is the difference in time between the actual and the possible, or 0.041 (.141 - .100) minutes. The "height" is 151,500 units; hence the time loss is about \[ \frac{0.041 \times 151,500}{2} = \frac{6,211.5}{2} \]

3106 minutes, or 51.8 hours. This represents a loss to the company which the operator herself might have made for herself if she had continued to work as hard as during the learning period, but was not aware of and did not choose to because of possible social restrictions of the group. By making a similar computation, it appears that she did make a bonus represented by the triangle between the 94% "slow actual curve" and the horizontal fixed standard time line of 0.175 minute per unit. This represents about \[ \frac{(0.175 - 0.141) \times 151,500}{2} = 2575 \text{ minutes} \]
or 43 hours.

At this point it may seem that these are insignificant, irrelevant details, hardly worthy of such attention. In Chapter IV, however, it will be found that a thorough understanding of these details is essential to a full comprehension of the basic proposal of this study that leads to the improved learning-curve wage-incentive concept.

Before closing this chapter, however, it might be well to determine what became of the money that is
represented by the mutual loss by both the operator and the company of the 103.2 hours represented above. In explanation, the writer quotes from Barnes again, from information he has taken from Younde. He points out that because the difference between the daily production curve and the 50 cycle time study curve in Figure 321 (Barnes) is greater during the "learning" period, "as a beginner the operator loses more time per day than she does after she has had some practice." To this, it might be added that after that point as her proficiency increases, and she does not choose to reveal it, she actually increases her "lost time," again since her production is held within the bounds of what she believes to be a "safe" rate of production that will maximize her take-home pay without risking a reappraisal of the job time standard or gain the ill will of her fellow workers.

The loss, therefore, is a matter of hidden idle time; the difference between what she could do with her human capability for learning and her actual net performance as represented by the difference between the two learning curves.

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8Barnes, op. cit., p. 569.
One possible effect of this type of situation is that this operator, or any other, who may have developed a high degree of proficiency on this or any other similar assembly operation and is earning a good bonus for such performance, may become both unhappy and frustrated for perfectly normal, human reasons.

It is the writer's opinion that she may be unhappy because she knows that if this particular job ends, or she must be moved to another unfamiliar operation at her foreman's request, she will again be forced to face the lower pay, harder work learning period on the next assignment. This prospect is not a happy one and may cause her some mental trauma because she will have to work harder for lower pay and she will have a real financial loss (for the benefit of the company).

It is possible, from the writer's unqualified point of view, that she also may be frustrated because she is bored to death with the monotonous routine. Many of these operators are much smarter than they appear because industry uses so little of their talent on such a horrible job that ought to be done by machines. Although she would like a change, she needs the money, so she does not dare to ask her foreman for a change in job assignment if such penalties are a necessary price to pay for the privilege.
Such circumstances make human operators feel that they are thought of and treated as if they were just machines or a pair of hands. Such feelings have been found to cause resentment and hostility in the work force and frequently bring about all kinds of labor problems, both real and fancied.

Herzog has reported that "Voluntary restriction of output, practiced on an enormous scale, is common knowledge in industry."\(^9\)

In the writer's opinion then, with a fixed (inhuman) time standard and an "informal group notion of a fair day's work"\(^10\) and a desire to not antagonize fellow workers, the task, even if repetitive, levels off at a "satisfactory" pace. (See Appendix A, page 106.)

It is believed that the learning curve wage incentive method described in Chapter IV will overcome, to a degree, at least the two basic problems noted above, i.e., voluntary restriction of output and the penalties of a job reassignment.

\(^9\)Herzog, p. 118.

\(^10\)Ibid., p. 8.
CHAPTER IV

THE DEVELOPMENT OF LEARNING CURVE

TIME ALLOWANCES

From the discussions of Chapter III it appears obvious that the fixed time standard does not adequately meet the needs of the operator or those of management either for a number of reasons, some of which may be stated as follows:

1. Old or new operators must go through a training period (80 hours in the example shown in Figure 5) at their base pay rate before they begin to earn any incentive pay at all.

2. This learning period taxes their dexterity and ingenuity to a far greater extent than later when they have learned to do the job. Hence they earn less pay for the harder work of learning the job.

3. Such a method tends to make the work-force inflexible by making it more difficult for supervision to change operators to new jobs because the operators do not like to lose pay, or to have to work harder for less.
4. It breeds frustration and unhappiness in the work force as the operators feel trapped—they are forced to lose pay when they change jobs regardless of whether it is their choice or that of the company.

5. No recognition or pay is provided for the operators' individual ability to learn quickly and to continue to improve their working speed. There probably will be group pressure against it.

6. It treats all operators as completely average or equal giving none of them any rating for past performance nor demonstrated versatility and talent that could provide a status symbol in the work force to be sought after and rewarded by management.

7. It does not permit adjustment of the standard to encourage optimum learning curve performance on the part of experienced operators. They must hold back their production to prevent criticism on the part of less experienced operators. If they do not they run the ever-present risk of having management reduce the standard time allowance. Should they do too well they "spoil" it for
those with less experience as well as reduce their own earning ability.

8. It results in higher costs in the long run for both the company and the operator because of the operator's lost and hidden idle time are illustrated by the discussion on pages 42 through 45 of Chapter III.

9. It results in higher costs because it does not compensate workers in proportion to their actual effort. More experienced workers find themselves on the "gravy train." Hence they do not need to produce. They have little incentive to improve but rather have a negative incentive as in item 7, while "learners," who are working very hard to learn the new task, receive only their base pay.

It should be explained that there is no intent in any proposed improved plan to equate pay with physical or mental effort but only to point out that if such expenditure brings tangible results that can be measured, they should be fairly compensated. For comparison, the hard working, but average student should not get a better grade because he works harder than the brilliant student who does not have to expend quite so much time in the learning process.
This chapter attempts to explain, by reference and example, the basic rationale behind learning-curve time-allowances that may be used to provide the foundation upon which learning curve wage incentive plans can be established.

It is believed that as the discussion proceeds the reader will see that such a new method, if applied correctly, will go a long way toward overcoming many, if not all, of the fixed-time standard disadvantages.

The real-life learning curves already referred to in Chapter III will be used to illustrate the development of the new learning curve time standard which will, hereinafter be called a learning curve time allowance, rather than a time standard, because it is not a fixed "standard" but changes as experience on the job changes.

Figure 11 was made by enlarging a portion of the pencil mechanism assembly learning curve shown in Figures 9 and 10 to the same scale as Figure 5, and including for clarity only the two learning curves.

To simplify the discussion, instead of using an old-fashioned fixed standard time for the operation, one might choose to design a time standard for each change in job condition. To establish some of its limits, logic would dictate that it is certainly unfair not to pay operators some bonus while they are in the more difficult
Fig. 11

Establishment of Logical Time Allowances

- **A** - Learning Period
- **B** - Production Period
- **C** - Standard Time
- **D** - Old Production Rate

- **94%**
- **82.5%**

Total Cycles

0 100,000 200,000 300,000 400,000
learning phase. This is particularly so if they are experienced operators who have been earning well on other operations that they have learned to perform with dispatch, but from which they have been taken by management, to learn the new operation.

When such a change is necessary, perhaps because of a production schedule or model change, management should permit an allowable time that is somewhat above the required learning time, as illustrated by the time allowance line marked "A" in Figure 11.

It is also reasonable to say that this new "learning" pay rate should not be constant or fixed, but should, when plotted, slope downward to the right so that it becomes lower as the learning experience moves to the right and results in greater proficiency. If this were not done there would be little incentive for the operator to learn quickly, so it must be lowered as learning proceeds, as shown by line "B."

Of course, from experience on other similar tasks, the company can determine about how much time it should take for the "average" operator to learn to do the operation well enough to perform it within the old "computed standard-time," i.e., the old original one that heretofore has been fixed. It should be possible to establish a crossover point where the learning period ends at the
old standard time level, as marked "E" on Figure 11.

