MEMORANDUM

All Governors

W.D. Hopper

ESTABLISHMENT OF AN IDRC PROGRAM DIVISION FOR INDUSTRIAL AND ENGINEERING SCIENCES

As a follow-up to the September meeting of the Board, I commissioned three consultants to review the potential usefulness to the purposes of the Centre of establishing a Program Division for Industrial and Engineering Sciences. The first report from the consultants is attached. It was prepared by Dr. Leib Wolofsky, a Canadian geologist and engineer with wide experience in the developing countries and a former Research Associate of the Centre. Dr. Wolofsky was asked to review a few potential areas of industrial and engineering useful to the developing regions that could benefit from Centre assistance. He was specifically requested not to make a comprehensive catalogue of opportunities but to select topics that a program division might include on its agenda of research support. He was asked also to provide a few examples of LDC institutions whose programs might be assisted by Centre resources. At my suggestion, Dr. Wolofsky focused mainly on opportunities for small- and medium-scale industrial and engineering activities requiring relatively little capital investment and holding promise of enhancing employment opportunities in developing regions.

In his report, Dr. Wolofsky recommends that the Centre create a Division for Industrial and Engineering Sciences; I think you will find many of the examples he has suggested for the work of such a Division most stimulating. The whole matter will be discussed further at the Dakar meeting.

W.D.H.

Attach.

W. D. H.
January 14, 1974.

The President
International Development Research Centre
P.O. Box 8500
Ottawa K1G 3H9
Ontario, Canada

Dear Dr. Hopper:

Study of Research Opportunities in Industrial and Engineering Sciences

In response to your letters of July 19 and October 3, 1973, I am now completing a report to you on the opportunities for support of significant research in the developing regions in industrial and engineering sciences.

I am sending you, herewith, a draft of my report. You will note that I feel there are needs and opportunities for IDRC in these fields. Sections 1 and 8 summarize my recommendations, and the remainder of the text amplifies them.

Please let me know if you would like to have any changes in the final version, such as fuller treatment of any particular subject or other changes of emphasis. You should also inform me how many copies you require. If I could have your reactions at your earliest convenience, I will make the necessary arrangements. I expect to be abroad between about January 24 and February 24.

Thank you for this opportunity to be of service to IDRC. If I can be of any additional help, please do not hesitate to call on me.

Yours truly,

L. Wolofsky
INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

DRAFT

STUDY OF RESEARCH OPPORTUNITIES
IN
INDUSTRIAL AND ENGINEERING SCIENCES

by L. WOLOFSKY

JANUARY 1974.
STUDY OF RESEARCH OPPORTUNITIES
IN
INDUSTRIAL AND ENGINEERING SCIENCES

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1 - SUMMARY

This is a report on about three months' study of opportunities for research in the general field of industrial and engineering sciences which IDRC might consider supporting. Brief descriptions of individual activities are contained in Section 8.

In view of the wide range of the Centre's objectives, a variety of avenues is suggested but the list is by no means complete. A continuation of the present support for industrial extension service is recommended, with a broadening of the area served and an attempt at deeper penetration through the co-operative strengthening of national services to better contact small industrial establishments. The importance of industrial inputs into agriculture and the possibility of integrating certain industrial activities into the agricultural cycle are discussed. In these connections, it is suggested that attempts be made to interest Chinese industrial and agricultural engineers in a co-operative endeavour, in order to make their experience available to the developing countries. Work on decentralized small power sources is recommended, for uses such as water pumping in individual farms or fields. The importance of internal market is emphasized. Some work on the relation between agricultural
and engineering systems of soil classification and testing is recommended. A study is suggested to determine whether heavy construction projects can be made more labour-intensive without financial penalty by concentrating the labour-intensive activities in those parts of the construction sequence which are not on the critical path.

Various types of institutions which perform research and development in industrial and engineering sciences are discussed. Aside from the specialized industrial and agricultural research centres, it is recommended that attention be paid to provincial universities which are in close contact with the problems of their regions, and also to government departmental laboratories. In spite of the difficulties which may be expected in managing programs involving the latter two types of institutions, it is recommended that serious consideration be given to co-operation with them.
2 - INTRODUCTION

2.1 - Terms of Reference

Terms of reference for this study were provided in a letter dated July 19, 1973 from the President of IDRC. After preliminary visits and telephone conversations, work started on August 13. The terms of reference were confirmed in a contract-letter dated October 3, 1973 (IDRC File: 4346-1).

