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by Steve Revay

I have often heard it mentioned, at times even by contractors, that every contractor ought to — or perhaps does — make provisions in his planning and tender price to accommodate a certain percentage of extra work, while not entitled to — or even requiring — any compensation in the duration or in the cost of the contract. This magic threshold, expressed in monetary terms, is said to vary between five and ten percent. The implication of such a totally unsupportable allegation has always bothered me, particularly when used to deny an otherwise valid impact cost claim.

The plain fact is that it takes additional time to perform additional work, albeit not necessarily in a straight-line proportion. Similarly, changes in the original scope can and usually do create disruptions in the momentum and perhaps in the sequence of the orderly performance of the contract. Simply stated, changes more often than not give rise to impact costs.

The quantification of such impact costs was the subject of a previous issue of the Revay Report. That article recommended the use of the "differential method" of cost calculation, calling it the "classical" method of quantification. Unfortunately, this differential method has its shortcomings, such as, it can be performed only after the operation in question has been completed, and even then, only if adequate cost and progress records were kept during its performance. Most owners insist on knowing the cost impact of contemplated changes prior to authorizing their performance, and are reluctant to proceed under a quasi-cost-reimbursable arrangement, while an after-the-fact impact cost calculation may easily end up being such. Notwithstanding this dilemma, until now no one has shown any interest in finding a practical solution. The lead article of this issue, in my opinion, takes a significant step in the right direction, by introducing the result of an extensive investigation carried out by Charles Leonard, one of our engineers, who developed a statistical relationship between the labour content of change orders and the resulting productivity loss.

Charles spent almost two years on this study, which is considerable in anyone's lifetime. More importantly, however, if counting the total time spent on this analysis, i.e., by including the time spent on research while preparing the original claims, the enclosed results represent eighteen man-years of work. The article is an abbreviated version of Charles's thesis, submitted as a partial fulfillment of the requirements towards a master's degree in construction management.

RAL President

THE EFFECT OF CHANGE ORDERS ON PRODUCTIVITY

by Charles A. Leonard

Contractors have been telling architects and engineers for a long time now to stop making untimely changes unless they are prepared to face consequences. In fact, more and more quotations submitted in response to the notice of a contemplated change contain qualification, reserving the trade contractor's right to make a claim for impact cost, if and when it can be determined. These qualifications, and impact cost claims in general, often give rise to heated arguments and indignant refusal on the part of those receiving them. Impact cost claims, or more particularly those for loss of productivity resulting from untimely and/or frequent changes, are considered by many, even today, as a means of getting compensation for either a bad bid or inefficient performance.

That stubborn reluctance in accepting that change orders can and usually do give rise to lost productivity, and therefore increased costs, may never be totally extinguished; nevertheless this article, it is hoped, will help those who are interested in the facts and are prepared to look at the construction process as it is, and not the way they believe it ought to be.

This article introduces the results of an extensive statistical analysis looking at the relationship between change orders and productivity loss. As any such analysis, this one also yields averages; accordingly, there will be situations resulting in either higher or lower values of lost productivity (if eventually quantified, using the differential method of calculation) than might be estimated using the enclosed charts. It is believed, nevertheless, that such deviations are no more pronounced than one may experience using other industry-wide statistics which are commonly used to estimate loss of productivity for: overtime, overmanning, congestion of trades, remobilization, and adverse weather. There are, however, no published productivity studies relating to change orders. In fact, there has been no study, empirical or otherwise, dealing specifically with change order impact. Accordingly, this investigation was undertaken in order to examine both the qualitative and quantitative effects of change orders on productivity. Qualitative analysis dealt with the reasons for and the sources of productivity losses and was an essential prerequisite for understanding the results. The relationship between loss of productivity and change orders was examined statistically in the quantitative analysis, with a view to developing models which could be used to estimate loss of productivity.

Information for this investigation, and the ensuing statistical analysis, was obtained from prior claims (prepared by RAL on behalf of contractors) or claim evaluations (carried out on behalf of owners), and from expert reports (prepared for presentation either in courts or in arbitration).

(Cont'd)

ROUTE TO/OR FILE:	

THE EFFECT OF CHANGE ORDERS *(cont'd)*

Methodology

Ninety cases (i.e., files worked on by RAL) were selected, representing contracts where the contractor had experienced productivity losses as a result of change orders. In total, the value of these cases was in excess of $220,000,000 and over 7,000,000 labour-hours were spent performing the work. These contracts were carried out on 57 independent projects, comprising different types of buildings and industrial facilities, ranging in value from a few million dollars to several hundred million dollars. For the purpose of this study, the cases were categorized according to the type of work as follows:

1) Electrical/mechanical contracts (i.e., "fine" motor skills) on building and industrial construction.
2) Civil/architectural contracts (i.e., "gross" motor skills) on building and industrial construction.

