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Canadian research and development in construction: a question of survival

by Steve Revay

Construction is often referred to as the *"Balance Wheel of the Economy"*. The total construction program is somewhat in excess of $100 billion (1990 figure) and it represents upwards of 15 percent of Canada's gross national product.

The importance of the industry is not determined only by its size, however, but by the impact of its products on Canada's economy. Construction produces those products which allow us to feed, clothe and shelter ourselves: the factories where our goods are manufactured; the structures where our harvests are stored and processed. The products of construction are roads, railroads, waterways, power plants, factories and communication facilities. Construction influences, if not controls, the competitiveness of many Canadian industries; accordingly, the industry's level of efficiency ought to be of national concern.

Construction, nevertheless, is far behind all other industries when it comes to research and development. Moreover, even what is being done is slow in reaching the practitioners engaged in design, building and operation of the industry's products.

According to some, that is why, during the last fifteen years, productivity in the construction industry has been declining at a significant rate. Simply stated, the buyers of construction services may no longer be getting their money's worth.

There is, unfortunately, little agreement among those involved either on the degree of deterioration or the reasons for it. In fact, there is little agreement whether the available statistics are at all reliable.

Construction is highly fragmented, both geographically and according to its products. Practitioners of the industry are as different from one another — in their activities, their interests and their organization — as day and night. For example, less than 55 percent of the total construction activity is "contract construction", executed by contractors and subcontractors. Out of more than 60,000 contractors in Canada, nearly sixty-five percent employ fewer than five people each. Construction is in a constant state of confrontation. It is the only industry where design and implementation are separated one from the other, and those engaged in design have significantly different interests and motivation than those responsible for the on-site construction.

Is it a wonder then that no coherent policy has been developed so far with respect to research and development for the construction industry?

There is a general consensus by most involved in the industry that Canada proportionately spends less on construction R & D than any other industrialized nation. However, there is a general disagreement on the consequences. Is our R & D expenditure too little, just about enough, or too much? Depending on the respondents affiliation the answer may be totally different.

For a long time the construction industry lived under the impression that it had a captive market: houses, schools, hospitals, etc. had to be built, and they were going to be built regardless of their cost; roads, railroads, bridges, etc. had to be constructed and maintained to facilitate traffic between neighbouring communities. It was believed that as long as the population increased there would be a growth in the volume of construction, and the competition for that volume would be governed by the relative entrepreneurial spirit, desire and ingenuity of individual contractors.

Contractors have often been heard to say, "As long as we are as aggressive and efficient as our usual competitors we will always get our share of the work".

Today, being as efficient as one's neighbour is not sufficient. Competition is no longer limited to contractors working in a well-defined geographical area. The available work is being sought by firms from other parts of the country — or of the globe. Similarly, construction work is not reserved for the traditional contractor. Many past buyers of construction services now tend to do more and more work "in-house". Is the Canadian construction industry pricing itself out of the market altogether? If the cost of building a factory in one region — or in Canada in general — is too expensive, then manufacturers might move elsewhere, and instead ship the finished products back. Such dislocation of the manufacturing process can increase unemployment, and perhaps even inflation — or at the very least reduce tax revenue. This, in turn, would cut the public works' budget, thereby reducing the volume of construction. But is this a real danger?

How do we measure competitiveness?

Measuring competitiveness in the usual way, that is by comparing one contractor against another, (as is done through the tendering process) one measures micro productivity only. This type of competitiveness is governed more by management techniques and the skill of the available tradesmen than by technology. It is true that introducing an ingenious and heretofore unseen method of proceeding, or the use of a new and more cost-effective equipment, can and will yield competitive edge. However, the so-gained advantage will be short-lived, probably limited to a single job. Moreover, here we are not measuring the cost-effectiveness of the product but simply judging the efficiency of the employed resources, i.e. labour and construction equipment.

The real competitiveness should, of course, be measured by comparing the prices of the products, always assuring that we are comparing similar (i.e. like) quality merchandise. Where applicable, we should be comparing the life cycle cost of one facility or structure with another. Simply stated, we ought to be measuring not only the cost of the facility, but also judging its usefulness for the purpose it is intended and the efficiency of its performance. Only in this way can we gauge the impact of construction on Canada's overall competitiveness.

In a statement before the Subcommittee on Science, Research and Technology of the U.S. House of Representatives Richard N. Wright, made the following statements:

"Competitiveness has three dimensions:

- Competitiveness with other opportunities for investments in the U.S. economy, and therefore, the ability of the U.S. built environment to support the Nation's productivity and quality of life.

