PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

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Increasing productivity has become one of the few remaining alternatives for improving our troubled economy. This report deals with productivity in construction and its purpose is to cover this topic broadly bringing up as many points as possible to the attention of the reader, thus demonstrating the order of magnitude of the problem.

This report defines the productivity problem and identifies the factors affecting it, and presently available, and suggested measurement and improvement techniques. The author's conclusions describe ways of dealing with this problem.

An extensive bibliography of literature pertaining to the topic of productivity is included.

Finally, it is hoped that this report will be the starting point of a broader study leading to measurable productivity improvement in the construction industry.

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INTRODUCTION

During the last few years, the country's economic situation has been suffering seriously from inflation and lack of sufficient growth. Of many suggested solutions, some were temporary, and most were superficial, but they all had ~~undesirable~~ side effects. It became obvious that the solution to many of our economic troubles is to increase our productivity as an alternative to lowering our standard of living.

Construction is an industry constituting approximately 20% of our GNP, which is presently close to $200 billion, and there can be no full recovery of the economy until construction recovers. It is so large an industry that anything that can be done to improve its productivity, must benefit, in turn, the economy as a whole.

It is claimed that productivity in the construction industry is low, and that it has not kept pace with other industries. One thing is sure though, construction costs have soared pushing prices beyond the reach of many potential users, and that is bad news to our industrialized economy which has to compete with other industrialized nations such as Japan, West Germany and the United States. Construction is a service industry to every existing industry, and if building maintenance is neglected or delayed due to high costs, then our economy might be suffering a fatal blow. Most indications are that both claims concerning low productivity are true, yet a complete study has to be conducted to achieve solid proofs and solutions, rather than basing our conclusions on speculation and individual interpretations.

To emphasize these claims, I include ~~the~~ findings of two individual studies. A Canadian report published in 1963 (1) found that the average construction worker was occupied productively for only 55% of ~~his~~ work day. Almost 25% of each working day was lost by involuntary idleness caused by delay.

In the United States where the construction industry is analogous to ours, a study (2) indicated that while the output per manhour has increased slightly, output per labour dollar has decreased by an estimated 50% for the same period.

Unfortunately, the productivity problem has a political aspect, and not many politicians would like to get involved in such a controversial issue against big business or big labour.

Yet the problem is there, and we still have to solve it. With this in mind, I produced this report, hoping to facilitate the task of prospective researchers by presenting the scope and magnitude of the problem.

The purpose of this report is not to establish a program, nor is it to find concrete solutions, because the magnitude of this problem is beyond the scope of such a paper. Instead, it is hoped that this paper will lay the groundwork for such programs, by identifying the problem and suggesting improvement methods for this diversified problem.

In this respect it has to be mentioned that the problem of productivity in construction is presently recognized as an urgent problem. Underlining this urgency; two conferences were organized to discuss this problem, the first was held in Lincolnshire, Illinois, in August 1976 sponsored by ASCE, and the second was held in Toronto, Ontario, sponsored by "The Ontario General Contractors Association" in March 1978. Also, several educational institutions both in Canada and in the United States are presently working on this topic, including Concordia University in Montreal where a specialized building studies research centre has been formed in which I am presently a graduate student, preparing this report under the guidance and supervision of Prof. A. Soda.

To produce this report, a thorough search and screening of the available literature has been done, including a computer search by the Concordia University library.

In my research, I noted that most of the work on this subject has been done individually and no coordinated program has been developed in an attempt to reach effective solutions and recommendations with the exception of the research done by the U.S. Navy which mainly serves its own requirements, but can be a useful guide in our research work covering the whole construction industry.

The need arises for a study program which is gigantic in scale; the kind of study that has to be sponsored jointly by Government, Management, labour and educational institutions. This study should extend to cover the whole range of functions that lead to the finished constructed product. These functions should not be limited only to the actual building functions in the field, but should also include design, planning, specification standards, regulations, inspection and all related aspects.

In the following chapters I include the result of my literature survey, covering the major aspects of construction productivity, from definitions to factors, measurement and improvement techniques. Of the recommendations included in the last chapter, some are a combination of research work done by different individuals, while others are personal points of view. These recommendations are in some cases idealistic, and difficult to implement in our society, and in some other cases are self-evident recommendations. Yet these recommendations are included in the hope that they will initiate the required debate that will ultimately produce a solution tailored to suit the needs of our society.

CHAPTER I

THE NECESSITY OF A CONSTRUCTION PRODUCTIVITY STUDY

The effects of improving productivity in the construction industry will be far reaching both directly and indirectly, covering many aspects of our life. Specifically, the following effects would be felt besides others.

A. The Country's Economy:

Improving productivity will essentially lower the cost of the finished construction product. Consequently, expansion plans become more attractive and Canadian products more competitive in the world market. Thus the improvement in productivity will increase our GNP and boost our exports.

B. The Construction Industry

1. With the expansion plans becoming more attractive; more investments will be directed to this industry leading to a direct improvement in the employment situation contrary to the widespread belief that the unemployment rate is directly proportional to productivity.

2. Another effect will be a general improvement of the industry's image with the public.

3. Contractors will benefit directly through increased profits.

4. Trade unions will also benefit through increasing their membership.

C. The Worker

1. The construction worker will benefit directly from continuous and more stable employment. A positive indirect effect of this continuous employment will be an improvement in his skills, through the learning curve process.

2. A needed psychological boost will develop through the feeling of belonging to a productive group well looked upon by the society.

If such an improvement in productivity is beneficial to everyone, then two questions arise:

What order of magnitude of improvement in productivity could be expected?

Can we justify the required expenses to achieve this improvement?

To answer the first question, I include the results of a study (3). This study was conducted on several industrial construction projects to determine the average time distribution of the construction worker's day. The regular work day distribution is shown below in fig. (1) and it demonstrates a great potential of improvement specially in sections b, c, d, g. Thus we can conclude that if an improvement of 10% is sizeable, yet the potential of improvement is even greater than that.

a	=	Direct Work	=	32%
b	=	Tool & Material Transport	=	7%
c	=	Travelling	=	13%
d	=	Waiting	=	29%
e	=	Instructions	=	8%
f	=	Personal Breaks	=	5%
g	=	Late Start/Early Quits	=	6%

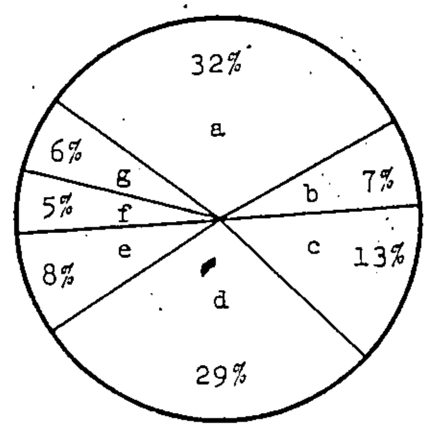


fig. (1)

To answer the second question I include an order of magnitude estimate of the expected return from a productivity study leading to improved productivity. Our GNP was $140 billion in 1974 and is presently close to $200 billion, the construction industry's share is approximately $34 billion almost equally divided between labour and materials. Assuming the labour's productivity improves by 10%, then their portion in the GNP which is approximately $17 billion will improve by more than $1.5 billion for the same yearly input.

This estimate not only justifies the expected expenditures on a construction productivity study, but also demonstrates that the rate of return on such a study could be very high.

The United States Navy was the first to recognize and investigate the potential of improving the productivity of their construction workers. They prepared and implemented a study program and followed it's recommendations achieving excellent results (4). They claim that an average journey man's productivity has increased from about 35% (productively employed about three hours per day) in 1955 to about 68% (productively employed about 5.5 hours per day) in 1976. Their final goal is 80%.

Their conclusion was that the cost involved in the development, installation, test and evaluation of management control systems is not small. However, the recurring savings from increased productivity and better material management and the ability to keep in line with the time requirements of limited resources are benefits which far out weigh the costs.

CHAPTER II

PRODUCTIVITY DEFINITIONS

To be able to tackle the problem of productivity, its measurement, and its improvement, the term "PRODUCTIVITY" has to be fully understood and its parameters well defined.

Unfortunately there is no standard definition for this term in construction as most of the suggested definitions did not achieve the acceptance of all parties involved.

Generally the following tendencies are expressed when attempting to define productivity.

A. User: The user or developer tends to define productivity in terms of the value received for the dollars expended.

This point of view seems to neglect, besides other things, the time factor, and the prevailing site conditions.

B. Designer: Designers tend to define productivity in terms of Manhours required to construct a unit of design.

This definition neglects the cost factor, and thus overlooking the quality of design which directly affects the site productivity.

C. Contractor: To a contractor, productivity should be measured as the output of a piece of equipment or a crew of workers to complete a unit of construction.