Experience has already shown that as soon as the operator finds out, under the old fixed time incentive systems, that she has met the standard time, she no longer sees any benefit in trying to become more proficient. (Remember the sharp break in the log-log learning curve of Chapter III?) Of course she is well aware of this point: First, she has been told the standard time value before she started to learn; second, as she now, for the first time, begins to earn her extra incentive pay. Now that she is earning incentive pay she can slack off her rate of learning (just the opposite of what management really would prefer).

For these reasons, should management give up the "standard time," and decide to pay her proportionately for her learning progress from the start, there would not be a break-point to disturb her learning pattern. Hence, the slope of the allowable time line should be down a bit to the right on the plot to keep the average earnings of the average operator at the average: hence the slope of the new time allowance from point "E" to the right, as shown by curve "C" of Figure 11.

It is logical to deduce from the "experience" of Chapter III, that as the operator gains in proficiency with the old fixed standard time, she has a normal human
tendency to slack-off, to take it easier. She will not
give the productivity that could reasonably be expected
by management as a result of her learning skill because
she does not want to be a "rate buster." She now learns
more slowly (perhaps on purpose), she earns less pay and
the company gets less output. The time allowance, there­
fore, should be automatically reduced as the experience
and proficiency of the operator slowly increases. The
new allowance shown as "D," matches, approximately, the
natural learning rate to be expected during this phase of
the normal production for this type of operation.

If the three pieces marked "B," "C," and "D," of
the new "variable" time allowance, that have been es tab­
lished using the logical step-by-step rationale described
above, are now connected smoothly together (of course,
there is no justification for an abrupt change at any
point), it can be seen that a rough approximation of a
"variable" time allowance begins to take the shape of a
learning curve.

Through the use of a smooth, variable time-
allowance curve, it is possible for the operator to be
motivated well enough for her to continue to learn and
produce at the 82.5% rate. Management could, if willing,
allow her to earn a fairly normal incentive pay throughout
the entire work period. She could continue to improve at
her own personal learning rate, from the beginning of training to the end of the job in return for an improved production rate. To this end it is possible to establish a time-allowance curve that follows the general shape of the 82.5% learning curve from start to finish, as shown in Figure 12.

This new learning curve time allowance can be established easily by "shifting" the log-log learning curve plot upward by a given amount, to allow the proper "bonus" to be earned, and then it can be used as the criteria for pay determination for any particular operator on this operation.

The concept, of course, calls for each operator, through performance, to establish an individual learning rate, and be compensated accordingly. An operator who learns slowly would have her base pay factored proportionately, and one showing considerable talent for learning rapidly would receive a greater base pay. These learning rate factors would be established for each operator, like a reputation worth having, and would be known and be posted to bring prestige and recognition to the operator, as well as a greater base pay rate. This rate would stay with her, and, adjusted up or down as her long-run learning performance varied. She would be incentivized to learn rapidly and to produce accordingly.
FIG. 12

ESTABLISHMENT OF LEARNING CURVE TIME ALLOWANCE

LEARNING PERIOD

PRODUCTION PERIOD

LEARNING CURVE TIME ALLOWANCE

OLD FIXED STANDARD TIME

"E"

94%

"F"

82.5%

OLD PRODUCTION RATE

PROBABLE NEW PRODUCTION RATE

CYCLES PRODUCED

0

200,000

240,000

300,000

400,000
In order that the benefits of learning curve time allowances to both the operator and the company can be understood, Figure 13 has been prepared. It illustrates the meanings of the various areas above and below the fixed time standard in terms of pay and savings. It shows the time donated (incentive pay lost) by the operator (53 hours), the bonus paid to the operator by the company (174 hours), and the hidden idle time paid by the company (261 hours). These amounts can be easily determined from the "areas" on the graphs, as already explained on page 41.

Figure 14 shows the differences that can be expected if a learning curve time allowance is used. The bonus paid by the company is 240 hours, somewhat more than that paid (174 hours) for much lower production. There is no idle-time loss. The difference between the "fixed" "standard time" and the learning curve time allowance is 253 hours and represents time saved by the company.

Through the use of the learning-curve time-allowance, production may be increased considerably (149,000 units for the period shown) and costs are not too much different than before (see computations above and on page 42.)

By keeping records of the production and performance of each operator in terms of his learning rate each
**FIG. 13**

**OPERATOR LOSS, OPERATOR BONUS AND HIDDEN IDLE TIME UNDER OLD “STANDARD TIME” SYSTEM**

- **LEARNING PERIOD**
  - Time donated by operator: $(16.4 + 36.4 = 52.8\text{ hrs})$
  - Bonus paid by company: $(137.5\text{ hrs})$

- **PRODUCTION PERIOD**
  - Hidden idle time paid by company: $(208.33\text{ hrs})$

- **TIME**
  - Fixed standard time: $94\%$
  - Actual production rate: $82.5\%$

- **PRODUCTION RATE**
  - Possible production rate:
    - $28,500$ cycles
    - $121,500$ cycles
  - Cycle production:
    - $121,500$ cycles
    - $250,000$ cycles
  - Hours:
    - $137.5$ hrs
    - $208.33$ hrs
    - $208.33$ hrs

- **CYCLES PRODUCED**
  - $28,500$ cycles
  - $121,500$ cycles
  - $250,000$ cycles

- **HOURS**
  - $121,500$ cycles
  - $250,000$ cycles
Fig. 14

Operator Bonus, Time Savings and Productivity
Under New "Learning Curve Time Allowance" System

**Learning Period**

**Productive Period**

**Learning Curve Time Allowance**

**Operator Bonus Paid by Company** = 240 hrs

**Time Saved by Company** = 253 hrs

**Old Fixed Standard Time**

**New High Production Rate**

**Old Production Rate**

**Increase in Production**

**Total Cycles**

- 212 hrs
- 4.01 hrs
- 0.36 hrs
- 250,000 cycles
- 400,000 cycles

- 94%
- 82.5%
- 0.05₉
- 0.03₆
operator will generate his own personal learning curve rate. It will be distinctly his and no one else's, hence the better his performance is the higher his individual pay will be. Since his pay will not be influenced in any way by the performance of anyone else on the work force nor will his actions affect the pay rate of others he cannot become a "rate buster."

While the administration of such a plan might seem (and will be) more difficult than paying on a fixed time standard rate, tables can be made up to compute the pay factors for each learning rate or, if available, a computer can be programmed to make all the computations without difficulty.

Figure 15 presents a composite of the data already presented in simpler form for explanatory purposes in Figures 11 through 14. The scales are the same as the other figures and are more completely scaled for measurement purposes in computing the hours noted in Figures 13 and 14.

To prevent possible confusion in interpreting the curves of Figures 5, 9, 11, 12, 13, 14, and 15 it should be noted that the lower scale, abscissa, indicating total cycles produced is not linear with respect to quantity produced (which would be normal), but is linear with respect to time because they were so plotted by Barnes.
FIG. 15.

COMPARISON OF LEARNING CURVE
AND "STANDARD TIME" PERFORMANCE
Each calibration point represents 40 hours of work. The figures could have been plotted either way and still be satisfactory for use in this explanation. In computing the "areas," however, rather than using a linear measurement along the scale, the "altitudes" were determined as the difference in quantity produced in each instance, hence an automatic correction for the variance of the scale was made.

It should be recognized, however, that if the new learning-curve time-allowance were actually used in this instance, and it did succeed in bringing forth the probable production predicted, that a greater number of assemblies would have been completed in the 1040 hours (twenty-six 40-hour weeks) required to produce the 400,000 assemblies under the old fixed time-standard.

The benefit to the company in production can be easily estimated by dividing the number of hours saved (253 hours from Figure 14) by the average unit assembly time for the new higher production rate between the 47,275 unit point, where the savings began, and the old 400,000 unit point where measurements were stopped. From the log-log plot of Figure 10, which has been extended into the margin for this purpose, normal human learning reduces the assembly time from 0.145 to 0.08 minute per cycle. The "average" time for the period
can be estimated from the "area" beneath the curve on Figure 14 to be 0.102 minute per unit. The number of additional assemblies that could be produced, therefore, becomes \[(253 \times 60) / 0.102\] = 149,000 units, which, when added to the 400,000 already produced would bring the total to 549,000 units! This is a 37% improvement in production from the point of view of the management, as well as, as has already been shown, an improvement from the standpoint of the operator.