- Competitiveness with foreign goods and services in the U.S. construction market.

- Competitiveness with foreign goods and services in foreign construction markets.

Problems are evident. The U.S. construction industry is losing ground on each of these fronts...

Construction, in this context, is considered to include the whole life of the project: initial planning and programming, design, manufacturing and site construction, occupancy and maintenance and renovation or removal. This whole life viewpoint is necessary to give realistic attention to values and costs of constructed facilities. For instance, for an office building, the annual operating cost, including salaries of occupants, roughly equals the initial construction cost. The primary value of the construction industry comes from the productivity of the occupants, which depends on the fitness to use of the building."

It is contended that the Canadian construction industry is less competitive than that of our southern neighbour and if the U.S. House of Representatives is concerned, then we should be too.

Today, there is a profound realignment of world political and economic interests. The principles of private enterprise are sweeping through Eastern Europe including the former U.S.S.R. The U.S.-Canadian Free Trade Agreement, the negotiations of the North American Free Trade Agreement, the European Communities Single Market Initiative, the recent negotiations in Latin America to remove trade barriers on a regional basis and the new ASEAN Pacific economic cooperation efforts are all putting tremendous pressures on Canadian industries, construction included, while providing opportunities for those among us who are prepared to take up the challenge.

A critical component of our efforts towards improved competitiveness is research and development. New technology historically has been responsible for a significant share of economic growth. Adoption of new and more cost-effective technology enables us to be more productive thus providing better climate for foreign investment. At the same time, technological innovations should make us more competitive with respect to foreign goods and services at home as well as abroad.

Technology has been defined and others) as — "society's pool of knowledge regarding the industrial arts". Research and development contribute to this "pool of knowledge". The state of technology at any given time controls "what", and "how cost-effectively", we can produce with existing resources. In simplistic terms, it can be said that, better (i.e. more advanced) technology will produce more competitive products.

Increased R & D efforts v. competitiveness

This one-to-one relationship, however, does not apply to construction and could be misleading in general.

It is true that Canada proportionately spends less on construction R&D than any other industrialized nation. However, knowledge does not recognize national boundaries and the Canadian construction industry can and does benefit from the R&D of others, such as the U.S.A., Japan, U.K., etc...

One should also realize that construction benefits from the research and development efforts of other industries. Many of the technological innovations, which to some extent revolutionized construction, were not the result of formal research and development. The use of structural steel and steel reinforced concrete, as a structural system for buildings and bridges, was almost entirely the result of the invention of the Bessemer process of steelmaking, and the introduction by practicing engineers of steel members into a long series of evolutionary improvement in structural design. Competing technologies often represent the best impetus for applied research: the significant advances in the design of steel structures occurring in the sixties and seventies came about in response to the gains made by prestressed concrete. The introduction of natural gas to heat residential houses was a direct answer to the aggressive drive by the power commissions to convert houses to electric heating. These are just a few examples of a long list of innovations benefitting the buyers of construction services.

Even some of those heralded management tools used by construction, e.g. PERT and CPM, originated with others.

Does this mean that construction will survive without formal R&D by pig-

gybacking on others? Unfortunately, many practitioners of the industry and some also in government are prepared to leave things as they are and allow construction to muddle through the coming years without a coordinated R & D approach.

Why? There are several reasons for this apparent complacency and shortsightedness. One reason is the different priorities which owners have for reducing construction costs. For example, in the commercial sector, the cost of construction has a much greater effect on profitability than it does in the industrial sector where differences in manufacturing process are much more significant. In many cases the first cost takes precedence over life cycle cost (e.g. in the case of condominium developers). Other reasons may be found in building codes or municipal regulations which often delay the application of technological developments. Our litigious tendency, giving rise to the practice of "defensive design", is a further reason for slow technological advancements. The most important barrier is, however, the way we buy construction services. The separation of design and building in the construction industry (which is the only industry operating in this manner) means that no entity has responsibility for the entire process and hence no one can capture the full benefits of research. It is contended that the ultimate (i.e. life cycle) cost of a structure or facility is determined, almost in its totality, before the general contractor breaks ground, i.e. during the engineering and design phase. Contractors (including trade contractors and suppliers) have little impact in this respect, except in very unusual circumstances. It is true that incompetent or disorganized contractors can waste a lot of time and money and thus add to the cost of completed project. Nevertheless the cost-effectiveness (i.e. competitiveness) of the facility depends more on the quality of engineering than on the skill, efficiency, dedication and/or the ingenuity of contractors.