The function of the study and of this report is to provide some of the material required by the President in preparing his advice for the Board of Governors of IDRC on the possibility of establishing a fifth program area in the form of a Division of Industrial and Engineering Sciences. Among the primary objectives of the study, as specified in the letter of July 19, were: to assess the opportunity for the initiation and conduct of a significant program of research into the technologies in the industrial and engineering sciences that would increase the employment potential of the processes of modernizing the developing regions of the world; to seek to identify concrete examples of possible research projects in the general areas of industry and engineering which might be considered for support by the IDRC; to strive to identify a sample of individuals and institutions in the developing countries that are qualified and willing to undertake such research work.
2.2 - Emphasis of the Study

The study and this report have been biased toward the fields of natural resources, energy supplies, and the construction industry by the author's own background. Nevertheless, advice has been sought from persons with other backgrounds and some of their suggestions are incorporated in this report. Section 6 of this report contains a list of the persons consulted. Section 3, below, contains discussion of some of the factors which lead to the concentration of efforts on problems which concern small industry, industry serving a domestic market, and engineering sciences related to rural populations. Section 4 contains discussions of some of the subject areas in which small investments in research support might most rapidly be repaid by benefits to the developing regions. Section 5 considers the types of institutions and research workers, particularly those in developing countries, with whom IDRC might co-operate in such research. In general, the suggested institutions are of the same types as those with which IDRC is already working, but it is suggested that consideration be given to increased co-operation with provincial universities in the developing regions. From the point of view of IDRC, this would have both advantages and disadvantages, which are discussed at some length. Section 7 of this report is a list of references. Finally, Section 8, to which
the reader may wish to turn first of all, is a collection of general descriptions of projects which IDRC might consider suitable for support.
3 - INDUSTRY IN DEVELOPING REGIONS

The Centre will wish to consider the industrial and engineering background in the developing regions, not only when making its decision on the creation of a fifth Division, but also when guiding the activities of this Division, if it should be formed. The following paragraphs present a few of these background considerations, with recommendations on fields of special emphasis where research and related activities might be most productive or where they are most needed.

3.1 - The Place of Agriculture

There are many valid reasons for the Centre's emphasis on projects oriented to the rural areas and populations of the developing countries. There is no need to repeat these arguments here. They become even more valid as the world's food and nutritional problems become more pressing (Boerma, 1973) and as the disparities between rural and urban living standards are increasingly evident. Some other international organizations are also more and more aware of the needs of rural areas (For example: McNamara, 1973).

With regard to industrial development, it must be kept in mind that the majority of the third world's population lives outside the larger metropolitan centres, and that the lives
of a very large number of people are dominated by agricultural pursuits. This means that the largest potential markets for consumer products or small capital goods are in the countryside and villages, or will be if and when purchasing power is more evenly distributed. With the same qualification, it also means that industries supplying inputs to agriculture or treating agricultural products can serve the largest proportion of users.

The Centre already has an active and productive program of activities related to agricultural products. Increased attention to industrial inputs into agriculture could perhaps be equally rewarding. The relations between agriculture and small industry are mentioned in Section 4.1 of this report.

3.2 - The Function of Small Industry

In the industrial sector of the developing countries small and medium-scale industries are of course far more numerous than large establishments. They also provide more places of employment but contribute proportionally less (in terms of production per worker) to the industrial product than do large industries. The definitions and methods of measurement vary from country to country, but two examples can be given, as reported by delegates to a recent conference sponsored by UNIDO and Nacional Financiera, S.A., of Mexico.
These two examples are perhaps not typical of developing countries (indeed, probably that concept has no real meaning), because they are among the larger and more industrialized. However, they may serve to illustrate.

In Brazil the definition appears to be (Carneiro, 1973, p.5) that small and medium industries are those with a "book value" of less than the equivalent of US $5,000,000. They number more than 98 per cent of industrial establishments, provide 73 per cent of industrial employment, and contribute only 56 per cent of industrial value added in the nation. In certain industries, however, they are overwhelmingly important. Thus, in the furniture industry, small and medium-sized establishments employ 93 per cent of the labour and produce 89 per cent of the value added. In the leather and hides industry the respective figures are 89 per cent and 87 per cent. In the wood industry, they are 95 per cent and 82 per cent (Carneiro, 1973, p.1).