With a view to arriving at a reliable statistical relationship between change orders and loss of productivity, it was necessary to ensure that all causes of productivity loss were taken into consideration. Accordingly, all of the evaluations included in the case files, such as period-by-period and cumulative productivity analyses, comparisons of as-planned and as-built schedules, manpower histograms, and physical progress curves, were examined to identify and assess potential causes. For the purpose of the quantitative analysis, only major causes of productivity loss were considered, such as inadequate coordination or scheduling, acceleration, and changes in sequence or complexity.

Change orders were measured as a percentage of the total labour-hours spent carrying out changed work to the labour-hours spent on the original contract work, (referred to hereinafter as "percentage change orders"). Similarly, loss of productivity is expressed as a percentage of the unproductive labour-hours to the labour-hours spent on the original contract work (hereinafter, "percentage loss of productivity"). To account for any contractor underestimating or inefficiency which may not have been recognized in the claim submissions, productivity losses were reassessed as part of this study using the differential method of cost calculation where possible or, alternatively, by comparing the contractor's tender with those of other bidders, and adjusting the contractor's estimate accordingly.

Qualitative Results

In the cases examined, the most frequently encountered impacts of the individual change orders were disruptions and delays. In general, disruptions occurred when workers were prematurely moved from one task to another, which delayed completion of a portion of the affected activity and frequently the commencement of succeeding activities. The extent of the delay caused by change orders was dependent on the time taken to issue the required instructions (e.g., clarifications) and authorization to proceed, and the time required to organize for and carry out the work included in the change order. Disruptions and delays caused by individual change orders were found to directly reduce productivity on the affected activities due to: the unproductive time inherent in the stop-and-go operations, the performance of work out-of-sequence, and the loss due to the need of repeating the learning cycle. Due to the interdependency of construction operations, change orders also had a ripple-effect on the productivity of activities otherwise unaffected by the changes.

In approximately 65% of the cases examined, change orders were found to have a cumulative impact on the performance of the work. Generally, delays and disruptions caused by change orders were found to bring about gradual deterioration of the contractor's planning and scheduling. Orderly sequences of operations were divided into several, perhaps isolated, activities completed in piecemeal fashion over an extended period. In such instances, productivity was further reduced due to: loss in productive job rhythm, demotivation of work force, unbalanced crews, excessive fluctuations in manpower levels, lack of engineering and management support, and acceleration (when equitable time extensions were not granted).

In the cases examined, productivity losses resulting from change orders were experienced mainly during later periods of the job when the majority of change order work was carried out and when the delayed or disrupted activities were being completed. In the majority of the cases examined, contractual duration was extended significantly (up to doubling the as-planned duration). This was true even on jobs which were accelerated, albeit to a lesser extent.

Quantitative Results

Data on loss of productivity and change orders was analyzed by regression techniques (i.e., method of least squares), using a commercially available software package. The results indicate a significant direct correlation between percentage loss of productivity and percentage change orders. Cases on which change orders were the only major cause of productivity loss yielded coefficients of correlations of 0.88 and 0.82 for electrical/mechanical work and civil/architectural work, respectively. Coefficients of correlations decreased slightly to 0.76 and 0.74 for electrical/mechanical work and civil/architectural work, respectively, when one additional major cause of productivity loss was present because of the varying effects that such causes have on productivity. The coefficients of correlation decreased dramatically when the percentage of change orders dropped below ten; therefore, those results were discarded and the use of the curves is not recommended in that range, even through extrapolation.

As can be seen on Figures 1 and 2, change orders have a significant effect on productivity. For example, 25% change orders, with no other major causes of productivity loss, decrease productivity by 20% on electrical/mechanical work and by 17% on civil/architectural work. At 50% change orders, productivity decreases by 23% on civil/architectural work and, by a greater amount, 31% on electrical/mechanical work.

As expected, additional major causes of productivity loss were found to have a cumulative negative effect, which was relatively constant over the range of change orders examined. Productivity losses for electrical/mechanical work were increasing by 11% to 14% with one additional major cause, and by 20% to 24% with more than one such cause. For civil/architectural work, one additional major cause increases loss of productivity by 7% to 8%. Although no data existed for more than one major cause of productivity loss on civil/architectural work, productivity losses in such cases would be expected to increase by 14%, based on extrapolation.