R & D: whose responsibility?

Because the design of most of the facilities and/or structures in question is carried out by consulting engineering firms, the ability to introduce technological innovations ought to be their stock-in-trade. Practice and theory, unfortunately, do not always go hand in hand. Canadian consulting engineers are seldom given the time and, with a few exceptions, have no facility to undertake the kind of research that would enable them to introduce technological innovations with a view to rendering the ultimate product more cost-effective.

More importantly, consulting engineers usually work for a fixed fee (e.g. a percentage of the contract amount, or that of the amount paid to the contractor) which leaves little or no margin to investigate new or perhaps more cost-effective solutions. They are forced, both because of their limited fee and the allotted time, to go with a welltried, safe design.

It is contended that it is not necessarily the lack of new technology which hinders cost-effective construction but more often the way owners today buy construction services.

Technological innovations and the resulting increase in competitiveness benefits the buyer of the construction service, who either markets the final product or relies on the efficiency of the means of transportation, etc., and not the contractor or the design engineer. At least, not as long as we continue to buy construction services in the current way. If it is the buyer of the service who benefits from an innovative solution, should he not be the one paying for the required research and development and taking the lion's share of the financial risks? This distribution of risk and cost is not easily achievable through the usual contracting practices employed on the majority of construction projects.

Yes! Technology is an essential ingredient of improved competitiveness, but in itself it is insufficient. To succeed, we must alter our ways of buying construction services as well as our attitude towards technology — both to its development and its diffusion. We must find ways to provide incentive (as opposed to the currently prevailing potential penalties) to develop and to apply more cost-effective technology. This is particularly important with respect to facilities and/or structures whose ultimate cost is not governed by the market forces. Corporations which tend to design their own facilities and market their own products already have such an incentive and they are probably already involved in suitable research and development, but they are in the minority. We must be thinking about those small or middle-sized corporations with no in-house research or engineering capabilities, as well as about the government financed enterprises which today must follow the public tendering route.

Unfortunately, buyers of construction services are often their own worst enemies both because they wait until the last minute before they retain designers for their projects and then restrict the designers' ability (both in time and money) to investigate alternate solutions and, at times, even to complete the design prior to tender call. Starting construction with incomplete drawings will, sooner or later, lead to disputes and eventually to litigation. It has occurred more than once that the owner paid more for his lawyer defending a claim than to the designers for the entire project. Maybe this is shortsightedness which allowed the situation to develop where the ratio of lawyers (and accountants) to engineers is totally distorted if compared to Japan (the nation leading in technology).

Enhanced competitiveness

According to a recent study in Ontario, there is a lawyer for every three engineers in Canada, whereas in Japan there is one lawyer for every four hundred engineers. The ratios of accountants to engineers are not that much more comforting. Enhancement in the competitiveness of the Canadian construction industry cannot be achieved by wishful thinking. It requires real and coordinated efforts, in at least four areas:

1. Engineering and Design Improvements
2. Improved Construction Sites
3. Advanced Materials
4. Technology Transfer Management

The engineering and design improvements must be accompanied by reduced risks (e.g. professional liability) on the part of the designers and more freedom to incorporate technological innovations. We must implement a "planned constructibility program" which will allow the introduction of most effective construction technology while safeguarding the ultimate usefulness and effi-

ciency of the project. Designers must make the optimum use of shop as opposed to field fabrication, preassembly, use of modular-sized units, but without jeopardizing ease of maintenance and operation. The use of computer aided design, engineering systems and materials selection systems must be encouraged now, and perhaps made mandatory later on, as is already the rule with some State Highway Departments in the U.S.A.

In the area of Improved Site Productivity, the trust of R & D should be a "user friendly" management system (e.g. estimating, scheduling, cost control) suitable to be used by small and medium-sized contractors. Unfortunately, recent developments are aimed at the upper quartile of the industry. Similarly, more attention ought to be paid to the improvement of material handling systems as well as the use of robotics.

In the Advanced Material area a whole range of new materials comes to mind, such as the wider application of ceramics, reinforced plastics, advanced cementation materials, etc.

One of the most important areas, however, where improvements are required is the Management of Technology Transfer. If new technologies are not effectively introduced into application, the real benefits of research will never be realized. The Department of Trade & Industry of the United Kingdom spends 68 percent of its research budget on technical improvement and 23 percent on its transfer. It would be difficult, if not impossible, to make a meaningful comparison of these figures with those in Canada. The absolute values of these figures are, in any case, inconsequential. Their ratios are, nevertheless, significant: one quarter of that Department's R&D budget is spent on transfer (or diffusion as we prefer to call it in Canada). New construction technologies now arrive faster than the information can be transferred to those who could benefit by the application of such an innovation. This bottleneck in the flow of technology is a major contributor to relatively low construction productivity.