In Mexico (Cacho, 1973, p.4) some figures for the year 1964 are available. Handicrafts and small and medium industry together accounted for 99.5 per cent of all process industries (as distinct from extractive industries) and absorbed 64 per cent of the capital invested in the sector, produced 70 per cent of the product with 77 per cent of the value added, and employed 86 per cent of the workers. (The definition used for small and medium industry at that time is unfortunately not known.)
Thus it is evident that anything that improves the productivity or efficiency of small and medium industry will affect the largest proportion of industrial workers, and can have a disproportionate effect on the productivity of the industrial sector as a whole. These are the industries which it is feasible to establish in a provincial centre, at least in some cases, and which provide many of the consumer goods which have a domestic market among the agricultural population when discretionary purchases are possible. They also include building contractors and subcontractors, repair shops, laundries, sheet metal fabricators, machine shops, wood working shops (boxes, doors and windows, furniture, boats, etc.), leather and plastic goods (such as shoes, purses, etc.), many building materials (concrete blocks and pipe, bricks), and numerous other types of enterprises. Most of them have certain competitive advantages over bigger establishments, so long as they stay within their fields of specialization. These advantages include relatively low overheads, an ability to expand and contract their scale of operations in response to demand without excessive penalty in terms of unproductive capital investment, and an ability to modify their methods and their products when styles or specifications change. From IDRC's point of view, these characteristics make them the most attractive segment of the industrial sector.
Another reason, perhaps a negative one, for taking a special
interest in small-scale industry is that large-scale enter-
prises or those with the skills and capital enabling them
to undertake large-scale ventures can help themselves without
IDRC assistance. The multinational corporations are outside
IDRC's field of interest. Many developing countries have
government agencies willing to provide assistance to their
larger national corporations on request, and many industrial-
ized countries also provide various kinds of help to their
own national corporations to assist them in their foreign
operations. The large enterprises, therefore, can flourish
or fail without assistance from the Centre. However, there
may be some fields in which a new technology could prove
profitable to the developing countries as well as to the large
corporations, but would not be developed by the corporations
because of their historical associations with the industrial-
ized societies or for other reasons. For example, one of the
projects recommended in Section 8 of this report relates to a
labour-intensive method of prospecting for certain types of
mineral deposits. Another relates to the harnessing of
solar energy through a variety of means. Both are likely to
be of interest primarily (though not exclusively) to large
organizations, whether corporations or government enterprises,
but both, if successful, might bring great benefits to
developing areas where the geographic and economic conditions
are propitious, and they are, therefore, worthy of being
considered by IDRC.

In spite of such exceptions, it is suggested that the Centre's major focus in this area should be on the small and medium-sized enterprise. This is not to suggest that the Centre interest itself in each of the different kinds of activities that make up the small-industry segment. Some approach is needed which would be of assistance to the segment as a whole. In this respect it is suggested that the Centre offer its assistance toward the establishment of a Latin American Commission for Technology Applied to small and medium industry, as proposed by Sr. Guillermo Martínez Domínguez of Mexico at the meeting mentioned previously. This was reported on page 2 of the author's letter to the President, dated December 31, 1973, which was accompanied by a copy of the proposal and a recorded translation.

Another way in which assistance could be made available to the developing countries' industrial enterprises is through industrial extension services such as the one IDRC is already operating from its Singapore office. A suggestion for a somewhat similar operation in Latin America is contained in Section 8 of this report and was also mentioned in the letter of 31 December, 1973.

A link between the previous discussion of agriculture-based industry (Section 3.1, above) and this discussion of small
industry is the topic of industries located in rural areas. Some comments on the Chinese experience are contained in Section 4.1 of this report.

3.3 - Significance of the Domestic Market

Most of the research recommended in this report relates to internal needs within individual countries, rather than to their exports or to balance-of-payments problems which they may face. One reason for this emphasis is that existing research efforts on problems of domestic economies are inadequate in view of the problems waiting to be solved in many fields. Very little attention is being paid to the engineering problems and needs of the small industrialist, to say nothing of the craftsman, bazaar manufacturer, or farmer. A few institutions...
are working diligently and usefully on problems of this scale, but their resources are limited. (Of the institutions visited during this study, several examples of excellent research efforts come immediately to mind: on engineering design of low-cost housing at the Asian Institute of Technology; on the physics and engineering design of green-houses at Brace Research Institute; on design and manufacture of cheap agricultural machines at the International Rice Research Institute. In each case some success has been achieved and further efforts are hampered by insufficient financial resources.)