This definition reflects the contractor's point of view which claims that much of the idle time is caused by factors beyond his control such as item (d) of fig. (1) particularly if this waiting is caused by the owner and/or designer. Thus contractors would like to introduce the involuntary idleness as a factor in defining productivity. Yet this definition fails to meet the users' acceptance as they are charged for input units.

D. Labour: Labours point of view was reflected by Mr. Kenneth Rose in his speech to the conference held in Toronto to discuss productivity (5). He said, "Perhaps we should interpret productivity on the basis of a definition of waste and inefficiencies on the job".

E. Other: Productivity can also be defined as follows (6): If productivity is the relationship of desired and saleable output to all inputs, and the value of productivity is the relationship of revenue from output to the cost of inputs, then improved productivity means either:

a. More output to the same input
b. Same output for less input
c. Relatively more output for more inputs

Each of the previous views of the definition relate to productivity, yet each of them reflects its definers' interests, which demonstrates the diversified nature of this industry.

This multiplicity in concepts means that there are many different ways in which productivity can be defined and consequently measured and improved.

Until standard definitions are put forward and in the absence of more accurate definitions, productivity can be defined in terms of chargeable cost/unit product, where cost can be expressed in terms of Manhours, dollars or any other desirable measurement unit. In this case, mainly identical activities (or products) can be compared. Yet it is possible to compare non identical activities (or products) approximately after introducing adjustment factors to account for the different conditions.

CHAPTER III

FACTORS AFFECTING PRODUCTIVITY

The factors affecting productivity on a construction site are numerous and largely diversified, yet for an effective control on productivity, these factors and their effect on the construction progress have to be studied and well understood.

It is through the knowledge of these factors that productivity will be controlled and improved. Accordingly, this chapter will deal with each of these factors individually, clarifying its effects on construction progress assuming all the other factors are constant.

These factors are listed in six major groupings as follows:

A. LABOUR RELATED FACTORS

1. Labour Disputes and Work Slowdowns:

Labour disputes are usually negotiated with management, but problems start when these disputes are not settled to the satisfaction of the trade union involved. One of the pressure tactics used by the unions is work slowdowns, which directly affects site productivity.

Unfortunately, it is very difficult for management to control, or even prove its occurence as its occurence is usually denied by the union leaders. In the meantime, salaries are being paid and management is liable to delay claims.

To neutralize the effects of these slowdowns, two possible solutions are:

a. Introduce and publish productivity standards, thus enabling management to prove the existance of work slowdowns.
b. Introduce a system of binding arbitration thus the need for work slowdown will diminish.

2. Strikes:

Strikes, when they occur, bring the construction activity to a halt, thus stopping all production, in the meantime indirect expenses are continuing.

The direct effect of a strike on the site also includes mobilization and demobilization costs, loss in the learning curves, besides possible losses due to weather conditions, delay claims and escalated interest payments.

Strikes also have a direct effect on other supply, transportation and related industries besides the irrecoverable losses in the economy both directly and indirectly.

A possible solution to the strike problem could be introducing a binding arbitration system thus ending the need for lengthy strikes.

3. Performance Restrictions and Featherbedding:

Restrictions occur on construction sites, they are mainly negotiated union agreements, but are sometimes non-declared restrictions applied by the unions without a previous agreement with the contractors.

A paper (7) refers to a report on restrictive practices of the building trades, prepared by the staff of the Associated General Contractors of America, acknowledges six major types of such practices that appear in union agreements signed by contractors:

a. Prohibiting labour saving machines.
b. Requiring unnecessary work or the duplication of work already done.

c. Excessive non-production time.

d. Limiting the work load of employees or the number of machines a man can operate.

e. Requiring unneeded workers.

f. Restricting the duties of workers.

Undeclared restrictions could be a common occurance such as the number of bricks a bricklayer can lay in a day, or protective restrictions introduced against an outside contractor to protect local contractors.

Restrictions affect productivity directly with a high cumulative resultant. Undoubtedly, solving this problem can be of great potential in our attempt to improve productivity.

Promising solutions to this problem could be:

a. Negotiating with the unions the addition of improved performance incentives.

b. Introducing and monitoring performance indicies.

B. MANAGEMENT RELATED

1. Management and Supervision:

The role played by management personnel in a construction site has a major direct effect on productivity, as decisions taken by this group, could add or eliminate hundreds of idle manhours. Also, their attitude towards their subordinates could have the same positive or negative effects.

When studying low labour productivity, poor management has to take its fair share of the blame. So far, the construction industry has been lagging behind other industries in upgrading its management personnel who are in many cases previous industrious construction workers promoted to the level of incompetence. Experience is certainly very important, but experience alone is certainly not enough. With the ever increasing complexity of construction projects, the requirement from this group expands to include a wide range of knowledge available only in specialized education.

The daily work of management personnel includes dealing with financial, legal, and human problems, besides dealing with the regular technical problems. Decisions at this level, specially those dealing with uncertainties, have to be based on a calculated risk, not just a guess.

The direct answer to this problem is to encourage the present management staff to attend specialized courses and provide more training to new graduate engineers.

2. Planning and Scheduling:

Planning and scheduling is one of the classic tools in construction management, yet the poor performance of this group can lead to reduced site productivity due to the failure of achieving optimum planning for a given job.

Given the complexity of modern construction jobs, computer optimization becomes a necessity, specially for planning and scheduling activities, and where resource allocation is needed. Employing a qualified planner capable of utilizing modern planning techniques can pay off handsomely by the end of the project, through saving time, money, and resources. On the other hand, the failure of the planning task can prove to be costly, not only due to lower productivity, but also through more overhead expenses required for the longer durations and the possibilities of legal claims, besides loss of reputation for the contractor or construction manager involved.

3. Motivation:

Many studies have been conducted on the motivation of the construction worker. Abraham Maslow has proposed a theory called the hierarchy of needs (8).

According to Maslow, there is a hierarchy of needs that begins with the basic physiological needs, as each of these needs are fulfilled, the person's needs expands to include other needs, till ultimately, he reaches self-fulfillment. These needs are listed below according to their hierarchy as put forward by Maslow.

a. Physiological Needs:
   Food, liquid, rest, exercise, shelter and protection from elements.
b. Safety Needs:
   Protection against danger, threat and deprivation, final security.
c. Social Needs:
   Belonging, association, acceptance and giving and receiving friendship and love.
d. Ego Needs:
   Self respect, self confidence, autonomy, recognition and appreciation.
e. Self Fulfillment Needs:
   Self development, creativity and potential realization.

Knowing the mechanism of motivation, management should manipulate these needs and use them correctly to achieve improved productivity.

4. Inspection and Rework:

The quality of work done is usually dependent on the applied inspection, thus poor inspection leads to poor workmanship. When the work is finished, and the owners' representative does the acceptance inspection, the contractor usually is required to redo the unaccepted part of work before he can collect the retention money. This repetition is an outright loss in terms of time and money for every one involved. Thus it can be demonstrated that poor inspection has a direct negative effect on productivity.

Applying a well developed quality control system, and enforcing it by qualified industrious inspectors, can therefore improve the overall productivity in a construction site.

5. Expediting:

The expeditor acts as a means of communication between the purchaser, and the manufacturer. He co-ordinates the requirements and capabilities of each, thereby, helping to establish the smooth association that is required to successfully complete a contract. Thus through the involvement of the expediting group, any possible delays are discovered before it is too late to initiate corrective action.

It becomes clear that if this group fails in doing its work correctly, there could be unsignaled delays causing the loss of many manhours which in turn negatively affects productivity on the construction site.

C. DESIGN RELATED

1. Design Changes and Change Orders:

This is a combined owner, design and management problem that has an adverse effect on productivity. A pending change almost brings to a halt ongoing activities of one or more trades. During the waiting period the workers if not transferred or laid-off, are idle thus lowering the overall site productivity. When a decision concerning a change is finally taken, the involved trades are usually asked to work harder and faster to make up for the lost time. This process in turn increases the possibilities of making errors, and weakens the moral of the workers.

It is interesting to note that change orders are originated by the same people who are always complaining about low construction productivity.

2. Quality of Design:

The quality of design directly affects the site productivity. Low quality designs can cause many delays and consume more resources thus increasing the cost of the finished product.

Hastily prepared unoptimized designs, and low drafting and printing quality causes more change orders, more time spent on site trying to solve the riddles of the drawings and increased chance of errors and re-work. All this has a direct negative effect on productivity.

D. HUMAN FACTORS

1. Human Capacities (9):

The human capacities can be affected by the following factors, consequently affecting productivity both directly and indirectly.

a. Physiological aspects
b. Energy limitations
c. Physical fatigue
d. Body temperature
e. Mental fatigue
f. Boredom

g. Heat and cold

h. Noise

2. Personal Effects:

Personal effects like mental problems, drinking habits, and loneliness in remote construction sites, could have a negative effect on productivity.