Dr. Harvey Brooks defined technology transfer in the following way:

"Technology transfer is the process by which science and technology are diffused throughout human activity. Wherever systematic rational knowledge developed by one group or institution is embodied in a way of doing things by other institutions or groups, we have technology transfer. This can be either transfer from more basic scientific knowledge into technology, or adaptation of an existing technology to a new use. Technology transfer differs from ordinary scientific information transfer in the fact that to be really transferred it must be embodied in an actual operation of some kind.

I have hinted at two different kinds of technology transfer, which might be called vertical and horizontal. Vertical transfer refers to the transfer of technology along the line from the more general to the more specific. In particular it includes the process by which new scientific knowledge is incorporated into technology, and by which a 'state of the art' becomes embodied in a system, and by which the confluence of several different, and apparently unrelated technologies, leads to new technology.

Horizontal transfer occurs through the adaptation of a technology from one application to another, possibly wholly unrelated to the first, e.g., adaptation of a military aircraft to civilian air transport..."

It is contended that the reduced competitiveness of Canadian industries, including the construction industry, results more from slow or non-effective transfer and not so much from the lack of R & D. No one can keep abreast of all technological developments on his or her own, accordingly the ultimate goal, i.e. improved competitiveness is unachievable without the development of effective and accessible means of technology transfer. This is not to say that no continued educational opportunities exist today, they do, such as through the continued educational efforts of Universities and Community Colleges etc. Unfortunately, these courses, seminars or workshops are uncoordinated, often competing with one another and cover "catchy" topics only.

The Canadian construction industry and more particularly the design fraternity must go beyond the existing

parameters of continued education and develop a more comprehensive plan. Working with engineering learned societies is probably the most promising avenue to achieve and maintain more uniformity in the level of courses provided, thus to maintain an acceptable level of up-to-date knowledge of practicing engineers.

Conclusions

More and more people are heard saying that Canada does not spend enough on construction R & D. Some simply support their position by comparing published statistical information, at times, even without taking time to understand the basis of those figures. Others, particularly those involved in R & D, support their argument by referring to the reduction in the amounts made available for their pet projects. Whether such a project would benefit the national economy is of no consideration in their mind. Finally, there are those who blame their inability to compete with foreign firms or suppliers on inadequate R & D.

There probably is some justification for these arguments, particularly from the point of view of the individuals affected. But are any of these reasons proving the truth of the argument? Hardly. They may prove that Canada's R & D efforts are not properly coordinated, or that innovative technology does not reach the organizations who could benefit from it, or simply that the Canadian construction industry is not organized with a view to benefitting from the already available technology.

There are numerous government departments, agencies, institutions, professional and trade associations who profess to speak on behalf or for the benefit of construction industry when it comes to R & D. However, most of them are more interested in maintaining (or improving) their "authority" than in helping one another in defining and satisfying the real needs.

We must realize that Canada is a large but sparsely populated country with limited financial and human resources. We must, therefore, be very discriminating in the selection of our R & D projects. There is no justifiable reason, even if it were achievable, to research every possible problem we may encounter. Construction R & D of other countries is easily accessible to Canadians, as long as we have effective means to transfer those findings. We must be prudent and should not compete with the research institutions of others just for the sake of individual pride. The proliferation of competing Canadian research organizations, whose efforts are totally uncoordinated, deprives us of significant sums of money which otherwise could be used for productive research.

The question we should be asking is not whether the total money spent on construction R & D is enough, but do we spend what we have, wisely and to the benefit of our economic well being.

We must, first of all, establish national priorities, as opposed to supporting the pet priorities of a select few. Then, we must assure that the so-defined needs are satisfied in the most cost-effective manner. Furthermore, we must establish an effective system for the transfer of technology. Finally, we must examine our existing contracting practices and alter them as necessary with a view to placing both the costs and the risks associated with technological innovations on the shoulders of the ultimate beneficiaries.

The danger is real and our survival may be in jeopardy unless we reverse the trend. The Canadian construction industry must improve its competitiveness not only for its own sake but also with a view to safeguarding our standard of living. This, unfortunately, will not happen unless we define the problems (i.e. reasons for the deterioration of our competitiveness) in an independent and unbiased manner.

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