Application of Quantitative Results

As previously mentioned, productivity losses are best quantified using the differential method of cost calculation because it compares the level of productivity actually achieved by the contractor during a normal unimpacted period with that of the impacted period on the same job. Such a calculation, however, requires accurate data on labour-hour expenditure and physical progress. In practice, many contractors do not maintain adequate records for such a calculation. Similarly, on severely delayed and disrupted projects, a representative normal period may not exist. In fact, differential cost calculations were not possible for those reasons in more than 60% of the cases examined.

Consequently, it is often necessary to

estimate loss of productivity using industry averages, such as the models shown in Figures 1 and 2. More importantly, the "front end" (i.e., before-the-fact) determination is possible only through the use of such statistics.

To use these models, two measures have to be determined:

1) total actual hours of the change order work, and,
2) combined total hours spent by the contractor on both the changed and original contract work.

From the total actual hours, actual contract hours are calculated by subtracting change order hours and any unproductive hours attributable to contractor's inefficiencies or underestimating. Percentage of change orders is then calculated by dividing change order hours by actual contract hours and multiplying the result by 100%. Percentage loss of productivity on the original contract work can then be read out directly from the appropriate model according to the number of additional major causes of productivity loss. The amount of unproductive hours on the original contract work is calculated by multiplying percentage loss of productivity by actual contract hours and dividing by 100%.