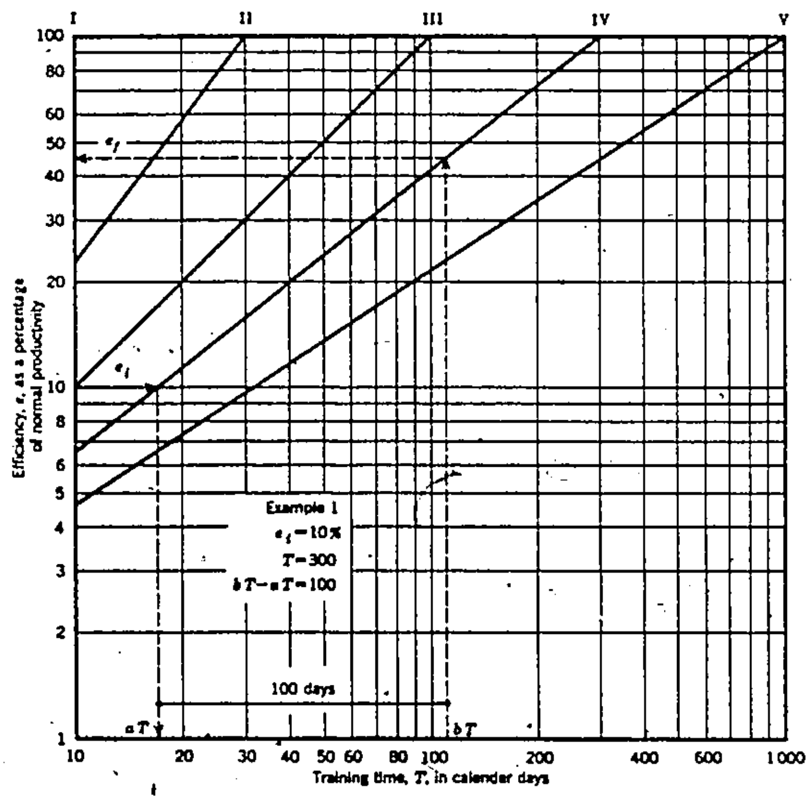
The magnitude of these effects is hard to measure, yet management should provide reasonable working conditions in an attempt to reduce these adverse effects.

3. Learning Ability:

The learning capacities for an average person were studied, and learning curves were developed to reflect the learning process (10).

Time gain for harmoniously progressing projects is significant, whereas projects that face several delays tend to show less gain in the learning curves.

The U.S. Department of Labour has published a compilation of the average training times and preferred traits of workers for 4,000 occupations, about 10% of this number relates to the construction industry, and fig. (2) shows a convenient grouping indicating the order of magnitude of training times for these groups.



LEARNING CURVES FOR CONSTRUCTION TRADES

fig. (2) Ref. (10)

Group I - Represents unskilled labour

Group II - Represents semi-skilled, common labour and helpers

Group III - Light equipment operators, truck drivers

Group IV - Heavy equipment operators and simpler crafts

Group V - Complex trades

The Authors of (10) suggested the following relationships for efficiency:

$$e = (aT)^g \text{ ....(1)}$$

where e = efficiency as a percentage of normal productivity

T = the duration of the total training period to achieve normal productivity, to increase e from 1% to 100% in calendar days.

a = fraction of T, denoting the completion of a part of the total training period.

$$g = \frac{2}{\log T} \text{ ....(2)}$$

The average efficiency of an apprentice's output between the aT and the bT days of the training period can be represented as follows:

$$e_{av} = \frac{(bT)^{e_f} - (aT)^{e_i}}{(bT - aT)\ (g+1)} \text{ ....(3)}$$

The less skilled a trade is, the greater is the initial efficiency, e_i, of the trainee in terms of productivity as a percent of normal prior to training.

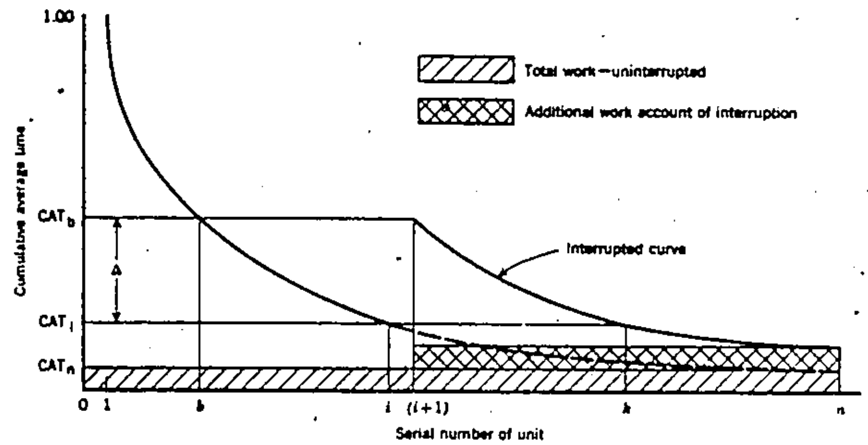
On the other hand, the project for which the on-the-job training program has been established may not extend for so long a period of time as to enable the apprentice to achieve journeymen's status; that is, T is greater than the construction contract period. Equation (3) is applicable to this case where the final efficiency, e_f, is less than 100%.

Example (10): As an example of the application of learning curves, assume that 300 days of apprenticeship training are required to achieve the normal level of productivity for a certain trade. If generally untrained workers are hired (assume $e_i = 10\%$) and trained on-the-job for 100 calendar days, what is their final and their average efficiencies? From Fig. 2, $e_i = 10\%$ is equivalent to 15 calendar days of training. Then, e_f for (100 + 15) days is 46%. From Eq. 2, $g = 2/\log 300 = 0.81$, and from Eq. 3:

$$e_{av} = \frac{115(46) - 15(10)}{100(1.81)} = 28\%$$

EFFECT OF DELAYS AND INTERRUPTIONS ON THE LEARNING CURVES (Fig. 3)

Whenever the routine-learning process is delayed for even a short time, some of the experience curve effect is lost, although upon resumption of the activity, the routine-acquiring process resumes at the same decremental rate. In Fig 3, the usual experience curve effect is shown (arithmetically) for the construction of n units. At i units an interruption occurs. Upon resumption of activities, the (i + 1) unit requires more man-hours to construct than the ith unit. In fact, not until the kth unit is constructed does the interrupted experience curve yield the same CAT as before the interruption. Furthermore, the interrupted curve from (i + 1) to k is identical to the uninterrupted curve from b to i; so that the interruption has resulted in the loss of the equivalent of (i - b) repetitions. This loss can be interpreted as the additional man-hours (work) represented by the double cross-hatched area. The single cross-hatched area represents the total man-hours of the uninterrupted operation.



CUMULATIVE EXPERIENCE CURVE WITH INTERRUPTION

fig. (3) Ref. (10)

4. Standard Work Day:

Productivity in a construction site varies with the variance of a standard work day as indicated from a study (11).

The study concludes that if a standard workday is defined as the first shift of eight continuous hours of work on a regular workday, then productivity is directly proportional to the number of regular workhours per day. In other words, productivity tends to decrease as the number of regular shift hours decrease. This is due to the fact that non-productive time lost in, check in and out, coffee breaks, personal time, etc... is constant (almost an hour). In this case, 8 hours will yield 7 hours of productive work, 7 hours will yield 6 hours, and 6 hours will yield 5 hours. It is clear that the percentage lost increases as the regular shift decreases. Yet, the relationship is not necessarily a linear one, as breaks and personal time might vary slightly, proportional to the length of the standard day. To clarify this point, the following graph is developed Fig. (4) . Assume:

Standard workday	8 hours	5 hours
Whole day	480 min.	300 min.
Coffee breaks	30 min.	30 min.
Personal time	20 min.	20 min.
Check in/out	10 min.	10 min.
Productive workday	420 min.	240 min.
Productivity	$\frac{420}{480}$ or 87.5%	$\frac{240}{300}$ or 80%

