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TECHNOLOGY TRANSFER

Questions to Arnon Bentur, Head, National Building Research Institute, Technion, Israel Institute of Technology, Haifa

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Professor Bentur, thank you for agreeing to answer a few questions regarding your experience in implementation of research-generated knowledge into engineering practice.

Question: As a professor at the Technion and the head of the National Building Research Institute, you are in a unique position to compare the effects of different requirements and perspectives of academic and industrial establishments on implementation of new knowledge. Would you be so kind as to comment on the modus operandi of your institute within the framework of a technical university?

Prof. Bentur: The establishment of a National Building Research Institute (NBRI) within the framework of a technical university (Technion-Israel Institute of Technology) is indeed unusual. In most countries, such institutes are usually set up as separate entities, because the terms of reference of a university and a national institute seem to be different. However, in the case of a small country like Israel, which is limited in both material and human resources, it is more cost-effective to utilize the infrastructure already existing at a technical university and mobilize it to also achieve the goals of a national research institute. Although there is a difference between the research objectives of the two entities—one is more oriented towards basic research (which is the infrastructure required for developing and maintaining high level faculty for teaching), whereas the other is more applied in its nature (having as the main "client" the industry)—there is still sufficient common ground to justify such co-existence. The modus operandi is achieved by identifying this common ground and developing sufficient activities within it.

For that purpose, considerable thought is given every year to establishing a research program that is balanced between basic and applied research. The balance is not only in terms of the "quantity" of research in these two areas but is also reflected in the choice of topics, giving priority to those in which there is a clear-cut dependency between basic and applied research. For example, a faculty member is given the opportunity to engage in basic research, but he is expected and required also to lead the effort on research application. This puts some constraints on the research topics that can be selected; but we have found it to be an excellent inspiration for new ideas and approaches, and it leads to more focused work. Applied work should be viewed favorably by the university, as it provides the avenue by which faculty members keep in contact with the industry, and their teaching is thus more balanced and more effective. The activities of our institute can be considered to be within this framework of the philosophy of a technical university.

Question: Putting on your other hat as a university professor, what function should academic establishments play in knowledge transfer, specifically in (a) educating students and (b) helping new technologies to be accepted and used by the engineering field?

Prof. Bentur: Academic institutes, like any other public organization supported by state funding (even if it is partial, like NBRI), are expected, much more than in the past, to demonstrate their cost-effectiveness. Universities have two major objectives: creating knowledge and transferring it. Educating students is obviously the major tool for knowledge transfer. Yet, in view of the po-

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tential of the university as a reservoir of knowledge on the one hand and the expectation and pressure to improve its "productivity" on the other hand, there is a clear need to broaden the scope of knowledge transfer beyond the conventional one. We see it already taking place, but it must be intensified.

I see two avenues where these activities should be developed: I would define one as "extended studies" and the other one as "technology transfer." The first one should be directed toward continuing education to allow the engineers to update themselves in the rapidly changing technology. Universities should take the lead here, because this aspect of education is likely to become increasingly important, and approach the level of intensity that is currently given to graduate studies. To be successful, this endeavor requires much greater market research to identify the needs of the practicing engineers. Perhaps it would be achieved most efficiently by cooperation between the universities and various professional organizations through which many engineers are affiliated. For this endeavor to succeed, there is also a need for the tenured faculty to get involved in this kind of teaching.

The second avenue, technology transfer, requires greater involvement of the faculty in national and local technical activities. Standardization is perhaps a good example. Although considered by many as an obstacle to innovation, this is perhaps one of the more efficient tools by which new technologies can become accepted, especially in the civil engineering field. I am familiar with the frustrating aspect of standard committee work, and it is indeed frequently tedious. However, if more faculty become involved, this tedious effort can be speeded up, in particular, if we take upon ourselves to lead such committees and prepare draft documents and focus our research to facilitate the establishment of standards for new technologies. This area of technology transfer is one in which there is an overlap between the activities required from a university (to boost and demonstrate its productivity) and a national research institute, and this is one of the common grounds to which I referred in the answer to the first question.