This concludes the discussion and explanation of the development of learning-curve time-allowances. It should be realized that the example shown represents only an academic study of the factors involved from a theoretical standpoint. Whether such an approach will prove to be advantageous in practice remains to be determined by trial in an actual work situation. The world famous Dr. Ralph M. Barnes has told the writer that until someone proposes a new theory it will never become a reality in practice. The basic purpose of this study is to explain the theory in simple terms that the reader will understand so that progress can be made toward bringing the learning curve time allowance into practice. By adding this new concept to existing wage incentive systems they may be broadened to include some consideration for individual learning ability as well as for cold, hard productivity alone.
CHAPTER V

THE APPLICATION OF LEARNING CURVES AND TIME ALLOWANCES TO WAGE INCENTIVE SYSTEMS

The discussion in the earlier chapters of this study has led to the concept of variable learning-curve time-allowances which, when developed and applied to work situations in which the individual's characteristics are matched by pay factors derived from learning ability, will lead to improved productivity as well as a happier, more integrated and contented work force. It is believed that such a method will also serve the objectives of management in better fashion than previous wage incentive methods.

While the writer, as already reported, found no indication in the literature that such a concept has been either proposed or adopted, Carlson reports that:

Some companies have evolved procedures, formulas or arbitrary allowances to compensate for the improvement phenomena on learning in this type of work. Reduction of fumbles, hesitation and delays, plus faster manual movement result in significant improvement in the manual times required to perform work.1

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He also observes that it is possible for companies ... to ascertain realistic performance standards. The theory and practice of improvement curve analysis brings together sufficient information to allow companies to make optimum use of time standards data ... standards can be established using either the typical log-linear model, or the incompressibility model of DeJong, together with basic operating data.²

Further study of the above references reveals that these factors were applied merely for the purpose of being more astute in establishing the fixed "standard time."

This study has already explained in Appendix A that the log-linear model, where the log of learning or performance is linear when it is plotted on log-log paper, as is shown. There is, however, a practical limit to log-linear models; excellent devices as they have been to represent empirical data. However, some do not accept the linear hypothesis in the log-linear representation and their evidence substantiates more suitable models.³


For use in operator performance evaluation there may be some preference for the incompressibility model suggested by DeJong. The advantage of this model is that it demonstrates a practical limit to the amount of improvement on learning. DeJong believes that time or cost asymptotically approaches a plateau as the number of units increases. For this reason the rate of improvement cannot be expected to continue at the same rate for the duration of the task—indeed the rate decreases. DeJong's incompressibility model expresses the time per unit in the following way:

\[ t_x = t_1 \left( M + \frac{1 - M}{x^{n'}} \right) \]

where \( M = \) incompressibility factor \( 0 < M < 1 \)

\( n' = \) improvement exponent similar to but not identical to linear model exponent

and \( t_x = \) time for the \( x^{th} \) unit

\( t_1 = \) the intercept or time required to produce the first unit

\( X = \) the cumulative number of units accomplished

\( n = \) the geometric slope of the curve, which, because of the logarithmic plot, becomes the exponent of \( X \)

\( \bar{t}_x = \) the cumulative average time for \( x \) units.

Using this nomenclature, more classical than the simpler terms used in Appendix B, the log-linear model can be stated as:
\[ t_x = (1 - n) t_1 / x^n \]

an approximation valid when \( X > 20 \) and \( t_x = t_1 / x^n \)

based on the assumption that the log of the cumulative average times is linear.

These trends can be shown, as they were in Figure 21, Appendix B, as follows:

Figure 16. Log-linear model showing
Equivalence of Cumulative Average Unit Time to Average Time Study
Cycle Time Stated at Mid-Point of Cycles Studied.\(^4\)

\(^4\)Ibid., p. 497.
Whereas Carlson shows methods for determining unit times and average cycle times by time studies made during the learning process, there is no indication that individual learning rates are incentivized in any way. This knowledge is merely used for labor and cost estimation purposes. It is not impossible that the "leveling off" factor already pointed out and described in Chapter III, is due, as has already been inferred, to the fixed "standard time" effect.

In an earlier analysis of the operator improvement phenomena, Carlson made no attempt to study the improvement or learning effect exhibited by new and inexperienced personnel but did study "the improvement exhibited by trained personnel as they encounter tasks which call upon their ability to adapt to a change in sequence or to other modifications of their manual movements."\(^5\)

Carlson came to the conclusion that "the number of any new manual reach decisions which had to be made by the operator was indicative of the rate at which improvement would be made."\(^6\) He directed research


\(^{6}\)Ibid., p. 4.
"toward resolving and developing relationships for use in the practice of setting standards for manual and manual-machine systems with particular emphasis on the errors generated by ignoring the improvement concept."

Carlson reports that a linear relationship on the log-log plot appears over and over again as a realistic approximation for the improvement phenomenon for industrial motor tasks. Among the classical improvement experiments performed in the controlled laboratory environment is the Barnes and Perkins study and also by Hammer, who treated the data with appropriate statistical correlation methods and found that subjects performed as follows:

Table 1

Improvement Indices for Subjects Performing A Punch Press Activity

<table>
<thead>
<tr>
<th>Subject</th>
<th>Estimate of Slope</th>
<th>Time Improvement Index</th>
<th>Performance Improvement Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.1375</td>
<td>90.9</td>
<td>1.100</td>
</tr>
<tr>
<td>B</td>
<td>.1588</td>
<td>89.6</td>
<td>1.116</td>
</tr>
<tr>
<td>C</td>
<td>.1328</td>
<td>91.2</td>
<td>1.098</td>
</tr>
<tr>
<td>D</td>
<td>.1694</td>
<td>88.9</td>
<td>1.123</td>
</tr>
<tr>
<td>E</td>
<td>.1581</td>
<td>89.6</td>
<td>1.116</td>
</tr>
<tr>
<td>F</td>
<td>.1667</td>
<td>89.7</td>
<td>1.115</td>
</tr>
</tbody>
</table>


Titleman shows how learning curves can be used to show the effects of incentives to increase learning rates. He shows that if an operation were to start out with no standard time, and he gives an actual history of an incentive program on 220 consecutive engine blocks, that the addition of an incentive, after an exhaustive time study, resulted in an increase in learning rate from 93% to 70% (Note: The learning curve slope percentage is set up so that the lower the percentage, the more rapid the learning. It really means that in this case it only took 70% as much time to make the same learning improvement as it formerly took 93% to do.) to get under the 540 man-hour allowed standard time. It is interesting to note that in the case he cited, that after the men had made 160 units and had dropped the time to 300 man-hours, all learning stopped!

"No further reduction was then apparent even though 50 more units were made."

Is it possible that the men decided among themselves that 300 man-hours was about right for a job figured at a 540 man-hour "standard time" allowable? This gives them a 240 hour bonus, which is 44% of the

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allowance and just about all that they have decided the traffic will bear. Any more would probably bring the time study men out again to refigure the job. It would be very interesting to try the learning curve time allowance method on this job and to determine if the learning would again stop abruptly at 300 hours.

Another application of learning curves to wage incentives is reported by Geppinger, who shows how the improvement phenomenon can be used for accurately estimating work efficiency levels and fixed time (again) incentive allowances for less than optimum short-order jobs. He proposes criteria for determining minimum lot sizes and shows how a short-order allowance table can be based upon estimated efficiency from learning curves and, from that, incentive "standard times" established for such jobs.10

Boehringer cites fourteen key things that must be done in installing an incentive system. Two of these are pertinent to this study. He states that:

Learning curves can be a valuable tool—but they must be thoroughly explained so they are not looked upon as rate cutting.