When one considers the export-oriented industries, the picture is often very different. In the case of those which are dominated by integrated multinational giants there is no shortage of funds for the research which interests the corporations, and in most cases there would probably be little point in doing research which does not interest them. In the case of other industries, where exporters in less developed countries are genuinely dealing with their buyers at arms' length, the major problems are likely to lie in the realm of commerce rather than in science or technology. It would be useful to a manufacturer of men's shirts in Korea or Trinidad to be able to foresee the fluctuating international value of the Canadian dollar or the reactions of Canadian
officials to pressure from our domestic manufacturers, or even the duration of the next fashion craze. The business prospects of the developing country exporter will continue to be dominated by such unpredictable and, for him, uncontrollable factors. Any marginal improvements he might make in the quality or price of his product or the efficiency of his production processes as a result of research will be a very minor factor in his success or failure to penetrate our markets.

All this can perhaps be oversimplified as follows: In the export-oriented industries, either there is plenty of money for research, or else research would not help much. In the industries oriented toward internal markets there are many problems, and a few organizations are working on them with inadequate means.

3.4 - The Trade-Off Between Labour and Capital

It is unnecessary here to repeat the well-known arguments for and against the idea of "intermediate technology". However, there are two points which are rarely made which seem to have a direct bearing on the types of research the Centre should consider, and which are worth stating.
First of all, it should be kept in mind that the adoption of a labour-intensive method of working does not forclose future options. Assuming that the labour-intensive method was first chosen because it was the best economic choice in view of the labour and capital situation of the country at the time, it can always be modified at a later time when the situation changes. A capital-intensive method, on the other hand, is much more difficult to change. This inertia is, of course, due to the sunk costs which cannot be recovered, the machinery which has not yet been fully paid for, the loans still outstanding, and so on.

Secondly, it should not be assumed that an improvement in technology which results in greater production per worker will necessarily throw workers out of jobs. It may very well result in the employment of more workers, rather than fewer. Thus, a change in spinning technology which improves the competitive position of natural fibres as compared with synthetics, either by increasing the quantity produced per worker and thus reducing the cost, or by improving the quality of the product, would result in the expansion of natural fibre markets, augmentation of demand, and expansion of the industry. An improvement in productivity of labourers in construction, even so simple a change as the introduction of wheelbarrows in mass excavation (a suggestion made by A. Churchill of the World Bank), would probably
result in an increase in the number of mass excavations being done by hand labour in preference to powered machines when both are available at a price. Even in countries where deliberate policy or the lack of bulldozers forces the choice toward hand labour, increased productivity per man-day would mean more rapid completion of each job at less cost, and hence increased possibilities for simultaneous construction of several projects.

These arguments refute two of the commonly-heard reasons for opposing the adoption of an intermediate degree of mechanization in developing countries: that it is inefficient as compared with the methods used in the industrialized countries and hence condemns the developing country in perpetuity to a cheap-labour economy if it wishes to remain competitive; and the contrary argument, that increases in labour productivity which result from the adoption of any labour-saving devices permit the same work to be done by fewer people, with resulting unemployment. In particular situations either view may in fact be correct, which only means that each situation should be analysed individually at the time the choice has to be made. In general, however, probably everyone will agree that it is a sign of failure of the economic system when human beings can find no more rewarding way to spend their time than as beasts of burden; that the human alimentary canal, lungs, and muscles make up an inefficient way
of turning potential energy into work; and that the most distinctive part of the human "machine", the brain, is too valuable an asset to be wasted.

It is conventional wisdom that the more technologically advanced an industrial enterprise is, the more elaborate an infrastructure it is likely to require for its success. A corollary is that there is an appropriate degree of technological complexity which can be supported by the society and the infrastructure of a given region, and which will give the highest rate of return on investment in the particular situation. Finding that appropriate point may be a matter of trial and error at the present state of economic science, but increased research in engineering and industrial sciences at intermediate levels would at least allow more options to be considered when a choice has to be made, whether the choice is being made by a farmer wondering what type of pump to buy or build, or a mining company wondering how to start an exploration program in a new area, or a public utility deciding how to write its construction contracts with the contractors who will build a dam.