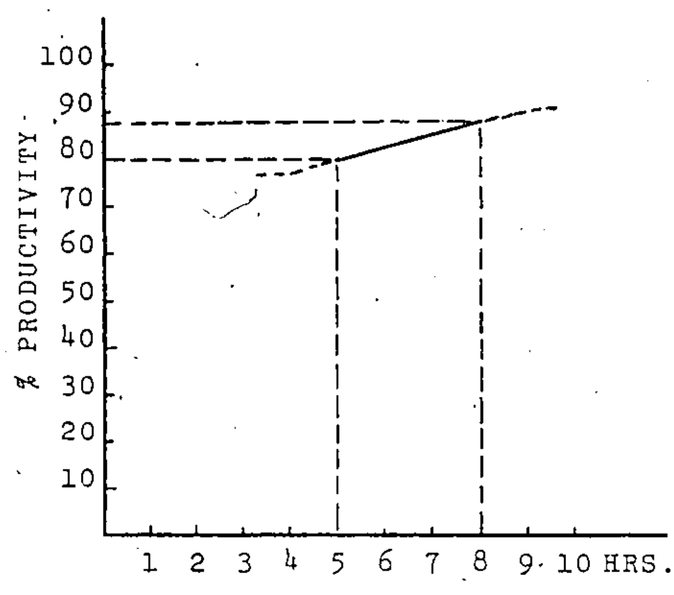


fig. (4)

5. Overtime:

According to a study on the effect of overtime on productivity (12), the loss of efficiency due to scheduled overtime extends to the entire day, not only the scheduled overtime hours. This loss will also continue for a number of days after returning to the regular workweek. Other effects of overtime includes increased absenteeism due to fatigue, where a day of absence becomes more affordable due to compensated overtime earnings. Also poor workmanship, and increased accidents can result from overtime. The graph shown in fig. (5) shows the expected efficiency or (overtime productivity factors) for different overtime schedules, as compared to the efficiency of a standard 5-day week (40 hrs), which has a 100% nominal productivity for comparison purpose only. It becomes clear that avoiding overtime where possible is recommended.

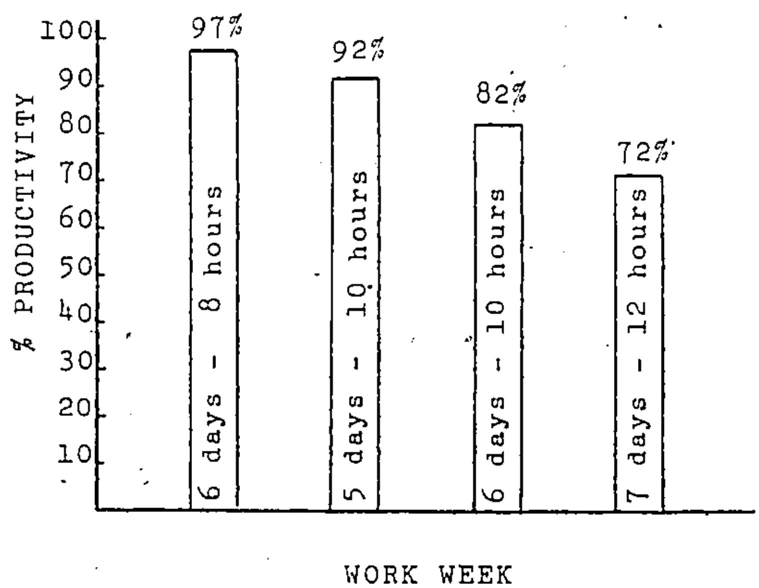


fig. (5)

E. GENERAL CONDITIONS

1. Shortage of Skilled Labour:

The availability of skilled labour in the construction area seem to have a direct bearing on the productivity of the site. It is clear that for a given optimum crew of 12 say (2 seniors, 4 intermediates, and 6 juniors) the productivity will be higher than for the same crew of 12 composed of (1 senior, 3 intermediates, 8 juniors). This phenomenon can be felt in sites lacking well-trained workers, the effect will be felt in terms of longer activity durations, more manhours, and more rework required.

2. Project Size:

The individual input varies with the size of the project, and it appears that the bigger the project, the less becomes the individual initiative and consequently, productivity is lower, mainly because of uncertain responsibilities, and lack of information and motivation.

Also in bigger projects, the big turnover of workers can adversely affect the gains that could be achieved through the learning process.

This is mainly a management problem, which can be overcome by good planning and defining responsibilities, in addition to introducing motivation programs.

3. Site Location:

The site location can affect the overall productivity in the following way:

a. Site near downtown areas, taverns or other recreational areas.

(i) Longer lunch breaks.

(ii) Afternoon productivity could be affected for people with drinking problems who could misuse a nearby tavern and satisfy their drinking habits.

(iii) Workers have to arrange to beat the rush hours, which could lead to early quits.

b. Remote sites.

Mental tension, boredom, or alcoholism can develop.

c. Sites that are not easily accessible.

These sites do not attract well trained workers unless they are sufficiently compensated, therefore a shortage of skilled labour can occur.

4. Travel Time:

Travel time should be minimized as it could affect productivity adversely as follows;

a. Travel time is usually non productive time.

b. Usually some idle time is spent before and after each trip.

c. Travelling consumes energy, money and equipment which are vital resources for any site.

F. POLITICAL FACTORS

1. Government Regulations:

Government regulations are complicated and time consuming, some of them are even vague and could leave the contractor open to technicalities.

Many contractors have complained from the adverse effects of these regulations on productivity, claiming an excessive number of forms have to be filled, and complicated procedures followed, thus resulting in bureaucratic tie-ups with the possibility of site delays. Many of these complaints were raised in the Linconshire conference on productivity (16).

It is generally recommended that the number of regulations and forms required to be filled should be reduced to a minimum.

2. The Economic Situation:

It appears that the prevailing economic situation during the construction period can affect the site productivity.

During a booming economic period, individual workers tend to become less productive and featherbedding prevails. This is mainly due to a general feeling of security, thus if a worker is laid-off, he will have no problem finding another job.

When the economy suffers a general slowdown, jobs become scarce and the above mentioned process reverses itself with workers tending to work harder in an attempt to secure their job.

3. Public Interface:

Many projects have suffered considerably through delays and sometimes through outright stoppages, because of public rejection, which is in many cases due to misunderstandings that turn the public hostile to these projects.

The negative effects of these delays and stoppages on productivity is known. It is therefore recommended that a public interface study should be conducted in the feasability study stage. This front end expense can save many manhours and dollars.

CHAPTER IV

PRODUCTIVITY MEASUREMENT

In the previous chapter most of the factors affecting productivity have been discussed briefly. This chapter will deal with measurement of productivity which is the only way of establishing standards, which in turn can judge the effectiveness of our improvement techniques.

Measurement techniques are numerous and diversified, but that agrees with the nature of the construction industry, thus each construction site can use the combination of methods that suites its needs for control, reporting and comparing.

The following pages will include some effective measurement techniques that can serve a wide range of construction needs.

A. MANHOUR AND PRODUCTIVITY CONTROL

This technique was developed by B. Gupta, Eng., Head of Project Control Systems Department, of the Shawinigan Engineering Company Limited, with the active participation of the writer of this paper.

Its main purpose is to give the project manager and/or construction manager, an effective control on the manhour expenditure through measuring and forecasting productivity trends. All the necessary control information is listed in one sheet. An actual manhour expenditure, as opposed to the planned, and the credit earned are drawn graphically together with productivity indicators.

ASSUMPTIONS:

1. The standard budget represents an accurate estimate of the manhour requirements for the given scope of work. This estimate is prepared by the group leaders, assisted by previously compiled data from previous similar projects.
2. The budget is broken down to subdivisions, each of which represents a separate entity in the project, e.g. (Bldg. No. 1, Bldg. No. 2, Bldg. No. 3). Each of the main subdivisions will have a separate sheet for reporting its progress as shown in fig. (6) with column (3) representing its share of the whole project budget, e.g. (Bldg No. 1 - 40%, Bldg No. 2 - 35%, Bldg No. 3 - 25%). A final (project summary) sheet typical to fig. (6) with column (3) reading 100% will serve as a complete project progress report.
3. Each main subdivision is further broken down to smaller well defined activities. It is evident that the accuracy

of this method increases as the number of activities increase. Table (1) demonstrates the method of compiling the back-up data which is to be used to complete the form in fig. (6).

4. Every update, the group leaders are requested to assess the progress and forecast the remaining time required to complete each activity. This assessment has nothing to do with the actual manhours spent.

LIMITATIONS AND ADVANTAGES:

This method has proved to be invaluable and effective whenever it was used. Yet in order to make full use of the provided data, one has to have a full understanding of the figure mechanics and accept the calculated data as trends, and not absolute figures.

The difficulty lies in working out an accurate standard time budget, as well as estimating the % complete. To reduce the margin of error, the budget is broken down into smaller sub-budgets that are better defined and easier to handle, also breaking down the budget facilitates estimating the already weighed sub-accounts. To clarify this, see example in table 1. Yet it has to be pointed out that the accuracy of measurement is dependent on human judgment which necessitates the choice of qualified dependable personnel to handle this task.