There should never be any limit on the amount of money a man can earn through wage incentives. That would create a psychological ceiling which is meaningless where good standards are applied.\(^{11}\)

Barron reports on an interesting application where learning curve methods are used to rate new or transferred workers brought into a small efficient team. He cites an example where an incentivized crew of four men are setting telephone poles. They have a specially equipped truck with power augur and crane. They go from one location to the next, all day long. They are paid on the basis of the number of poles they erect in the eight-hour day.\(^{12}\) He observes that learner curves help provide the following advantages in this painless method of getting a man through on-the-job training where he must work as a member of a crew:

1. Regular crew members must enjoy their normal earnings.
2. No slack-off must be allowed in the working pace.
3. Productive losses must be minimized.
4. Unit-cost increases must be controlled.


Under these circumstances, when group production depends upon the learner, allowance is made for the effect of the new worker on the group and experienced crew members are subsidized according to the learner curve. Barron notes that one of the most important functions of learner curves is to allow comparing a new man's progress against an established standard to see how he improves. If his performance is poor, he may be a misfit and should be transferred before he becomes a permanent employee on that job. Another important function is to provide a reasonable basis for subsidizing regular trained workers during the break-in period without making the allowances so generous that the whole crew can just quit working.

Both of these functions are served by establishing a ratio of percentage from learner curve theory which represents the amount the new man will hold back the group until he is trained. His retarding effect must diminish as he stays on the job until he finally becomes an experienced worker.

Wertman refers to the learning curve as a means for determining efficiency by comparing the estimated production time against standard time.\textsuperscript{13} From this he

\textsuperscript{13}Lou Wertman, "Putting Learning Curves to Work," The Tool Engineer, Vol. 43, No. 3 (September, 1959), 100.
shows how to determine break-even points, i.e.,
(1) where the worker finally reaches a point where he
begins to earn incentive pay, (2) where the time saved
due to workers having learned the job will offset the
time lost in learning, (3) where the total productivity
and total cost to the company balances out, i.e., where
"standard time" times items produced equals hours
actually spent. The learning period of lower efficiency
must be included, of course.

With this type of information available, manage-
ment can determine where on the learning curve a new
worker should be and the learning ability of the indi-
vidual for the type of operation in question can thus
be established. Wertman also comments on the wide
range of learning curve applications that are possible
and cites several.

O'Connor observes that improvement in effort
caused by incentives seems to be derived from two
sources: (1) some increase in work pace, (2) some
improvement in consistency of application to the task
(which he is inclined to regard as the bigger contributor
from his experience). He refers to linear and

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curvilinear wage incentive plans which have the property of automatically curbing earnings in the event that standard time is slack.\textsuperscript{15} He is also concerned with two important decisions that must be made: (1) How much incentive pay (bonus) to award to the standard worker (whose average time is standard time)? (2) How to regulate the pay of others (naturally all workers are non-standard to some degree) who produce at some different rate, either higher or lower than standard.

The writer observes that learning curve time allowances might prove to be an acceptable answer to the problems mentioned by O'Connor, since they make allowance for differences in learning ability (non-standard performance) rather than strictly production output.

Van Der Bokke reports that learning curves have been used in incentive wage payment programs, in union negotiations involving grievances about incentives, and in job evaluation. He believes they are very useful but are not used enough because many people do not understand them, or think they are much too difficult to be bothered with. Nothing, he observes, could be farther from the truth!\textsuperscript{16}

\textsuperscript{15}Ibid., p. 41.

He explains in great detail how to set up a new learning curve for a new job but instead of using the curves to establish variable time allowances, which would continue to motivate the worker, he uses standard data for establishing times for the various operations, determines the base time for the job after the learning period is completed and then uses the learning curve only to estimate how long it will be until the level-off point is reached! This is based on standard data and past experience with an eye on what the competition will stand!

After this, one looks up the constant for the per cent curve chosen (70% to 80% for general assembly) (80% to 90% for welding) (90% to 95% for machine shop) and, using this curve, plots backwards (upwards to the left on log-log paper from the level-off point) and obtains an estimation of how long it will take for the learning period to be completed! A very complete table of values is included to make these determinations possible.

It seems inconceivable to the writer that no-one, even Van Der Bokke, who came so close, chose to carry the learning curve variable time allowance into the production period and used it as a motivator for both the learning period and the production period as
proposed in this study. It is such a logical next step.

Everyone seems to have the fixed idea that there should be no bonus pay during the learning period. Neither the workers nor the company like the interminable, uncomfortable, hard-working, no bonus pay learning period of high costs and inefficiency. Everyone also feels that there must be a fixed "standard time" thereafter! As has been shown, this concept actually discourages continued learning after the workers become able to produce at or below "standard time." Standard fixed time seems to be a tradition that no one dares to break!

Whyte observes that:

... the theory of motivation ... promotes full effort from probably less than 10% of the work force ... They contend that the few who respond fully to wage incentives, the "rate-busters" are individualists who "have renounced the group." At the other extreme ... "the bottom producers have renounced the incentive."¹十七

At this point a thought from a poem referring to the attitudes of Christ toward the people might be pertinent. It was said that the people "drew a circle that left him out, but that he, with love in his heart, drew a circle that brought them in." It is possible

through the use of learning curve time allowances for all workers, the slow ones, who cannot meet the "standard," and the fast ones, who are often ostracized by their fellow workers because they are sharp and fast, the "rate busters," can be taken into the same game and play under the same rules without fear of recrimination. The "rate busters" will then become the high-rate learners and will be honored by their less fortunate associates, rather than rejected because of the fear that they will "spoil" the job by doing it so fast that everyone else is afraid that the "standard time" will be cut and that they will suffer a loss in pay as a result.

Louden and Deegan, in their outstanding text, give recognition to the progress made in the area of work measurement through the use of the "statistical method," predetermined time systems and performance rating research.\(^\text{18}\)

From the above, it is believed that the time has come for industry at large to be ready and willing to accept a new idea in this area. Enough has been done already by many investigators on both sides of the two

disciplines, learning curves and wage incentives, that their merging, as proposed herein, is an almost predictable consequence.
CHAPTER VI

CONCLUSION

In this study the writer has introduced the theory behind learning curves, which serve as a mathematical model for the human improvement phenomenon, and basic wage incentive plans, which are used throughout the world for incentivizing productive workers in industry.

There are many benefits from smoothly operating wage incentive plans as engineers and business managers know. These include increases in productivity, they provide a tool for regulating costs, they provide more pay for employees without increasing labor costs, they permit greater personal initiative on the part of workers and they reduce the need for supervisory pressure in achieving high production. The basic problem, however, lies in striking a balance between a technically sound, well administered program and the human relations problems that such programs generate if they are not properly communicated to the rank and file of workers. It is believed that inadequate study has been given to these administrative human problems.¹

¹Dale S. Beach, "Wage Incentives and Human Relations," Journal of Industrial Engineering, XII, No. 5 (September-October, 1961), 349.
This study has considered the effects of a number of aspects of human relations in the industrial environment. From the information presented it appears that all existing wage incentive systems fail to make sufficient allowance for the individual differences that are bound to show up in any normal group of people. It is these differences that provide a major reason for trouble.

In an effort to take into consideration one of these differences, learning ability, and to overcome the hardship imposed on the worker (and the company) by the learning period, it is proposed that a learning curve time allowance be adopted in place of the traditional fixed "standard time" that seems to be in universal use.

Researchers have found that if all people in the work force had equal talent things would be easier. As they do not have there is a social cleavage and conflict between the "rate busters," who do not care how much they produce to earn the maximum, the average worker, and the "output restrictors." Frequently the individualistic "rate busters" are ostracized by the group because they create a hazard to group security (fear of rate cutting) and solidarity. ("The very idea that he would spoil that good job.")

Collins found a definite correlation between employee rates of production and their ethnic backgrounds,
political beliefs, union affiliation and social participation. Employees believe that incentives are for their "hands" and not their "heads," and there are many examples to prove it.

Overcoming the human problems of incentive plans is not easy and no claim is made that the suggestions herein will solve all problems, the quest for better, more variable learning curve time allowances being but one aspect. The real key to success lies in management's attitudes, precepts and principles which must show to the workers beyond any question of doubt, their honest concern for their workers and the human side of the enterprise.