3.5 - Seasonal Activities

A research program oriented toward the rural areas should attempt to make some contribution toward the alleviation of
the seasonal unemployment which results from seasonal variations in demand for agricultural labour, which occur even where crops are grown all year round. Some basic principles that should be kept in mind when considering the appropriate research are: Capital invested must be minimal, since capital equipment and space will stand idle for much of the time, but must be paid for even then. The demand for the product or service must be such as can be satisfied by part-time supply or the product must be of a type which can be stored until needed. The labour skills required must be such as can be quickly learned by agricultural workers, as the periods of time available for training may be very short. The facilities and infrastructure needs must be such as can be provided in rural areas or small towns easily accessible from areas with seasonal surplus of agricultural workers.

These conditions are difficult but not impossible to meet. For example the Eastern Canadian pulpwood industry was for many years a seasonal operation employing large numbers of farm workers during their off season. Enough wood was cut to last the mills through the summer, so that the capital-intensive part of the operation could continue to work full time. Now that work in the woods has become more highly mechanized, (i.e., the capital invested in the woods operation has become more important) this seasonal tendency is disappearing. Prospecting for minerals in Canada was at one
time a summer occupation for men who spent much of the rest of the year following trap-lines. This seasonal tendency has also almost disappeared with the increased sophistication and cost of the equipment used for mineral prospecting in recent years. The research recommended in section 8 of this report on a labour-intensive prospecting method which might be especially applicable to parts of Africa would, if successful, result in a large demand for workers during the dry season, but would permit all-year employment of the few costly devices and skilled personnel involved.
4.1 - Industry and Engineering for Agricultural Inputs

Along with the spreading use of high-yielding varieties, increased mechanization of farming operations is likely to occur in many countries. While increased productivity and financial benefits can be shown to result, the question arises as to the long-term economic and other social effects on agricultural employment. Does not increased labour productivity imply a decrease in the need for farm labour and a consequent increase in unemployment? The answer to this question is relevant to the Centre's decision on whether or not to support engineering research on industrial aids to farming. The Centre has experts on agricultural subjects who will, no doubt, participate in making this decision, and the following comments are offered for their consideration.

Even the short-term effect on labour demand of on-farm mechanization is difficult to predict. Each agricultural operation on each crop, in each region, would have to be studied individually. Tables have been produced (Khan, 1971, Table 5, and Khan and Duff, 1972, Table 1) for the purpose of comparing total farm labour requirements, degree of mechanization, productivity per hectare and per worker, etc., in different Asian countries. No clear pattern emerges from a comparison of these figures, probably because of variations
in other factors, such as use of high-yielding varieties, different crop requirements, differences in soils, irrigation, fertilization practices, and so on, which cannot all be considered simultaneously. The systems are too complex for a simple method of statistical analysis (and, incidentally, the quoted figures are not all self-consistent. There are evidently arithmetical or copying errors, or both).

However, some studies on more limited areas are instructive. In research involving 76 farms in Central Luzon and Laguna Province, Philippines (Barker et al, 1971, Table 10) between 1966 and 1971, it was found that total labour requirements increased slightly during the period. In terms of man-days per hectare, the increase was from 63 to 67, or about 6 per cent. During the same period the percentage of farms using tractors increased from 14 to 49, the percentage using weeders increased from 9 to 17, and the percentage using threshers decreased marginally, from 62 to 61 per cent.

At the same time, yields per hectare were rising rapidly, partly due to the spread of high-yielding varieties, and labour productivity was improving from 33 man-days per ton of rice in 1966 to 25 man-days per ton in 1970 (Barker et al, 1971, p.17). The important point to note here is that on-farm employment was increasing while this was going on.
(It is entirely possible, of course, that unemployment may also have been increasing at the same time, because the natural increase in the working force during this period was certainly larger than that represented by the 6 per cent increase in agricultural employment).

Data are also available from a single, 4-hectare farm in the southeastern part of West Punjab, in Pakistan. Comparisons are made between traditional technology, three different seed improvements, and three different levels of mechanical technology innovation. The variables of interest are net revenue, cropping intensity, and labour utilization. As compared with traditional crops and methods, the changes are as follows (recalculated from figures given in Duff, 1971, Table 6).