Building # 1 Budget = 400 MHs Project Budget = 1000 MHs

Activity (1)	Budget (2)	MHs spent to date (3)	Actual % complete (4)	Credit (5) (4) X (2)	Forecast to compl. (6)	Forecast total (7) (3) + (6)
A	80	60	50	40	45	105
B	120	25	25	30	85	110
C	60	30	40	24	40	70
D	140	10	10	14	120	130
TOTAL	400	125	27	108	290	415

TABLE (1) (COMPILATION OF BACKUP DATA)

1. Activities are already weighed against the budget.
2. The number of sub-divisions is directly proportional to the accuracy of forecast. This is due to positive and negative errors eliminating one another.

COMPILATION AND PRESENTATION

The data is compiled in the sheet shown in fig. (6) as follows: (Note that figures shown in table (1) and fig. (6) do not match. They are included for method demonstration only.)

Column 1 - Report Date: Indicates end of data compiling period.

Column 2 - Budget MHs: The standard time budget for a given scope of work.

1. Going through column 2 vertically, the budget history can be obtained.
2. This figure should indicate the standard time for finishing a given project or activity rather than the available time (fixed price contract say).

3. This figure can only change when the scope work changes.

4. Determining the standard time budget is the most important part of this exercise. It can be determined by using previously compiled data and through direct consultation with group leaders. It has to be noted that an over-estimated budget will cause the performance ratio (productivity indicator) to give high readings, whereas an underestimated budget will cause a low productivity reading.

Column 3 - The budget as a percentage of the total project budget. Refer to assumption No. 2.

Column 4 - Forecast Revised MHs: This column is equal to MHs to date+estimate of remaining hours required to complete the work as determined from the group leaders.

Column 5 - Forecast as Percent of Budget: Gives the forecast trend as compared to the original budget.

Column 6 - Manhours Spent this Period: Periodical manhour expenditure.

Column 7 - Total Manhours to Date: To date (accumulated expenditure)

Column 8 - Credit Earned: This column as is the case with column 4 is compiled by breaking the budget into several sub-budgets. These sub-budgets are compiled in a separate sheet to determine the actual credit. Credit earned = Actual % complete X budget MHs.

Column 9 - Actual Progress (% complete)

$$\frac{\text{Credit earned}}{\text{Budget}} = \text{Actual progress as a \%}$$

Column 10 - Percent of MHs spent

$$\frac{\text{Total MHs to date}}{\text{Budget}} = \text{Actual MHs spent as a \%}$$

Column 11 - Percent of Forecast Total

$$\frac{\text{Total MHs to date}}{\text{Forecast MHs(Col. 4)}} = \text{A tool of forecasting the total cost}$$

Column 12 - Cumulative Performance Ratio

$$= \frac{\text{Actual progress (Col. 9)}}{\text{\% of MHs spent}} = \text{a productivity trendicator}$$

For the total job as of the periodical update

C.P.R. $<$ 1.0 indicates low productivity

C.P.R. $>$ 1.0 indicates high productivity

Column 13 - Periodical Performance Ratio

$$= \frac{\text{Periodical credit earned}}{\text{Periodical MHs expended}} = \frac{\text{Col}(8n) - \text{Col}(8n-1)}{\text{Col}(6)}$$

This indicator provides the most important means of control, it is the manager's steering wheel. If the project is falling behind schedule, and this figure is higher than one, then the manager can safely commit more personnel to expedite the work. Adding more manpower though will force this ratio down, and when it reaches 1.0 this is an indication that committing more manpower will be at the expense of productivity.

On the other hand, if this figure is lower than 1.0, then it acts as an alarm bell to check the reason of this reduced productivity and take corrective action.

SE13-14

PROJECT STATUS REPORT

JOB NO: ______

REPORT DATE: ______

ISSUE DATE: ______

PREPARED BY: ______

APPROVED BY: ______

$$\text{PROGRESS} = \frac{\text{CREDIT EARNED}}{\text{REVISED HRS}} = \frac{\text{COL (8)}}{\text{COL (2)}}$$

$$\text{PERFORMANCE RATIO} = \frac{\text{EARNED VALUE}}{\text{ACTUAL COST}} = \frac{\text{COL (8)}}{\text{COL (10)}}$$

REPORT DATE LINE

JOB TITLE: ______

CLIENT: ______

(1) REPORT DATE	(2) BUDGET: REVISED HRS	(3) BUDGET: % OF PROJECT BUDGET TOTAL	(4) FORECAST: REVISED MAN HOURS	(5) FORECAST: % OF BUDGET TOTAL	(6) MAN HOURS SPENT: THIS PERIOD	(7) MAN HOURS SPENT: TOTAL TO DATE	(8) MAN HOURS SPENT: CREDIT EARNED	(9) % MAN HOURS SPENT: % PROGRESS	(10) % MAN HOURS SPENT: % OF BUDGET TOTAL	(11) % MAN HOURS SPENT: % FORECAST TOTAL	(12) CUMULATIVE PERFORMANCE RATIO	PERIODICAL PERFORMANCE RATIO	REMARKS
15 SEP	20290	100	19159	94.4	1014	2386	2293	11.3	11.8	12.5	0.96	0.96	
30 SEP	20290	100	18629	91.8	1986	4047	3654	18.0	19.9	21.7	0.90	0.63	
15 OCT	20290	100	16865	83.1	2251	5298	5743	28.3	31.0	37.0	0.91	0.93	
31 OCT	20290	100	17251	85.0	2411	8709	9017	44.4	42.9	52.3	1.03	1.45	
15 NOV	20290	100	17047	84.0	2542	11251	11943	58.9	55.5	66.6	1.06	1.15	
30 NOV	24246	100	20569	84.8	2370	13671	15164	62.5	56.2	66.2	1.11	1.36	
15 DEC	24575	100	21819	88.8	2410	16082	18425	75.4	65.4	73.7	1.15	1.35	
31 DEC	23000	100	22822	92.9	1218	17300	17922	77.9	75.2	75.8	1.03		
15 JAN	23000	100	23150	100.6	1568	18868	19360	84.2	82.0	81.5	1.03	0.91	
31 JAN	23000	100	23449	101.9	1706	20574	20615	89.6	89.4	87.7	1.00	0.73	
28 FEB	23000	100	23796	101.4	2487	23061	22550	98.0	100.3	96.9	0.98	0.78	

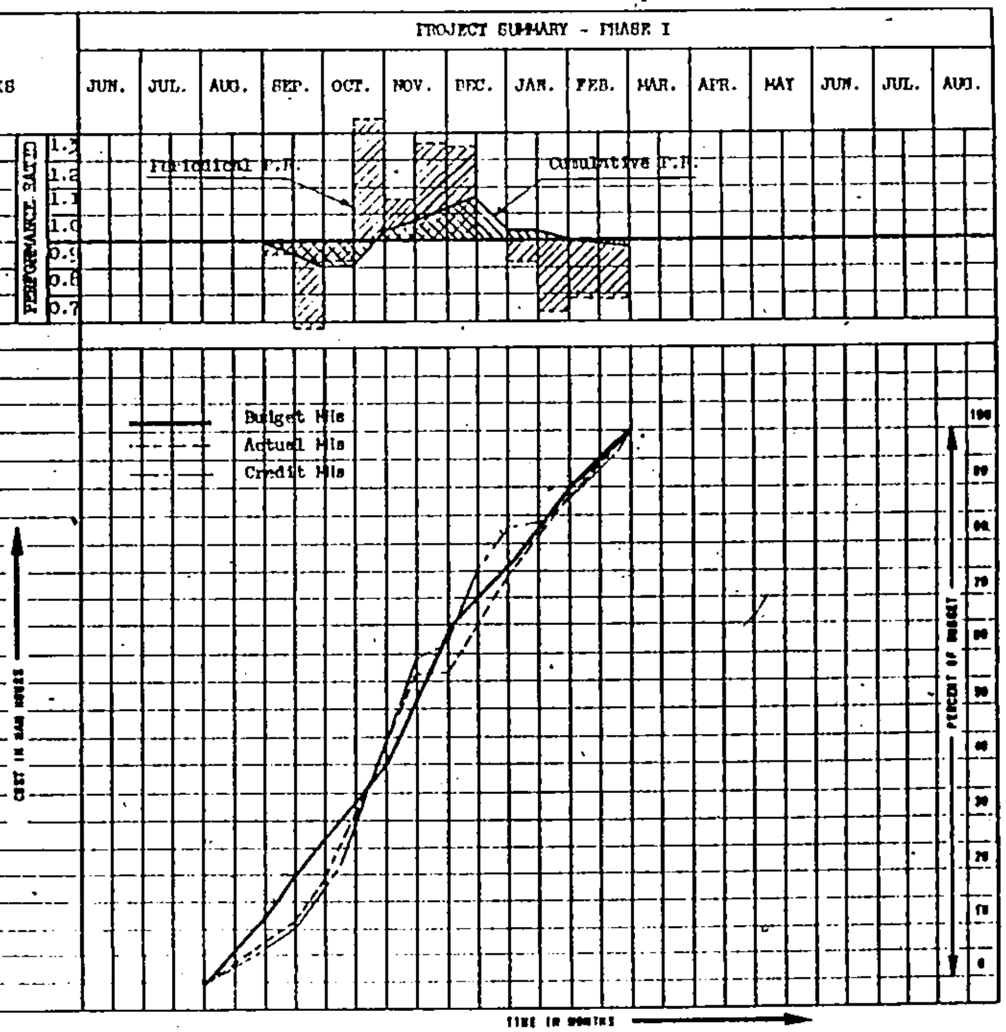


fig. (6)