Beach believes that the emphasis must be shifted, as worker output depends upon how they feel about their work, what incentives are offered, the treatment they receive from management, and the internal group spirit. He feels that engineers need greater education in the behavioral sciences from both a theoretical and from a practical standpoint so that they are fully aware of the total work environment. They must build programs that stimulate and reward employees for their ideas, not for

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3 Beach, op. cit., p. 351.
just their physical effort! It is the whole man, with his differences, that must be motivated. Initiative and ingenuity must be rewarded—it must take advantages of contributions resulting from combined ideas and energy.4

This study shows how, by considering the human improvement phenomenon, a plan for incentivizing workers through both the learning and producing phases of a task can be established that will, it is believed, meet the needs of both the worker and management to a greater degree than earlier "standard time" plans. It is, to be sure, only one small aspect of the larger problem but a very important one.

In this study the two separate disciplines were brought together to provide a foundation upon which a new one can be established that will provide learning curve wage incentives. These will not only accommodate the traditional rewards for productive performance but will also allow sensitive evaluation of differences caused by the varied sociological and humanistic needs of individuals in the work force.

It is believed that this new concept will aid management in their basic objective—to be able to produce satisfactory, competitive products on time and at a profit.

4Tbid.
If the twelve hypotheses (page 2) which set up the thought matrix for this study are reconsidered it appears that although both wage incentive and improvement phenomenon theories deal with the human characteristics of workers in performing repetitive tasks current literature does not show that they have ever been brought together for benefit in the manner proposed in this study.

Wage incentive plans of the past have used fixed time standards (pages 23 & 24) hence workers have resented unrestrained production by the few who are willing and capable (page 28) for a number of reasons including the fact that such systems do not incentivize individual learning rates (page 67).

In general, literature supports the first eight hypotheses delineating past conditions (Chapter II and Appendix A). It appears that hypotheses nine and ten, which deal with the future, can be supported if methods recommended in this study are adopted. Proof of the eleventh hypothesis which is well within present knowledge and the state of the art in the computer field is beyond the limits of this study.

It appears obvious to the writer that the innovations suggested will not solve all of the problems of managing a wage incentive system (hypothesis twelve, page 3) but should assist greatly in meeting the needs of the exceptional worker.
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WAGE INCENTIVES--THEIR ORIGIN AND PRINCIPLES

Historical Review

In the early 1880's the American Society of Mechanical Engineers started to concern themselves about the economic and industrial aspects of engineering practices. Frederick W. Taylor, who later became president of that society in recognition of his fine work as the founder and popularizer of scientific management, provided effective impetus to the exploitation of the area of labor relations which resulted in wage incentives being provided to raise output. Taylor's factory experience at Midvale Steel Company led him to turn his attention to methods of increasing labor productivity by superior physical organization of the shop and by controlling or eliminating unnecessary and wasteful motions in the performance of work.

While his discoveries resulted in enormous gains in productivity and reductions in costs, he devoted himself to disseminating his ideas and methods, won numerous

disciples and in 1912 the Taylor Society\textsuperscript{2} was organized for the propagation of scientific management. It was widely accepted by industry and, of course, opposed by organized labor. While it may have been abused in practice, it has proved to be a constructive and effective method for organizing modern production and for making human labor less, instead of more, burdensome.

Taylor believed that management should assume all of the responsibility for planning work and that the worker should be free to devote all of his efforts to physical production. He believed that scientific investigation would discover the best way to perform each element of a worker's performance. Detailed planning, therefore, replaced "rule of thumb" or the traditional unscientific methods for determining the time required to perform these tasks. These efforts led to maximization of the amounts of goods or services produced with the smallest degree of effort on the part of labor. Taylor's time study "scientific method" was composed of two parts: (a) The analytical work, which consisted of dividing the work performed by the man into simple elementary movements; picking out all useless movements and discarding them;

\textsuperscript{2}The Taylor Society merged with the Society of Industrial Engineers in 1936 to become today's well known Society for the Advancement of Management.
studying each elementary movement as made by skilled workmen and determining the quickest and best known in the trade; describing, recording and indexing it with its proper time for reference; and making allowances for unavoidable delays, interruptions, learning processes as well as rest and fatigue intervals. (b) The constructive work, which consisted of adding together the combinations necessary to complete the task in the proper, most effective sequence and motions; removing the defective conditions surrounding and accompanying the work, perfecting fixtures and tools for efficiency, and then training the worker to perform the task in the best possible fashion within the time set, after he had learned to do it well.\(^3\)

Although Taylor knew that the management of an industrial enterprise was more than conducting investigations on methods of doing work, he stated strongly that one of the first duties of management was "to develop a science for each element of a man's work." He used and advocated the scientific approach in the solution of every problem that arose in this connection.\(^4\)


Probably the first real incentive bonus or overall wage incentive plan occurred in 1902 after Taylor had been with the Bethlehem Steel Works for three and one-half years and had made an investigation of the shoveling of coal and iron ore in the yards. He found that the men lifted from 3-1/2 pounds of coal to 38 pounds of ore per shovel-full, depending upon, among other things, the shovel size, and each man provided his own shovel. His studies revealed that for maximum tonnage a shovel-full should weigh about 21-1/2 pounds. He had Bethlehem provide the men with standard shovels, sized for coal and ore, that would hold just that amount. Then he trained the men, measured the tonnage each loaded, motivated them by offering a bonus (60% above day wages) when each did the specified amount. If a man failed to earn the bonus another man was sent out to show him how, so he could again earn it. It was possible, using this scientific wage-incentive approach, for 140 men to do the same work that formerly took from 400 to 600 men. The men made a higher wage, costs were cut in half, and the plant saved at the rate of $78,000 per year.\(^5\)

No discussion of the methods used in establishing time standards for wage incentive purposes would be

complete without at least some reference to Frank and Lillian Gilbreth. They refined task and time study techniques of Taylor, invented micromotion study, identified the seventeen basic elements of work, which they called "therbligs" (Gilbreth spelled backwards), each describing a minute operation which might be performed in completing any job.

The Gilbreths took motion pictures of workers in action, studied the pictures carefully, frame by frame, and depicted each motion and its time on a chart by the use of the seventeen basic therbligs, which are: search, find, select, grasp, transport loaded, position, assemble, use, disassemble, inspect, preposition for next operation, release load, transport empty, rest for overcoming fatigue, unavoidable delay, avoidable delay, and plan. Through the use of the Gilbreth method of facilitating analysis, unnecessary movements can be eliminated, work-place can be rearranged, jigs and holding fixtures can be provided that will aid the worker and decrease the number and length of his physical movements, work time can be cut to a minimum, work effort can be made more efficient and time standards based on scientific facts can be established.

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These time standards, established for each job, then become the basis upon which wage incentives are based. If the worker can learn quickly to perform the task the best way and do it repetitively within the established standard time rate, or better, he then earns his incentive pay.

**Wage Incentive Systems**

Taylor, the father of time study, was a very capable man who took a direct and scientific approach to the matter of setting correct standards of performance which would automatically eliminate rate cutting and restriction of output. Taylor, himself, made this statement:

> Since the rate fixing is done from an accurate knowledge instead of more or less guess-work, the motive for holding back on work, for "soldiering" and endeavoring to deceive the employer as to the time required to do the work is entirely removed and with it the greatest cause for hard feelings and war between management and the men. 7

As a management tool wage incentives have now become an aid in obtaining minimum unit costs, thereby contributing to enterprise profits. Lytle says that "the primary and universal reason for the installation of wage incentive plans is today, as ever, to secure the lowering of unit costs on the one hand, and to improve the earning

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of employees on the other."\(^8\)

Many unique formulae for relating earnings to output were developed from 1891 through 1920. A few of the better known plans, as summarized by Wolf, are as follows:\(^9\)

**Piece Rate.** Payment made at constant price per unit of output.

**Standard hours plan.** Same as piece-rate plan except that standards of performance are stated in units of time, instead of money, and worker is paid his established hourly wage for all standard hours of work he produces. This plan allows a simple correction for cost-of-living wage increases, permits different pay rates for different employees and allows for economic growth.