<table>
<thead>
<tr>
<th>Technology</th>
<th>Net Revenue (% increase)</th>
<th>Cropping Intensity (% increase)</th>
<th>Labour Utilization (% increase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tubewell</td>
<td>50</td>
<td>50</td>
<td>33</td>
</tr>
<tr>
<td>2. 1 plus improved wheat</td>
<td>70</td>
<td>59</td>
<td>38</td>
</tr>
<tr>
<td>3. 1 plus improved rice</td>
<td>67</td>
<td>55</td>
<td>41</td>
</tr>
<tr>
<td>4. 1 plus improved wheat and rice</td>
<td>91</td>
<td>69</td>
<td>43</td>
</tr>
<tr>
<td>5. 4 plus wheat thresher</td>
<td>114</td>
<td>76</td>
<td>39</td>
</tr>
<tr>
<td>6. 5 plus seeder and improved land preparation equipment</td>
<td>136</td>
<td>85</td>
<td>41</td>
</tr>
</tbody>
</table>
In each case the comparison is with traditional technology. Here, too, it can be seen that the initial stage of mechanization, the installation of a tubewell, results in increased utilization of land and labour as well as increased labour productivity. Later stages seem to make less difference in labour use, and no overall trend is evident in this respect, although both cropping intensity and net revenue continue to increase with the progressive introduction of a thresher, a seeder, and improved land preparation equipment.

If the Centre should decide that the industry related to mechanization of agriculture merits its interest, then it will wish to concentrate on the design and industrial engineering of small-scale equipment for specific purposes. Large machines, of course, have their place and are receiving due attention from the manufacturers. Needed is study of the type of equipment which might be attractive and available to the farmer with 5 or 10 hectares. The experience of the machine design program of the International Rice Research Institute (IRRI) may provide some guidance. This program is aimed directly at wet farming of rice of the varieties grown around Los Baños, near Manila, and modifications have been required to some of the machines in order to adapt them to very similar varieties grown under similar conditions in other places. Manufacturers of the machines have also made
some modifications, primarily to reduce the already low costs. Some of these modifications have been successful in service and others have not. (F.E. Nichols, oral communication.)

Apparently no comprehensive figures have yet been published which would permit an assessment of the impact of the IRRI program on farming, employment, or the manufacturing sector. However, information is being gathered for this purpose and some preliminary figures on the manufacturing aspects were obtained (B. Duff, handwritten draft, October 1973). These cover preliminary data from five of the twelve manufacturers who are currently producing machines of IRRI design. (There are said to be other manufacturers doing the same, but using "pirated", or adapted, designs which are not approved by IRRI).

The five manufacturers have provided the following information.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Years in production</th>
<th>Manufactured number</th>
<th>Sold number</th>
<th>Sold per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Power tiller (5 &amp; 8 hp)</td>
<td>1-1/2</td>
<td>2,275</td>
<td>2,101</td>
<td>92</td>
</tr>
<tr>
<td>2. Batch drier</td>
<td>2/3</td>
<td>34</td>
<td>34</td>
<td>100</td>
</tr>
<tr>
<td>3. Table thresher</td>
<td>*</td>
<td>84</td>
<td>77</td>
<td>92</td>
</tr>
<tr>
<td>4. Grain cleaner</td>
<td>2</td>
<td>19</td>
<td>18</td>
<td>95</td>
</tr>
<tr>
<td>5. Bellows pump</td>
<td>1</td>
<td>40</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>6. Multi-hopper seeder</td>
<td>1/2</td>
<td>112</td>
<td>89</td>
<td>79</td>
</tr>
<tr>
<td>7. Single-hopper seeder</td>
<td>2</td>
<td>388</td>
<td>380</td>
<td>98</td>
</tr>
</tbody>
</table>

**TOTAL**          2,952  2,739  93

* No longer being manufactured.
Retail prices range from the equivalent of US $37 for a bellows pump to about US $665 for a power tiller or batch drier, and they are being sold largely for cash to small-to-medium-sized farms. So far, therefore, they appear to be meeting a demand. Four of the five companies producing them report that they employed a total of 199 employees before they undertook production of these machines (the fifth company did not provide this information). These four companies ranged in size from 10 to 130 employees. The five companies report that they have had to hire a total of 183 new workers since the inception of production, of whom 134 are in the manufacturing end. They use a total of 40 subcontractors to supply component parts. (The power units are small gasoline engines, being imported. Attempts to manufacture such engines domestically have not yet come to fruition. It is becoming more difficult to obtain deliveries from the overseas supplier, and there may be more incentive for domestic production because of this).