Question: In view of the comments you made earlier on technology transfer issues, could you provide us with more details about the transfer mechanisms used at your institute?

Prof. Bentur: As a national research institute, we are committed not only to create basic and applied knowledge, but also to facilitate its implementation. This is the distinction between a research institute that carries out work for various agencies and industrial sponsors and a national institute that is partially supported by public funding. The latter must also be committed to technology and knowledge transfer to the consumers in those areas where industry has no direct interest (e.g., industry would be effective in generating new products but would not be as active in areas such as long-term performance and safety). I have already mentioned standardization as one of the avenues of technology transfer. We have developed over the years a host of activities, shown in Figure 1, which we subdivide into "knowledge dissemination" and "assistance to solving engineering problems." Although these two activities represent a small part of the overall activities of the institute (the main one being research), it is the most visible and the most efficient in taking our research into practice. Standardization and national activities such as earthquake hazard policy making are examples of where the knowledge gained in a variety of research activities is utilized and clearly justifies research funding. Included in such activities is also research in areas of general interest to accumulate knowledge of general significance, without the need to prove the usefulness of each project on its own but rather to view the benefits that such projects provide to the overall activities listed in the chart under the title "knowledge dissemination."

Another example is our involvement in assessment of new building products that was found to be extremely effective for the acceptance of new technologies that are too new to have been approved through the standardization process. In such activities, the process of technology transfer is funneled to provide the infrastructure to assist the industry in developing new products or modifying new technologies to adjust them to local conditions and to help in getting them established. Technology transfer should be distinguished from product development, which is beyond the scope of a national research institute but is the goal of the industry. To succeed in these efforts of technology transfer, it is essential to get the researcher to understand the need of spending part of his time (usually a small portion) in these activities. In most cases, it is impossible and ineffective to have two sets of experts, one doing research and one doing technology transfer. Getting this understanding is not always easy, but gradually we have been able to establish the notion that the research and technology transfer have to go together as one package.

Question: Technology transfer is closely related to the issues of human needs and productivity. Could you comment on the approaches taken by your institute? What mechanisms do you use in selecting the technically and economically best research topics?

Prof. Bentur: Technology transfer cannot stand on its own and must rely on a broad and sound basis of technical achievements and know-how developed through research. We have seen in the field of cementitious ma-