**Halsey premium plan.** Similar to the standard hours plan except that employee and employer share (usually on a 50-50 basis) the savings in direct labor cost arising from above standard output. This sharing


mitigates management's need to cut rates, hence eliminates the main cause for worker restriction of output.

**Rowan plan.** Similar to the Halsey sharing plan except that the sharing percentage for above standard performance is not fixed (at say 50%) but varies from zero to 100%—better performance, higher bonus above pay for hours actually worked. This self-limiting feature makes it impossible for earnings to get too far out of line.

**Bedaux point premium plan.** Originally this plan was identical to the Halsey 75-25 sharing plan but is now revised so that workers receive 100% of time saved, and hence is identical to Halsey 100% and standard hours plan. Each job is reduced to a common denominator consisting of so many "B" point units of time required by an average worker under normal conditions (usually an average minute). Sixty "Bs" per hour represents standard performance—eighty "Bs" per hour is expected of experienced workers.¹⁰

**Taylor's differential piece rate plan.** Taylor hoped to motivate workers by providing two piece rates for

¹⁰Lytle, *op. cit.*, p. 13. (Several similar systems are described, such as Hayes-Manit plan and Dyer plan, pp. 246, 253-254.)
each job—a "high task" production standard rate approximately 50 to 60 per cent greater than the average output maintained by workers under a time wage system, one that might be expected from an average skilled worker, properly trained, working at an incentive pace. This higher rate was paid only when workers attained or exceeded a given level of performance established by a systematic time study. He also provided a "low task" standard to discourage inefficient workers from remaining with the company.

**Merrick multiple piece rate plan.** In actual practice Taylor's plan did not work well. As soon as workers saw they could not produce at a "high task" level they would slacken their pace. To overcome this weakness, Merrick added another piece rate to the differential plan. The first rate, the lowest price per piece applied up to 83 per cent of "high task"; from 83 to 100 per cent of "high task" an intermediate piece rate applies and for higher levels of output the highest piece rate is paid.

**Gantt task and bonus system.** This system was designed to remedy a problem similar to that which the Merrick plan attacked: the complications arising when workers failed to qualify for high piece rate. Gantt
did this by guaranteeing hourly earnings and paying the equivalent of Taylor's high piece rate when workers produced at "high task" or above. For output above that level the worker received 100 per cent of time saved plus a 20 per cent bonus. In this manner, Gantt attempted to overcome opposition encountered with the Differential Piece Rate Plan and to ease the burden on trainees and new employees.

**Parkhurst differential bonus system.** The Parkhurst plan kept bonus earnings separate from regular pay, thus avoiding the difficulty of having the bonus considered as a part of wages, instead of a reward for work well done. Under this plan the bonus is a definite scale of dollars and cents established for different levels of efficiency on various classes of work, based upon the responsibility of the worker, the skill required and the physical effort involved. The bonus, paid by separate check, is determined by comparing actual output per unit of time with a standard established by time study.

The unique features of many of the plans arose from specific operating problems--Halsey and Rowan designed theirs to remove the fear of rate cutting--Taylor designed his to force out the slower, less skilled worker--Merrick and Gantt attempted to mitigate the harshness of the Taylor plan while Parkhurst attempted to
maintain premium earnings as distinct and separate from normal hourly wages and thus maintain the "bonus" characteristic of extra earnings. It remains, therefore, for Broadston, in this thesis, to introduce the concept of adding the effect of the improvement phenomenon to the basic formulae for wage incentive determination.

Contemporary Problems with Wage Incentives

Every few years a major management controversy arises over the value of wage incentive systems. One was brewing in 1964 between management and the union at General Electric, Schenectady, New York, where an incentive pay plan was permitted, because of human nature again, and management disinterest, to get out of control. Cyrol observed that most plans go haywire somewhere along the line because management substitutes charity for justice. Management permits a standard to be bargained instead of measured--or management gives "average pay" where base wage should be applied--or permits a worker to do the job his own way instead of requiring him to follow the "best method."

The basic problem, a human one again, is that management is too often "too busy" to do the things that will maintain a successful incentive system and bring low unit costs and high worker morale.11

11J. R. Boehringer and E. A. Cyrol, "How to make
Boehringer lists ten vital factors that must be present for a wage incentive system to be successful:

1. Top management understanding of the importance of integrity in standards for work performance.
2. A competent, experienced, professional staff to install and maintain the system.
3. An adequate budget to maintain and operate the system.
4. A good unit cost system (preferably standard cost or standard direct cost) must be available and management must understand that lowest hourly wages seldom equal lowest unit costs.
5. Supervision must be thoroughly schooled in the workings of incentive wage plans.
6. Workers must be interested in high wages and high output.
7. Essential is a manufacturing engineering department with competent methods men who are willing and able to work with supervisors and operators alike in developing the most economical methods of production.
8. The plant must have a good quality control system that properly rewards high quality output.
9. The production control department must be capable of providing the right tools, materials, and instructions to the right men, at the right machines, at the right time.
10. The most important ingredient in any effort involving people—especially where the effort involves wage rates and job security—is mutual respect, understanding and trust. If that is not present—or if either party departs from high ethical behavior, incentive systems will

Another error made by top management is that it often wants to establish a pay plan in the terms it understands rather than in the terms the worker understands. Management thinks in terms of three months from now, or a year, or five years, whereas the worker thinks in terms of today, tomorrow, this week, next week. Any plan must be based on the workers time interval if it is to be successful. Incentive plans cannot be based on inventory increments or year-end profits—like turkeys at Thanksgiving—they are nice but they do not motivate. Pay must be based on factors the worker can control—a shipping standard based on tons per man per month is not easy for him to grasp—he cannot sustain effort for a month, so it does not motivate him. But he will understand that he gets $1.12 every time he puts a certain crate together. That will incentivize or motivate him to do it as quickly as possible, in the prescribed manner, and earn the money now.

It is also well to note that group incentives do not motivate nearly as well as individual incentives—again the human individual factor enters the equation for success—the individual must feel and know that his progress is proportional to his effort alone and not

\[^{12}\text{Ibid.}, \text{p. 91.}\]
that of other persons. He cannot be expected to accept others whose actions can reduce his ability to earn.

Wolfe observes that:

Wage incentives are most useful in gaining short run benefits. . .over a period of time the benefits gained. . .tend to be offset by associated costs.\textsuperscript{13}

and that

The use of a system of payment by results sharpens and accentuates differences between the goals of management and those of workers.\textsuperscript{14}

so, as can be seen, many varied opinions exist regarding the benefits and hazards of wage incentive systems.

\textbf{Conclusion}

The way employees feel about their work situation accounts, in a large measure, for their willingness to produce. It is significant that where the elected union leadership favors the wage incentive method of payment, such programs flourish. Witness the women's wearing apparel industry where the International Ladies Garment Workers Union fully supports piecework and 71\% of all workers are paid in this manner. The union participates in the time-study and rate-setting process, hence employees feel they have a part in establishing the

\textsuperscript{13}Wolfe, \textit{op. cit.}, p. 119.

\textsuperscript{14}Ibid., p. 127.
piece rates. By contrast, the low percentage (13%) of the labor force in the automobile industry on incentives is due to the long-term hostility of the UAW.\textsuperscript{15}

It is most important to realize that a positive form of ego involvement and participation in such programs is an ingredient necessary to success. People, being human, tend to support those things they had a part in creating and controlling. Taylor's planning and doing must be recombined to include the whole man. The potentials of the employees' minds must be tapped as well as their bodies.\textsuperscript{16}

In the past fifty years, perhaps because of wage incentives, scientific management and methods improvement, the whole work-force has raised its income, hence standard of living, to the point where it is now more highly educated and more capable than it once was when, for the most part, it was satisfied to perform laboriously, to use only the body and not the brain. Now, because of its higher intelligence, it is not satisfied unless the "whole person" is involved in a gainful occupation and feels that its full talent is being used to advantage.

\textsuperscript{15}Dale S. Beach, "Wage Incentives and Human Relations," \textit{Journal of Industrial Engineering}, XII, No. 5 (September-October, 1961), 352.