B. MODELING METHOD - PRODUCTIVITY

This is a model suggested for the physical on site measurement, called Method Productivity Delay Model (MPDM) (13). The model focuses on method productivity parameters that are measurable and controllable by the average construction firm. Method productivity parameters are addressed by documenting productivity delays such as environment, equipment, labour, material, and management. This model recognizes the environment and constraints of the average construction firm, by providing inexpensive technique that is not too complex and that is compatible with industry practices. The model requires only simple mathematics and most important it is compatible with existing union work rules. This technique focuses on measuring, predicting and improving a given method's productivity.

REQUIRED DATA:

1. Identify the "production unit" and "production cycle". Where the production unit is an amount of work descriptive of the production which can easily be visually measured.

   Examples:
   a. Arrival of a scraper in a borrow pit.
   b. Releasing of concrete from a crane bucket.
   c. Placement of a structural member.

And the "production cycle" is the time between consecutive occurences of the production unit.

2. Identify the "leading resource".
   Where the "leading resource" is identified as the most basic or fundamental resource used in the construction method. As a guide, one can visualize the leading resource as the resource which, if changed in its amount, will change method productivity regardless of the presence or lack of current inefficiencies and regardless of the amount or makeup of the other support resources.

3. Time required for the completion of production cycles. Also document productivity delays.

Using a data collection form carry out a Production Cycle Delay Sampling (PCDS). The following is documented.

1. Time required to complete production cycle.
2. Occurence of productivity delay such as (environment, equipment, labour, material, management, etc.)
3. If more than one productivity delay, the total delay of the cycle.
4. Any unusual events that characterize a given production cycle.

PROCESSING:

$$\text{Overall method productivity} = (\text{Ideal productivity}) \times \left[1-\left(\sum_{i=1}^{n} D_i\right)\right]$$

Where D_i = expected delay as a decimal fraction of total production time, for each of the delay causing elements: environment, equipment, labour, material, management, etc.

INDICATORS:

1. Ideal cycle variability =

$$\frac{\dfrac{\sum\left[(\text{Non-delay cycle time}) - (\text{Mean non-delay cycle time})\right]}{\text{Number of non-delay cycles}}}{\text{Mean non-delay cycle time}}$$

2. Overall cycle variability =

$$\frac{\dfrac{\sum\left[(\text{Overall cycle time}) - (\text{Mean non-delay cycle time})\right]}{\text{Total Number of Cycles}}}{\text{Mean overall cycle time}}$$

Where:

Non-delay cycle times - are durations of cycles in which no delays are detected.

Overall cycle times - are the durations of all cycles without regard for detection of delays.

C. WORK SAMPLING

Another approach to measuring productivity is the activity and work sampling techniques. They have the advantage of giving an answer in minutes.

Basically, activity sampling consists of observing and classifying a small percentage of the total project activity, with a representative sample that is large enough to have statistical validity. This sample should also provide an agreed upon confidence limit, and limit of error.

For work sampling of construction operations, there is a general consensus that a confidence level of 95% and a limit of error of ±5% give a good indication of the overall effectiveness of an organization. The working proportion of activities usually fall within the range of 40 to 60% of the whole for most activities. With these limits, and with the opportunity that the split may be 50 - 50, the minimum sample can be determined (9).

The following general rules for activity or work sampling must be observed in sampling construction labour.

1. A sample shall contain no less than the minimum sample size observations.
2. Every workman must have the same chance of being observed at any time.
3. Observations must have no sequential relationship.

4. To preclude any bias, the rating must be made at the instant each man is first seen, the observer must not rationalize on what tasks the workmen have just finished or what they are about to do.
5. The basic characteristics of the work situation must remain the same while the observations are being made. Likewise, comparisons among sets of observations are valid only if the work situation is substantially the same.

Several types of activity - sampling techniques are in use; they vary only in the degree of sophistication, two of these techniques are discussed below.

1. Field Ratings

   These require only that the activity of workers be classified at the moment of observation in one of two classifications, namely, "working" and "not working". (for details refer to"Methods Improvement for Construction Managers"(9)).

2. The Five-Minute Rating Techniques

   This is a quick, but less exact appraisal of activity than the field rating method: Yet, it is an effective method for making a general work trend evaluation. It is based on the summation of the observations made in a short study period, with the number of observations usually too small to offer the statistical reliability of work sampling.

Labour-Utilization Factors (9)

The results obtained from a work - sampling study can be converted to give a Labour-Utilization Factor.

This factor may be defined in two different ways depending on whether the definer gives merit to (essential contributory work) or not.

Labour-Utilization Factor =

$$\frac{(\text{Effective Work}) + \frac{1}{4}(\text{Essential Contributory Work})}{\text{Total Observed}}$$

Where Total Observed = Effective + Essential Contributory + Ineffective

or Labour-Utilization Factor = $\dfrac{\text{Effective Work}}{\text{Total Observed}}$

Where:

Effective work - is the actual process of adding to the unit being constructed.

Essential Contributory Work - that work not directly adding to, but (through associated processes) essential to finishing the unit. This could include handling material, receiving instruction, reading plans, etc...

Judgment and experience must be used in interpreting labour utilization factors. The value of this factor changes for different trades as follows:

Labour	=	30% to 35%
Electricians & Pipefitters	=	40% to 45%
Painters	=	60% to 65%

D. OTHER MEASUREMENT TECHNIQUES

1. Stopwatch studies:

   This technique is the cheapest and fastest way to record a specified sequential event. Unfortunately, its results are limited by the proficiency and training of the operator, and they cannot give a general picture of a job.

2. Time-lapse Motion Pictures:

   The motion film can record the movements of each man or machine, it also has the advantage of permitting replays of interesting work sequences. One disadvantage is the high cost of this process.

3. The alternative to motion pictures, is time-lapse or memo-motion photography. The selection of the time interval between pictures governs the detail in which the work is recorded.

   The most significant advantage of time-lapse photography is that it makes an indisputable record. For the superintendent or foreman who will argue for hours that the tabulated results of a stopwatch or cost study are wrong, the time-lapse film is an easy irrefutable way for him to see his problems.

   Another advantage is recording an already perfected method, which can be used later in demonstrations to new personnel and on other jobs.

E. INDICES

Indices are one of the modern industry's most effective tools. They provide guidance in policy making and forecasting, as well as providing judgment for policies already being pursued.

So far, the construction industry has not profited from the flourishing indices business, and that seems to be quite striking, since complaints about low productivity are so persistent, that it would have appeared that indices would provide the required productivity indicator. Yet the main reason for lacking indices in the construction industry appears to be poor coordination between governement, management and labour.

Amongst the few attempts to measure productivity trends, the most notable is the exercise by Prof. Sara Behman. This study was initiated when union officials approached the University of California to undertake research to determine labour productivity data for carpenters (14).

The findings of this research were tabulated in a way that permits comparison between 1930 and 1965 labour requirements for a given activity. All activities required substantially less time in 1965 than in 1930 averaging 66.2% lower, mainly because of mechanization and prefabricating many components. The report also showed that over the 35-year period, labour productivity for the integrated crew grew at a compounded annual rate of 3.2% per annum. Over the same period, hourly money wage rates, indluding fringes increased by 4.7% per annum for the same crew. Consequently, the unit labour cost related to the portion of the single-family dwelling dealt with in this research grew at 1.5% per annum.

This research work indicates the possibility of measuring and comparing labour productivity in construction. It is recommended that further studies cover all sectors of the construction industry, and the resultant productivity indices be published quarterly.

PRODUCTIVITY INDICATORS

Suggested format for our productivity indicators would be as follows (15):

1. Total Factor Productivity (TFP): The measure which was made popular and used most extensively by John Kendrick. It represents the productive nature of the total firm.

$$TFP = \frac{\text{Total Output of Firm}}{\text{Total Inputs}}$$

   When the total output for a construction firm could represent the total sq. ft. of built area for the year. And the inputs would include the productive resources used in the production of the product. These inputs will include labour, fuel, capital, etc...