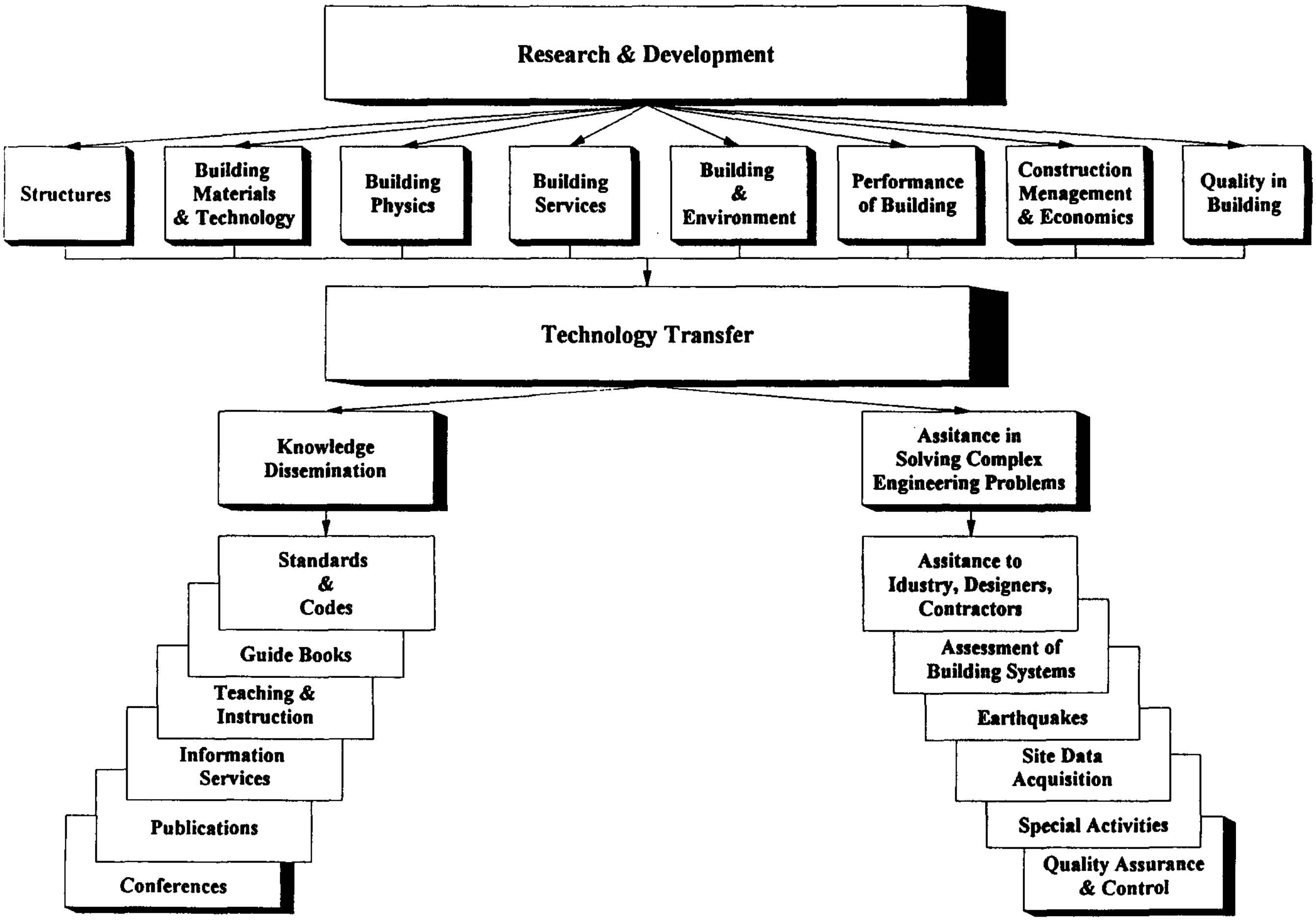

FIGURE 1. National Building Research Institute.

terials a constant and successful effort to advance technology by incorporating various scientific disciplines such as physics and chemistry and fostering the materials science approach. The achievements have been impressive. However, for a new technology to be transferable, it must meet also the human needs and the economic constraints. With this view in mind, we are developing interdisciplinary research with disciplines such as construction management, economics, and building physics. This is achievable in an institute like ours where all the traditional building engineering disciplines are under the same roof (see chart).

We have also gone beyond this in trying to develop ad hoc cooperation with disciplines such as architecture and medicine. Here, there is a clear advantage of having the NBRI within the framework of a technical university, where there is access to such disciplines that are not present in the NBRI itself. We are more aware that materials and structures are part of a system, and a systems approach is needed in the research program. Thus, we are trying to incorporate in our studies of advanced technologies and materials related topics that address human needs (e.g., acoustics, climatology) and efficiency by considering factors such as initial cost, savings in manpower needs (which is sometimes the bottleneck due to limited availability of professional workers), maintenance, and their overall quantification by life-cycle costing analysis. This interaction, in addition to providing a better base for implementation of the research itself, is also effective in identifying needs and directions to be taken in the advancement of new studies. This is of particular significance in high performance materials, where we have developed superior properties but where we need further research to utilize these advanced properties.

Having in mind the significance of interlacing economic aspects in research, we are experimenting with the possibility of developing a methodology for cost-effectiveness assessment of research proposals to be used as one of the tools for assisting in selecting proposals for funding. We are aware that this may be treacherous and, therefore, the activity is carried out in carefully controlled stages. We are addressing the following issues: (1) definition of categories of studies (e.g., exploratory-basic, studies in established domains, and studies in well-researched areas), (2) development