\textsuperscript{16}\textit{Ibid.}, p. 354.
Beach believes that a fruitful approach lies in creating programs which include employee participation in decision making. With proper leadership they can contribute to the "how" part of the work—can propose ideas for improving their jobs and the work situation in general through suggestion committees, awards, and by other means.\(^{17}\)

The next step, of course, is for the educated work force to have a high appreciation (as they have at Lincoln Electric) for the forces involving the company and its overall role in the economy (market place). If they can become so oriented that they will be seeking solutions to problems that will improve their chances to win this larger battle—the company versus the economy—rather than the shortsighted provincial and traditional battle, the worker versus management, a sizable step forward in management-worker relationships and wage incentive practices will have been achieved.

Along such lines Barnard made the observation that "collective cooperation instead of collective bargaining must prevail."\(^{18}\)

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\(^{17}\)Beach, \textit{op.cit.}, p. 353.

APPENDIX B

THE IMPROVEMENT PHENOMENON AND ITS
MATHEMATICAL MODEL,
THE LEARNING CURVE

The improvement phenomenon and its mathematical model, the learning curve, provide insight into a human capability that has a direct bearing upon the ability of workers to do work and the time required for them to learn new skills.

Learning curves are based upon the simple observation that the improvement phenomenon follows an underlying natural characteristic of organized or individual activity and can be accurately depicted by the learning curve in the same manner as the normal natural random distribution of anything can be accurately depicted by the bell curve.¹

Learning curve theory states that if the cumulative number of units produced is doubled, the last unit will cost (in time, hours, or dollars) a given percentage less than the last unit produced prior to doubling the quantity. If it is assumed, for this explanation, that this reduction is 20%, it means that the second unit requires 80% of the time required for the first unit, the fourth 80% of the second, the eighth 80% of the fourth, and

so on. By this method the following table of values for an "80%" learning curve can be computed, assuming that 10 direct labor hours are required to produce the first unit.

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>Man-Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>6.4</td>
</tr>
<tr>
<td>8</td>
<td>5.1</td>
</tr>
<tr>
<td>16</td>
<td>4.1</td>
</tr>
<tr>
<td>32</td>
<td>3.3</td>
</tr>
<tr>
<td>64</td>
<td>2.6</td>
</tr>
</tbody>
</table>

If these values are plotted on normal graph paper, see Figure 17, the characteristic shape of the learning curve is immediately apparent. This "true curve" dramatically reveals the amount of reduction in man-hours as succeeding units are produced. Notice that the line dips sharply at first, then slopes downward more gently as the percentage of improvement is spread over a larger and a longer period of time between doubled quantities.

Even though the percentage of improvement is constant (80% between doubled quantities), it is difficult to tell this at first glance, due to the method of plotting on ordinary arithmetical graph paper, where both the ordinate and abscissa are alike and follow the arithmetical scale. For this reason learning curves are seldom plotted on this type of paper. Another disadvantage is that it is too difficult to show unit 1 and unit 1000 on
Figure 17
80% Learning Curve on Arithmetical Graph Paper

Figure 18
80% Learning Curve on Log-Log Graph Paper
the same graph—it would be too big or too small depending upon which area of the curve was needed for close estimation purposes. Interpretation of the curve on arithmetic paper is difficult.

As can be seen on the sample chart, as the sequence (unit number) increases in geometric progression, the variable (time) decreases in geometric progression. To interpret the curve would require a knowledge of analytical geometry and would be somewhat complex. For these and other reasons the curve is usually plotted on log-log paper.

If the same data is plotted on log-log paper the 80% learning curve becomes a straight line, as in Figure 18. (Production figures, when plotted on log-log paper almost invariably follow a straight line.) By using log-log paper the learning curve becomes much easier to interpret, easier to draw, easier to project, and easier to understand. A person can immediately read the approximate man-hours required for any given unit—also the curve can be easily extended to accommodate 1000 units or more.

The curve may appear to be decreasing too rapidly, but this is actually not the case. Because of the expanding scales on the log-log paper, the curve actually decreases at a decreasing rate and therefore approaches
zero at infinity.

Log-log paper is laid out so that the vertical and horizontal scales are the same as on a slide rule, i.e., so that the distances between markings are proportional to the logarithms of the numbers they represent. As the difference between the logarithm of a given number and twice that number or half that number is equal, the distance between doubled quantities on the log-log paper is equal, hence our learning curve becomes a straight line and can be plotted easily. Note that the distance (Figure 18) between units 1 and 2 is the same distance as between the lines for 2 and 4 and also for units 8 and 16. Also note that the doubled quantities, 1, 2, 4, 8, etcetera are equally spaced along the "curve."

The same spacing holds true on the vertical scale on the left side, where the distances between the lines representing consecutive figures is not the same, but is the same between doubled figures. This paper, also known as "ratio" or rate or "rate of change" paper has "cycles" that are identical and that repeat themselves. Note that there is no zero on log-log paper and that there would be none by definition no matter how big it was or no matter how many cycles were represented. The numbering for each cycle is the same and if we choose to represent units in the first cycle, the next will represent tens, the
following hundreds, and so on. Each cycle can represent any multiple of unity that may be desired, and the scale of each succeeding cycle is ten times the cycle below or to the left.

The 80% learning curve that has just been constructed for illustrative purposes was found to be the average curve for the aircraft industry by Stanford Research after post World War II studies of forty-five different cases. In the same manner as companies have different rates of learning, depending upon their product and their experience with similar products, individual people in the work-force also exhibit different learning rates. Improvement rates may vary from a "low" of 100% (no improvement) to a "high" of as much as 55%. For reference purposes, a series of typical learning curves are plotted on log-log paper in Figure 19.

There are many reasons why one person's may show a more rapid rate of improvement than another. One may have more to learn at the outset or may have a faster grasp of new information and more manual dexterity and/or greater learning ability. It is generally believed that improvement can be shown no matter how perfect the planning,

---


Fig. 19.

Straight line learning curves

From 95% to 55%
engineering, tooling, workmanship, et cetera, have been accomplished. Individuals should not always be judged by their learning curve percentage, but it does serve as an index to their ability to apply themselves to varied tasks and to the rate at which they learn such tasks or show capability to enter an incentivized work-force.

It will not be necessary, for the purposes of this study, that the reader understand all of the formal mathematics of the learning curve, but enough of it to use certain basic factors intelligently and to understand the basic principles. The writer assumes that all readers understand logarithms well enough to perform the simple computations shown, if required.

The basic learning curve equation is:

\[ Y = CX^{-N} \]

Where: 
- \( N \) = slope of the learning curve (on log-log paper)
- \( C \) = Man-hours for unit 1
- \( X \) = Unit number of any unit beyond 1
- \( Y \) = Man-hours at unit \( X \)

By taking the log of both sides of the equation (1) we get:

\[ \log Y = \log C - N \log X \]

Learning curves are commonly identified by the per cent of improvement, or ratio of unit-two man-hours to
unit—one man-hours or any other like ratio of the doubled quantity to the original quantity, i.e., 32 to 16 units.

To find the numerical value of the slope $N$ for an 80% improvement curve:

Let $C$ be 100, $Y$ be 80, where $X$, the unit number is 2. Substituting in equation (2):

\[
\log 80 = \log 100 - N \log 2
\]

\[
1.903090 = 2.000000 - .301030N
\]

\[
N = \frac{2.000000 - 1.903090}{.301030} = \frac{.09691}{.30103} = .3219
\]

White expresses the "slope," $N$, relationship in this way:

This relationship is such that the logs of $X$ and $Y$ are in a linear relationship . . . and has the convenient property that every time $X$ doubles, successive values of $Y$ are a constant multiple (some fraction between 0 and 1) of the preceding value. This multiple of $Y$, expressed as a percentage, is commonly called the learning factor or the learning curve "slope." This is misleading since it is mathematically illogical—it is neither the slope of $Y$ nor of the log $Y$. In other words, when the "slope" is plotted on log-log paper it is defined as the unit cost at quantity $2X$ divided by the unit cost at quantity $X$, expressed as a percentage. 4

This value of $N$, the "slope" of the improvement curve, is not, therefore a sound mathematically correct expression, since it assumes that the learning curve is

superimposed on an arithmetical graph grid and represents
the normal slope of a straight line. It is, however, very
useful in analyzing learning curve data both mathemati-
ically and graphically. Table 2 shows the value of N for
various improvement curve slopes from 60% to 95%.