   A comparison of TFP's for different years indicates changes in overall productivity.

2. Partial Factor Productivity (PFP):

Considers productivity solely in terms of one or a limited number of inputs.

$$PFP = \frac{\text{Total Output}}{\text{One Input}}$$

Where input could be: manhours, administrative personnel, fuel consumption, dollar, equipment, etc. . .

3. Unit Cost:

$$UC = \frac{\text{Total Cost}}{\text{Total Output}}$$

4. Input-Operating Expense Ratios:

$$IOC = \frac{\text{Cost of One Input}}{\text{Operating Expenses}}$$

Where a decrease in this factor would indicate an increase in productivity.

5. Production Function Coefficient:

Relate the level of service provided to the quantity of input factors (labour, fuel, capital, etc..) used to produce it. A convenient production function form is the Cobb-Douglas production function.

$$Q = A\,L^{b1}\,K^{b2}\,F^{b3}\,C^{u}$$

Q = Quantity (say sq. ft. of built space)
L = Labour Input (say Manhours)
K = Capital Input
F = Fuel Input
A = Constant
C^u = The Stochestic or random error of production.

$b_1\ b_2\ b_3 =$ The elasticity coefficients (i.e. an indication of the percent increase of output if the input increases by 1%).

This function can be estimated with regular regression techniques, and the coefficients of the production function (i.e. the numbers which indicate the relationship between the inputs and outputs) would provide information on the productive nature of the venture. The sum of the input coefficients of the Cobb-Douglas function will indicate whether increasing returns to scale or decreasing returns to scale exist in the relevant range of output. Coefficients could be estimated over time for single companies and then compared with those of other companies to indicate their relative productivity. Or coefficients could be estimated across several firms in one year and then compared for a similar cross-sectional group in another year. This would indicate the productive improvement of the industry over time.

CHAPTER V

IMPROVEMENT TECHNIQUES

Improving productivity can be achieved by fulfilling the following conditions:

1. Defining productivity and locating the factors affecting it.
2. Maintaining standard measurement techniques.
3. Applying improvement techniques whenever possible.
4. Achieving complete cooperation between Government, Management and Unions.

Items 1, 2 and 3 can be achieved through concentrated studies, research and perseverance. Yet the main problem appears to be that of achieving complete cooperation between the parties involved, as it requires changing attitudes, habits and mentalities. Also politics and the power game is responsible for limiting this cooperation.

In this chapter, some of the suggested improvement techniques shall be discussed briefly in an attempt to achieve maximum coverage.

A. LABOUR RELATED IMPROVEMENTS

1. Performance Incentives:

   The introduction of performance incentives for workers producing more than a given output, should replace the prevailing performance restrictions.

   The positive effects of performance incentives are:

   a. Direct improvement of productivity
   b. Act as a motivator
   c. Fulfill the sense of achievement
   d. Increase the workers' income
   e. Will result in creative competition producing new talents
   f. Accelerate the learning process

2. Multiskill Training:

   Multiskill training is a practice that has so far been resisted by the unions, yet it appears that it could be a highly rewarding practice, specially in smaller jobs.

   Present construction costs leaves this option worth serious consideration.

3. Elimination of Featherbedding:

   Featherbedding affects productivity negatively and its elimination can only have a positive effect.

4. Increased Technical Training:

Workers should be encouraged to attend periodically held sessions to improve their skills, and introduce them to the latest technical advancements.

B. MANAGEMENT RELATED IMPROVEMENT TECHNIQUES

1. Motivation:

Motivation of the construction workers can have immediate positive results on a project's productivity. For maximum effect the mechanism of these needs should be fully understood by management. This mechanism is discussed below and is complimentary to the discussion started in Chapter III on Abraham Maslow's Hierarchy of Needs.

a. Physiological Needs:

Food, liquids, rest, exercise, shelter and protection. These needs are at a low scale of importance in construction now as construction workers' present salaries can satisfy these needs. It has to be noted though that lack of money can be a negative motivator (dissatisfier).

b. Safety Needs:

Once physiological needs are satisfied, safety needs arise. These needs are often collectively referred to as security.

c. Social Needs:

The desire to become a member of a group. It was proved by experiment (performed by Van Zelst) that by allowing the men to choose their work partners, turnover was reduced, and productivity was improved.

d. Ego Needs:

A workman often finds satisfaction for his ego needs in competition, praise or status. This is often stymied by union working rules which limit output. However, some men continue to do more than the minimum acceptable standard, because they get satisfaction from the knowledge they are doing a little more than the next man. A bit of supervisory praise to these men can be very effective. It is also advisable to increase their decision making scope.

e. Self-Fulfillment Needs:

The last need in the hierarchy of needs is the need to work at a job which one enjoys and is capable of performing. The fulfillment of this need is a rare phenomenon in our society. Yet recognition of this need has saved many good workmen from rising to a level of incompetence.

The following motivation techniques are recommended.

1. Provide leader construction managers and foremen as opposed to pushers.

2. The desire by some of the workers to attract favourable attention should be rewarded when it leads to increased productivity.

3. The worker with a reputation of being a hard worker has usually the most security between his group.

4. The workers should have a bigger feeling of participating in the decision making.

5. Teaching construction managers, engineers and foremen to appreciate the work done by subordinates. It is of great importance for a worker to feel he is doing important work. As a matter of fact any kind of work being done no matter how small it is, is important, otherwise it would not be done at the first place. This appreciation when demonstrated could be very rewarding productivity wise.

6. Holding information meetings to brief all the workers on the latest status of the job and the interface between different trades.

Finally it has to be mentioned that a potential return is expected on money invested in properly conceived and administered motivation programmes for construction workers.

2. Education:

It is time for the construction industry to recognize the importance of education, this industry can no longer afford to shun the educated under the pretext of lack of experience. Experience only might do the job, but at what cost? As shown in the chapter of factors affecting productivity, management has a big share in affecting productivity, and specialized education for managerial personnel can certainly help the productivity problem.

It is not true that training a new graduate engineer or encouraging personnel to attend evening courses is an overhead that most construction firms cannot afford. The construction industry will have to accept the fact that survival is dependent on improvement and innovation.

The question is no longer who can do a given construction project, it is at what cost and how fast.

Good planning and management is now a must.

A typical example that demonstrates this need is a huge Federal Government project in downtown Montreal where the construction manager has no educational background. His qualifications do not include the capacity of reading graphs, let alone CPM, forecasting or risk analysis. Yet his responsibilities included supervising several graduate engineers. The resulting cost overruns and delays of this still ongoing project are to say the least, excessive.

3. Better Management:

The most common practice from weak management is failure to provide adequate instructions, thus leading to enormous waist of time with the success of the work depending not on how well it was done, but on how well the worker guessed his supervisors intentions. This is a wide spread practice because supervisors can always claim they never suggested this at the first place, thus saving their own skin. But at what cost?

This practice should be eliminated or at least reduced, by choosing well qualified personnel and giving them enough authority and security in case of justified wrong decisions.

4. Methods Improvement:

Construction operations have many repetitive work cycles and repetitive work lends itself to methods improvement. While it is true that no two construction jobs are the same, it is also true that the same basic operations make up a large part of the tasks of the craftsmen or equipment operators from job to job.

Poor utilization of labour is a principal reason for low productivity and is in many cases a fault of management.

Good management will provide complete instructions, materials, tools, equipment and a reasonable environment, and inspection, besides motivation.

5. Formalized Techniques of Analysis for Improving Labour Performance:

Graphical analysis procedures and mathematical models in addition to being a method of recording, are also a means of communication. They are useful tools for analyzing methods currently being employed and for developing new ones, some of these techniques are discussed below.

a. Crew-Balance Chart:

This is an effective way of showing the interrelationships between the work of individual members of a crew and its equipment (9). In form the Crew-Balance Chart is a vertical bar chart that has an ordinate of time or percentage of total time and an abscissa that labels each vertical bar according to the separate elements being studied. The bar for each man or machine is sub-divided vertically into the various types and sequences of activity including non-productive time. Since each element of the crew being observed is plotted to the same time scale, the interrelationship of the various elements of the crew can be seen by comparing the activities along a horizontal line on the chart. Such a graphical portrayal allows the comparison of sequences to reduce idle time. Fig. (7)

Crew-balance charts: analysis of concrete placement in a column.