A survey of users is also being undertaken, but no data are available yet. It will be interesting to see just who is purchasing these machines, and with what consequences. This effort at IRRI is costing about US $250,000 per year, most of it from AID. It employs professional engineers, an economist, technicians, mechanics and others, and a moderately well-equipped machine shop (some photographs are attached to this report) for the production of prototypes.
The overall impression is that the type of activity being undertaken here is proving its worth, although user data are needed. If the Centre's experts on agricultural matters feel that there is a place for the development of small machines for crops other than wet rice, then the scale and style of the IRRI program would probably be an appropriate model.

Another area which needs attention is supply of water for small-scale irrigation. In spite of the ancient and universal awareness of this requirement, too little work has been done on small-scale water supply equipment such as might be installed on the individual farm or field. Ancient devices, mostly driven by manpower or animal power, or occasionally by wind or water, are in daily use. There are, of course, well-established principles for large-scale irrigation systems. However, these need large-scale economic justification and financing, expert design, competent management, and intensive use, one or more of which is sometimes lacking. They also require a source of water within economic reach, and this is generally interpreted to mean a river, since it is not immediately evident in most areas whether or not an adequate supply of underground water can be developed.

When conditions are right, however, farmers have shown that they can and will develop their own groundwater supplies for irrigation use. For example, in Pakistan, the completion
in 1960 of the first large hydro-electric project in the northwest (the Warsak multipurpose project, supported by the Government of Canada) coincided with large-scale studies of some saline and waterlogged parts of West Punjab. These studies provided some assurance of the abundant availability of groundwater at reasonable depths. Within a few years, thousands of individual landowners had made and equipped their own tubewells, which resulted in a substantial change in the region's requirements for power. By 1965 about 25 per cent of the electrical demand on the northern Pakistan grid was for pumping (Wolofsky, 1967, p.36). There were additional thousands of pumps driven by diesel or gasoline engines and not connected to the electrical grid. All this apparently happened without express government encouragement.

Thus there appears to be a need for small-scale equipment for extraction of groundwater from reasonable depths for use in individual fields. For many reasons it would be beneficial if such small units could be independent of power lines and fossil fuels. Solar energy, captured either directly or indirectly by any of several possible methods, would offer the farmer the power he needs in areas where conditions are suitable.

Water pumping would seem to be the ideal application for the use of intermittent energy sources such as direct sunlight or wind, since the problem of storage of energy need not
arise and overall efficiencies can be higher than when electricity is generated as an intermediate step. In the case of solar radiation, where energy flux is large and the required power is small, even very low efficiencies might be acceptable. This may open the possibility of designing such units for rather crude fabrication methods, similar to those used in the manufacture of the IRRI power tiller, for example.

One of the objectives of a machine design program, or of a program to design solar pump-engine combinations for irrigation service, should be to provide for manufacture in unsophisticated surroundings. That is not to say that the village blacksmith should necessarily be able to manufacture the devices, but certainly the market-town motorcycle mechanic should be able to repair them. The market for more complex machinery no doubt exists, but it is a different market-- not the individual small farmer or village co-operative. Machines and equipment should be simple enough to be built in provincial cities or towns, in machine shops whose main work has been repair of sugar-mill equipment or mining machines, or agricultural tractors or trucks. These are likely to be the places which can expand production by hiring and training more people with little capital expenditure. They are also more likely to be able to mobilize small amounts of local capital when required,
which is an important point. They are also likely to be responsive to their market, so that local design variations can be made to suit the local soil conditions, water hardness, or whatever. It is important that the equipment design should be adapted to the methods of fabrication which are likely to be available to such places, and, insofar as possible, to the standard shapes and sections, such as pipe and plate, with which they are likely to be familiar. This combination of a small fabricator, surrounded by his market and intimately acquainted with it; in touch with local sources of finance and using materials which are, if not local, at least national; would be the ideal to aim at and a great challenge to any researcher or designer.