Table 2
Learning Curve Slopes

<table>
<thead>
<tr>
<th>Per cent Slope</th>
<th>Value for N</th>
<th>Per cent Slope</th>
<th>Value for N</th>
<th>Per cent Slope</th>
<th>Value for N</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>.7370</td>
<td>72</td>
<td>.4739</td>
<td>84</td>
<td>.2515</td>
</tr>
<tr>
<td>61</td>
<td>.7131</td>
<td>73</td>
<td>.4540</td>
<td>85</td>
<td>.2345</td>
</tr>
<tr>
<td>62</td>
<td>.6897</td>
<td>74</td>
<td>.4344</td>
<td>86</td>
<td>.2176</td>
</tr>
<tr>
<td>63</td>
<td>.6666</td>
<td>75</td>
<td>.4150</td>
<td>87</td>
<td>.2009</td>
</tr>
<tr>
<td>64</td>
<td>.6439</td>
<td>76</td>
<td>.3959</td>
<td>88</td>
<td>.1844</td>
</tr>
<tr>
<td>65</td>
<td>.6215</td>
<td>77</td>
<td>.3771</td>
<td>89</td>
<td>.1681</td>
</tr>
<tr>
<td>66</td>
<td>.5996</td>
<td>78</td>
<td>.3585</td>
<td>90</td>
<td>.1520</td>
</tr>
<tr>
<td>67</td>
<td>.5778</td>
<td>79</td>
<td>.3401</td>
<td>91</td>
<td>.1361</td>
</tr>
<tr>
<td>68</td>
<td>.5564</td>
<td>80</td>
<td>.3263</td>
<td>92</td>
<td>.1203</td>
</tr>
<tr>
<td>69</td>
<td>.5353</td>
<td>81</td>
<td>.3040</td>
<td>93</td>
<td>.1047</td>
</tr>
<tr>
<td>70</td>
<td>.5146</td>
<td>82</td>
<td>.2863</td>
<td>94</td>
<td>.0893</td>
</tr>
<tr>
<td>71</td>
<td>.4941</td>
<td>83</td>
<td>.2688</td>
<td>95</td>
<td>.0753</td>
</tr>
</tbody>
</table>

The simplest way to show how useful the N can be
in laying out or determining the slope or percentage of
any given or desired learning curve is to note that it
is the decimal part of one log-log cycle where the
"curve" (or any line parallel to it) intercepts the right-
hand cycle boundary when the origin is at the upper left-
hand corner of the cycle, i.e., for an 85% curve,
N = .2345, as shown in Figure 20.

If, for example, a series of time-cost points can be determined for a given sequence the same repetitive operation, as plotted in Figure 5, and a best-fit straight line established, such as line A-B, a line parallel to it, through the origin as shown, will cut the right-hand cycle boundary line proportional to the slope "N," i.e. (in this case N = .2345) and the rate of learning (per cent of the learning curve) can be determined from Table 2, or computed from equation (2).

Equation (2) can also be used to determine the time required for any given single unit number. If we let C equal 100, any answer for Y will be in terms of the percentage ratio to unit 1 hours. In this sample computation let us solve for the time required for unit 37 on an 80% learning curve.

From equation (2)

\[
\log Y = 2 - .321928 \log 37 = 2 - (.321928)(1.568202) \\
\log Y = 1.495152 \\
Y = 31.28
\]

As has been stated, this value of Y = 31.28 equals the percentage of the time to produce the first unit, that will be required to produce the 37th unit. If the first unit took, for example, 14 hours to produce, the
Fig. 20

USE OF LEARNING CURVE SLOPE "N" FOR PLOTTING PURPOSES

Curves are parallel

85% Learning Curve

1 - N

Production Data Points

85%

"Best Fit" Curve

A

B

1 Cycle
37th unit (at an 80% learning rate) would require 
14 X .3128 = 4.38 hours. Tables of values of Y (ex-
pressed as a percentage of C) have been published for 
curves from 51% to 99% and for units of X up to 1000. 
The use of such tables avoids the "complicated"mathe-
matics in solving the above equations, but for this 
study, the requirements are simple.

Cumulative Total and 
Average Curves

Before getting into the mathematics of the 
modifications to the simple straight-line learning curve 
needed to adopt it for learning curve time-standard use, 
as proposed in this study, it seems only proper to 
briefly explain the next logical step of the above 
sequences for predictive purposes now in use by the air-
frame industry. These are the cumulative total and 
cumulative average values computed in Table 3.

Figure 21 shows these tabular values plotted on 
log-log paper. Assuming that the 80% curve is for unit 
values, curve B is the same curve plotted in Figure 18. 
Curve A, then, represents the cumulative average values 
from Table 3. After the first fifteen or twenty units the 
two curves become parallel for all practical purposes, 
i.e., they have the same slope. These curves are all
Table 3
Cumulative Average and Total Values
of Man-Hours During a
Learning Experience

<table>
<thead>
<tr>
<th>Unit Number (a)</th>
<th>Unit (b)</th>
<th>Cumulative Average (c/a)</th>
<th>Cumulative Total (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>(18/2)</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>6.4</td>
<td>(31/4)</td>
<td>7.9</td>
</tr>
<tr>
<td>8</td>
<td>5.1</td>
<td>(53/8)</td>
<td>6.7</td>
</tr>
<tr>
<td>16</td>
<td>4.1</td>
<td>(89/16)</td>
<td>5.6</td>
</tr>
<tr>
<td>32</td>
<td>3.3</td>
<td>(147/32)</td>
<td>4.6</td>
</tr>
<tr>
<td>64</td>
<td>2.6</td>
<td>(239/64)</td>
<td>3.7</td>
</tr>
</tbody>
</table>

used in computing future costs, delivery schedules, etcetera, and are very useful if used with full knowledge of what they really mean; otherwise they are confusing and may lead to erroneous conclusions. The unit form of the theory provides the most practical approach to learning
Fig. 21:

80% Unit Learning Curve,
Cumulative Average Curve and Cumulative Total Curve on Log-Log Paper.

Main Hours Total

Main Hours Per Unit

Number of Units

1 2 3 4 5 7 10 20 30 40 50 100 200 400 800
curve analysis in contract negotiations.⁵

Quart discusses the proper use of time reduction (learning) curves in the estimation of costs for greater proposal accuracy. He shows how such curves can be used to estimate manpower, training, space, facilities, tooling and time requirements when sound judgment, a knowledge of the product and past history are available.⁶

There are two relationships, namely the linear logarithmic relationship, and zero as a limit of Y, that are frequently criticized, but the equation continues to be in almost universal use. The linear relationship is usually questioned from the point of view of goodness of fit. Occasionally someone advocates rounding off the first part of the line and/or the last part of the line or changing the parameters for various segments of the line. That these modifications improve the model is problematical.⁷

White concludes that there has been a singular lack of progress in extending the use of learning curve

⁵White, op. cit., p. 16.


theory outside of the aircraft industry. Specific examples of such applications, together with an application of their usefulness, are extremely hard to find.

Managements are slow to adopt new techniques, particularly in the form of mathematical models. It is a truism to say that either no targets are set or such targets are only unsubstantiated guesses.\(^8\)

This writer, having had experience in both commercial industry (the machine tool industry—one of the largest) and the aircraft industry, feels somewhat the same way about the reluctance on the part of the aircraft industry to adopt wage incentive methods. It is probably due to the fact that there is relatively little cross-flow of qualified people between the two. By the time a man becomes qualified in either, he is so well established, and so familiar with his special field that he does not choose to change into a completely new field where he may find less pay, yet more opportunity to apply what he has already learned to the new field of endeavor.

\(^8\)Ibid., p. 411.