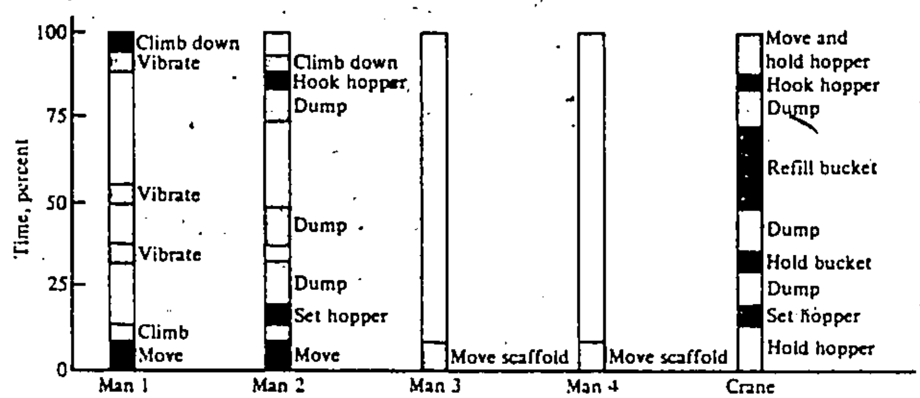


fig. (7) Ref. (9)

b. Flow Diagrams and Process Charts:

Basically the flow diagram is a line sketch showing the interrelations and movement of things, while the accompanying process chart is a chronalogical, itemized description of the various steps.

The purpose of such a technique is to help indicate where time, effort, and money are lost because of ineffective methods and movements of material.

For complete details of this method refer to "Methods Improvement for Construction Managers". (9)

c. CPM & PERT Scheduling Techniques:

These techniques have a direct bearing on improving productivity and eliminating many costly interferences and delays through advanced planning.

It is disturbing to see that while management is complaining from low productivity, yet such an improvement technique is resisted by the pretext of being too complex, or too expensive. As for being too complex, construction has become complex and those who cannot cope with its complexity will have either to learn to, or depend on the guidance of those who can. As for being too expensive, that also is not valid reasoning, as the savings through improved productivity will by far outweigh the expenses.

CPM & PERT Scheduling Techniques provide the construction manager with a unique control on the construction site activities; it guides his decisions and provides him with a means of performing a sensitivity analysis. Thus properly used, both idle time, and unnecessary overtime are reduced to the benefit of the overall productivity of the construction site.

It has to be noted though that much of the complaints about these methods are mainly due to incorrect application rather than the techniques themselves.

d. Risk Analysis:

Formalized risk analysis techniques such as the decision tree, or others, transform the decision making process from guess work to scientific analysis based on the valid laws of probability. This process guarantees right decisions for the majority of a multi-decision making process. These techniques can provide productivity gains through ensuring realistic manpower loading calendars, and resource allocations.

e. Simulation:

Simulation is the term generally given to mathematical representation that take random samples from a probability distribution curve in order to simulate a real-life situation.

The basic concept underlying simulation is that the times required to carry out the individual steps that make up construction operations are not constant; rather these times are distributed over a range of values falling in some fashion on either side of a mean value. Both the mean time and the distribution of individual times must be statistically defined so that they fit the real on-the-job situation to the extent that it is known or oan be estimated. It is then assumed that the time interval required to carry out this particular step in a specific construction sequence is determined purely by chance. By selecting a number at random, and using the cumulative distribution curve, the value of the specific time interval is then determined. Although this specific time is determined by chance, the mean and distribution of an infinite number of values determined by the random-number process will fit the originally stipulated mean and distribution.

The simulation process itself is a step-by-step reconstruction of the end-to-end sequences that make up a production scheme. Starting at time zero, which might be beginning of a shift, the situation at each succeeding point in time at which a change occurs is appraised. At the end of a stated time period (shift) the simulation is stopped and the outcome determined.

The limitations of simulation programs are:

i. Inspite of the fact that they attempt to simulate real life situations, they are restricted by the parameters established by the program writer.

ii. Although simulation programs can be extremely reliable for comparing alternatives, such as examining the productivity of two proposed systems, yet their accuracy at predicting actual output or actual costs for a particular system may be limited by the accuracy of the input data and the length of the computer run.

C. DESIGN RELATED IMPROVEMENTS

1. Field Training for Design Personnel:

Periodical field assignments and practical training will result in designs that reflect awareness of existing field construction conditions. Presently, most designs reflect an optimization of one resource (such as steel for a structural engineer). This kind of single resource optimization could be deceiving as it could lead to unoptimized usage of several other resources when it comes to field construction.

2. Improving the Finished Product Quality:

Drawings and sketches should be clear, with all the revisions indicated clearly to minimize costly errors and rework due to misinterpretations.

D. OPTIMIZING HUMAN CAPACITIES

Human capacities should be optimized such that workers should not be exploited, nor should a worker be left with half a man's workload.

E. GOVERNMENT RELATED IMPROVEMENTS

1. Regulations:

   Should be kept to a minimum, with a permanent government body responsible of continuously checking these regulations to prevent duplications and eliminate outdated standards.

2. Improving Labour Management Relations:

   Government should interfere quickly to force settlements when it appears that long strikes are inevitable. It is the author's belief that a good binding arbitration system would serve this purpose.

F. GENERAL IMPROVEMENTS

1. Feasibility Studies:

   A feasibility study that includes resources besides profitability can help foresee unexpected problems and plan for them ahead of time.

2. Public Interface:

A public interface study at the feasibility study stage could enlist the support of the public, thus avoiding the possibility of work stoppages due to public resistance.

3. General Conditions:

The general conditions such as site location, project size, availability of skilled workers near the site etc., differ from site to site, yet these conditions should be studied for each site individually and their effects predetermined before construction starts.

CHAPTER VI

CONCLUSIONS

In the preceding chapters the productivity problem in the construction industry has been broadly covered.

Having identified the major factors, and the suggested measurement and improvement techniques, the way is now clear for further in depth studies each focusing on one of the factors, covering its effects on productivity and setting standard measurement and improvement techniques. My recommendations at the termination of this preliminary study are included in this final chapter; some are based on proven studies, some are personal convictions based on experience, while others are self-evident recommendations. Yet the apparent difficulty of applying these recommendations does not deny their usefulness.

A. Pressure has to be exerted on the involved parties, especially government, to get the required task force study started. This preliminary study has proved the feasibility of such a study.

B. Productivity indices have to be established without delay and published monthly or quarterly, thus allowing for seasonal adjustments. These suggested indices would be the final output resulting from a trade by trade index for each construction division (residential, commercial, industrial, etc...) thus providing an index for each of the macro and micro levels. These indices could be the previously described TOTAL FACTOR PRODUCTIVITY, PARTIAL FACTOR PRODUCTIVITY, UNIT COSTS, INPUT-OPERATING EXPENSE RATIO, PRODUCTION FUNCTION COEFFICIENTS.

C. Completing these studies and setting the indices is only part of the task, the remaining part is more difficult and not easily controlled, this remaining part will have to deal with management attitudes.

All these studies and indices are meant to serve management and can only be effective if management can make use of them. Productivity is mainly a management problem, so management will have to deal with it instead of blaming labour. Once effective labour relations are achieved, and strikes are reduced, management will have no excuse. We can no longer look at construction as an art, construction should be looked upon as a science. More education should be provided for all construction personnel at all levels. Good construction workers should not be promoted to the level of incompetence, financial reward is the alternative.

It is saddening to see that up to date, only a few big construction firms are using modern management techniques (maybe they are the only ones who can afford the switch), yet these firms are growing fast, and in the process, the leftover firms can only expect to be forced out of business. Training young engineers and technicians and providing more education and training for present personnel can no longer be considered as an unaffordable overhead, because it is a must for survival.

D. The parallel change will have to come from the trade unions, these unions will have to divert their attention from politics to their original task of promoting the interests of the trade and its workers. So far the so called pressure tactics applied by the unions have proved to be a failure, with their negative effects reflected not only on the taxpayer or the employers, but also on the workers who are supposed to be beneficiaries of these pressure tactics.

E. The present negotiating process often fails and it has to be modified. The taxpayers (users) have been drained to the maximum by the present negotiating system. Strikes should have time limits or abolished completely. If negotiations failed within a given time limit, it has to be replaced by binding arbitration and agreement enforced by legislation.

F. A productivity bargaining strategy should be applied, where restrictive work practices are identified and eliminated or modified, replacing these with improved work methods and practices in return for substantial improvement in pay and/or working conditions. These improvements should be linked directly to the gains in productivity.

G. Construction contracts should be clear and void of ambiguities, defining expected risks which are to be properly shared in a known manner by Owner, Engineer and Contractor, also efficiently handling changes.

H. Government regulations should be kept to a minimum and systematically updated.

Finally, improving productivity in the construction industry is not a lost case, on the contrary, with some dedication, hard work and perseverance, it looks like a promising one. There are several fronts on which direct gains could be achieved, besides what has already been achieved by individuals working on this subject, what is presently needed is an organized task force to continue the thrust for measurable improvement.

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