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of detailed guidelines and examples for researchers (which are going to be different for the different categories), and (3) limited experiments in which the new guidelines will be tested. The object is to have an appendix to each proposal assessing its cost-effectiveness. A similar approach is planned for completed research projects. However, the methodology there should be different. At present, the process of identification of research needs and evaluation of research proposal is based on more conventional and qualitative criteria. It consists of an organized process that involves many participants such as individual researchers, the leadership of NBRI, the research sponsors (industry and government), and a group of senior practitioners who represent the client, construction, and engineering communities. This process is administered by a steering committee consisting of representatives of all of these organizations and bodies. For most studies, the major criteria are a qualitative evaluation of their expected contribution to the industry and the prospective chances for wide implementation, either in the short term (~2 years) or medium term (~5 years). Support is also granted to basic studies, mainly to sponsor graduate research of students working at the NBRI laboratories for a master's or doctor's degree in science granted by the Department of Civil Engineering, which is the academic unit with which NBRI is affiliated.

Question: With the recent large influx of immigrants, your construction industry faced a challenge of accommodating them at a high rate. What technical, economic, and political decisions were made to deliver needed housing in a timely and economically affordable manner? What were the main barriers and how did you overcome them?

Prof. Bentur: The recent massive immigration amounted to about 450,000 new immigrants which is about 10% of the population of Israel, within a period of about 2 years. Urgent measures were required to provide housing within a short time, because a political decision was made not to allow any solution that would lead to the formation of refugee camps. Thus, the major effort was directed toward construction of permanent housing, using technologies that enabled fast erection and were not labor intensive. These two requirements were essential for the rapid solution, to avoid bottlenecks in the construction process that are either the result of the technology itself or its sensitivity to labor requirements. In view of the limited resources of the new immigrants, the construction was largely financed by the government; and upon completion, the dwelling units were housed by the new immigrants. They obtained generous mortgages or, in some cases, were allowed to rent the apartment for an interim period at a subsidized rate until they were able to take upon themselves the required mortgage. The role of our institute was largely technical; to assess the prototypes of the various systems offered for the rapid construction and to ensure that they met the performance required in Israeli conditions, taking into account the local climate and habits. Many of these technologies were new to Israel and were not covered by standards. The division of assessment of building systems in NBRI, which usually operates at a low key, turned out to be the only practical solution to ensure that the rapid construction would not be at the expense of quality and that the systems used could indeed perform satisfactorily in the local conditions. The core of the team who evaluated these systems (about 150 systems) was largely made up of researchers from the institute. It was an excellent demonstration that the knowledge gained through research and accumulated in the institute could be implemented within a short time when required by emergency conditions.

Question: What are the crucial pressures on your institute by your industrial and government customers? How do you respond to them? What are the most important lessons research organizations can learn by closely cooperating with the customers?

Prof. Bentur: The pressures by the industrial and government customers are usually focused on performing short-term research and implementing it immediately. The pressure from the researchers is to do just the opposite. The optimal path, both from practical and technical points of view, is to develop a coherent research plan that includes a balance between short- and long-term research, accompanied by a commitment for research implementation that is not necessarily just the outcome of each study but is reflected in the cumulative activities of technology transfer outlined in the chart. This mix of different kinds of research projects should not necessarily be viewed as compromise but rather as an optimal way to benefit all involved. The pressure for research implementation brings about a better identification of research needs and encourages development of new avenues of research. On the other hand, applied short-term research will be less effective if those involved in it will not be exposed to more fundamental and long-term studies. Success along these lines does not come easily, and it is a continuous struggle that requires education of all involved and a visible demonstration for research implementation accompanied by a clear policy that is well communicated. The mechanism by which decisions are made in a steering committee consisting of all interested parties allows us to gradually develop mutual understanding: The customer better understands that research is not only short-term work, and the researcher grasps the need for implementation and realizes that a more balanced approach and allowing some time for research implementation builds the customer's trust, which allows the customer to understand the need for long-term research. This understanding is fostered and strengthened when the industrial and government funding bodies see in front of them a comprehensive research program and a plan for activities for research implementation, thus allowing much more flexibility and diversity in the research compared with a mechanism in which funding decisions are made by addressing each proposal separately without having the overall view.

Professor Bentur, many thanks for your time. I am sure our readers will appreciate learning about your views and approaches.