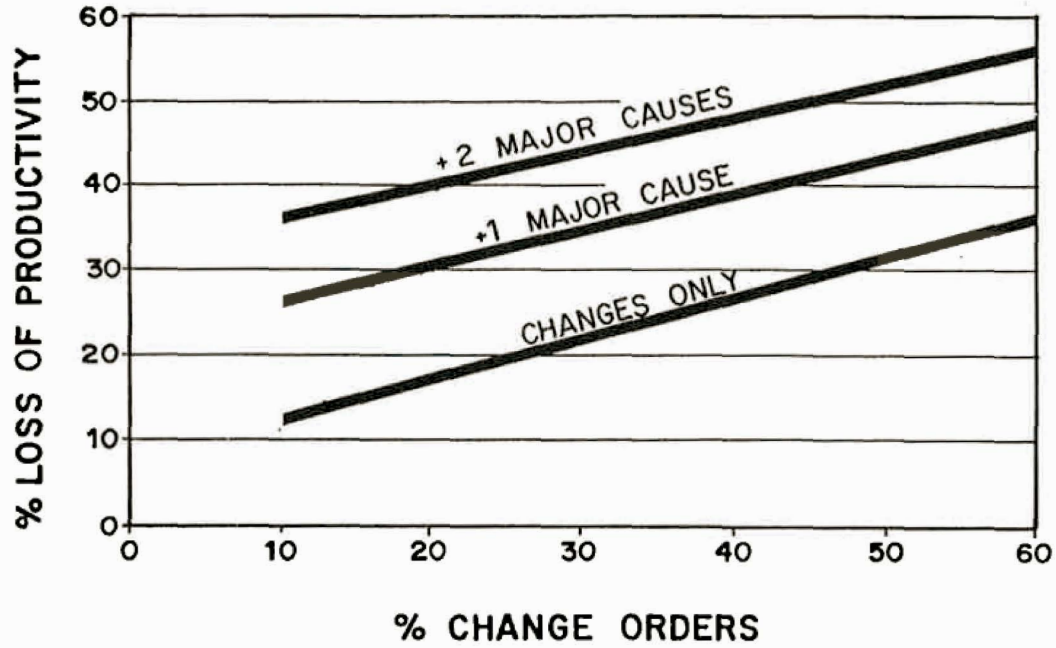

FIGURE 1 ELECTRICAL AND MECHANICAL WORK

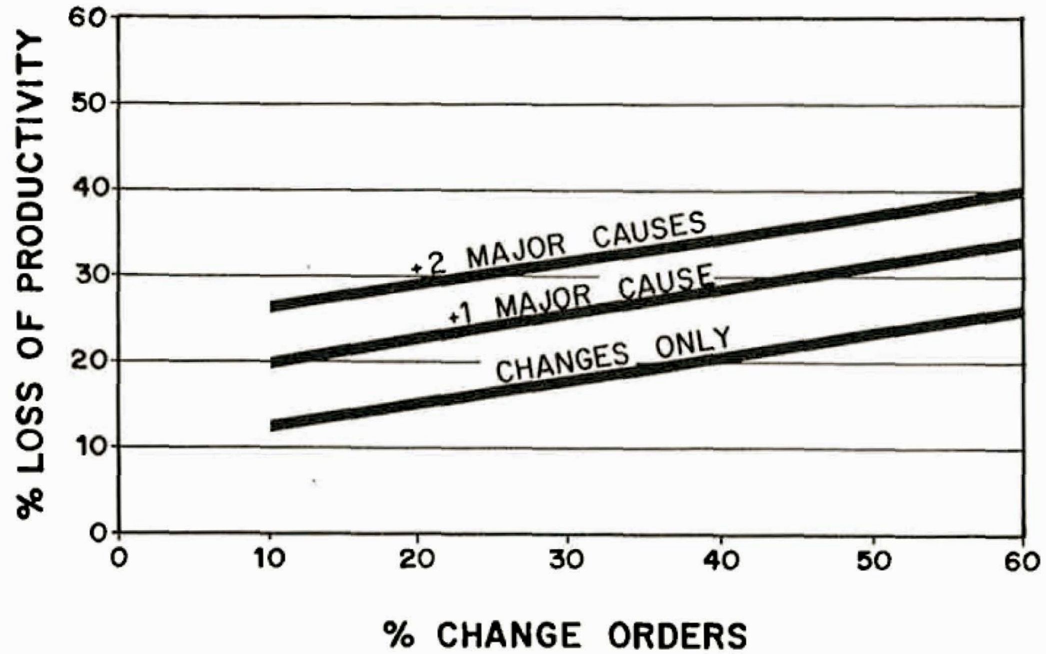

FIGURE 2 CIVIL AND ARCHITECTURAL WORK

C.C.I.S. USERS' NEEDS SURVEY CONDUCTED BY RAL

Canadian Construction Information Services Limited (CCIS) was incorporated in August, 1986, sponsored jointly by the National Research Council Canada, Descon International Ltd. and Southam Communications Limited. The new company was formed to develop and provide a common medium for a very comprehensive information system and communications tool for the users and providers of construction data. NRC's participation is through its Industrial Research Assistance Program.

CCIS contemplates acting in a "broker" capacity for the quick delivery of up-to-date data. Emphasis is placed on the use of electronic on-line and on-disk databases on a very "user friendly" basis. An important component is a "people network" whereby users would be electronically provided with the names and phone numbers of those with special expertise in a wide variety of subjects. This service would recognize the widespread practice in the industry of making direct contacts with knowledgeable people, rather than indulging in researching a subject through publications. Printed sources of information — e.g., catalogues — would also be included in the overall service.

Another feature of the CCIS system is its ability to transmit construction drawings and other graphics with a high degree of resolution. This recognizes another fact-of-life in the construction process — i.e., that people "read" drawings more than texts.

A series of detailed "Users' Needs" interviews was commissioned by CCIS as part of its concept research and consultative program. It so happened that RAL and IRAD Corporation had submitted a proposal to the Canadian Government in late 1985 that practitioners in the construction sector be interviewed to assist in the development of a "specification" as to the contents and nature of a computerized linked datasource. Such a specification would also provide guidelines to the suppliers of future construction databases designed to facilitate easier access by users.

This proposal had evolved from:

- national surveys conducted by RAL on Construction RD&D and on a proposed National Construction Materials Evaluation Service, both of which indicated the scope for electronic dissemination of technical information.
- emphasis placed by the National Research Council and by participants in Canadian Construction Research Board regional meetings on the need for more effective Technology Transfer.
- the realization that much of the information covering a wide variety of business and technical needs received by construction practitioners in print form had originally been prepared on a computer or word processor and therefore could be transmitted electronically.

The proposed activities were in concert with those which, by coincidence, were being developed by the sponsors of the CCIS. They were incorporated in the overall CCIS project in September 1986.

One hundred interviews were conducted — firstly with 16 experts in the fields of information science and construction information; then with national associations based in Ottawa; next at the "Building Tomorrow" Conference in Toronto; and then in practitioners' offices in Halifax, Montreal, Ottawa, Toronto, Winnipeg, Calgary and Vancouver.

Very few industry practitioners in Canada are now using their computers as a communications tool — i.e., by going on-line. It was therefore deemed to be essential to whet their imagination by demonstrating how simple, portable computer equipment, requiring only a power source, a telephone connection, and a few commands on the keyboard, can call up information on demand. A sampling of data now available, or soon to become available, was compiled, including portions of the National Building Code, National Master Specification, building project reports, credit information, product literature, graphics and association bulletins. Also, speedy access to technical information sources in Canada, the United States and Europe was demonstrated.

Detailed questioning on the present sources of essential information and "wish lists" took place with a sampling of designers, contractors, association leaders, suppliers, educators, owners etc. The interviews were interactive; the practitioners being specifically asked to help to design a system which in turn would be helpful to them.

Interview reports and a 187-page summary report were prepared on the survey's findings. Subsequently, CCIS sponsored a series of "focus group" sessions and a comprehensive market research project. The company plans to complete a "Demo" early in 1988 to show its proposed wares and to have its Directory available towards the end of the year.

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