The high proportion of all industrial jobs which is provided by small establishments was mentioned in Section 3.2. The question arises whether there is some way that such small establishments could be integrated with the agricultural activities of a region in such a way as to soak up unemployed labour during the slack periods of the agricultural cycle. This was discussed above and in Section 3.5, where it was pointed out that one deterrent to this practice is the need to pay for production equipment, whether it is being productively employed or not, so that such seasonal industrial activities must not be capital intensive. Such workshops have been integrated into agricultural communities in some
Israeli and Chinese communes. "The characteristic feature of the Chinese process of industrialization is the emphasis laid on establishment small and medium-size mines and factories based on local supplies, in various lines of production. In 1971, about 60 per cent of the country's production of fertilizers and 40 per cent of cement came from such local plants. Much importance is attached to factories and workshops for making and repairing farm machinery and implements, in line with the needs of the program for the mechanization of agriculture". (United Nations, 1972, pp.62-63).

A recent description (Galbraith, 1973, pp.94-99, 108) of a Chinese commune mentions small factories (at most a few dozen workers in those observed) making elementary threshing machines, furniture, basketware, boxes, light bulbs, chemicals, and steel pipe at the Hsu Hang People's Commune near Shanghai. These turn out the equivalent of US $2.7 million annually and produce half of the total revenue of the commune. Since the commune has only 1688 hectares (all irrigated, however), for its 20,500 inhabitants (an average of about 0.08 ha per person, or 0.36 ha for each of its 4,694 households), and managed in 1971 to provide an average net income (after taxes etc.) to each of these inhabitants equivalent to US $75, it appears that the contribution of these small workshops must be important. It is also interesting to note (Galbraith, 1973, p.95)
that, in spite of the high population density, the communal farming activities are, by Chinese standards, highly mechanized, with a total of somewhere between 1,000 and 2,000 hp in the form of 84 small tractors (maximum size 45 hp). This probably amounts to between 0.1 and 0.2 hp per agricultural worker, which would be a large amount by the standards of most developing countries. Although this commune is probably more highly mechanized than most others, it illustrates the high productivity which can be achieved by mechanization, even on this scale, combined with labour-intensive methods.

Two crops of rice plus one of grain per year total 12,015 kg/ha, and cotton production is said to be 540 kg/ha, ginned basis. If there is any labour displaced from the fields by such mechanization presumably it is employed elsewhere or is unemployed, since the factories mentioned could not absorb much more than 1 per cent of the total population of the commune, if the figures quoted above are correct.

It appears that China has always been willing to employ mechanical devices. "......Whatever characteristics ancient and medieval Chinese labour conditions may have possessed, they proved no bar to a long series of 'labour-saving' inventions altogether prior to those arising in Europe and Islam...

In Chinese culture inventions were never rejected because of the fear to technological unemployment. In all our studies we have so far come upon no case of this ......" (Needham, 1965, pp.27-28).
Another interesting and valuable contribution by the same author is his frequent reference to the "style" of Chinese traditional engineering and craftsmanship, much of which is being incorporated into modern Chinese technology as well, particularly in agricultural machines. The word "style" in this sense refers to rather intangible, but no less real, elements of design: preference for wood as the main material in agricultural machines (such as the three designs reproduced in Needham, 1965, pp.173 and 175, which are quoted from a modern catalogue, Anonymous, 1958); a tendency to use a wheel in contact with the ground as a source of motion to drive the working parts of the machine, even when the device is intended to be pushed or pulled by manpower (as in the case of the wooden crop-spraying wheelbarrow and the mowing machine illustrated on page 175 of Needham, 1965); a general preference for a vertical axis of rotation for water wheels and windmills, as contrasted with the usual European tendency to use horizontal-axis wheels, with right-angled gearing to transmit the power to the vertical-axis grinding machinery. (The writer has seen such vertical-axis water wheels, made of wood, busily making flour in Kashmir and in Turkey. They are indistinguishable from ancient Chinese designs, at least to an eye less knowledgeable than Needham's. Some very ingenious and efficient-looking vertical-axis windmills using sail technology, which may have originated in the 12th century, are apparently still
The significance to the developing countries of the Chinese "style" of design of small agricultural machines is that it evolved over a long period of time in regions where the marginal productivity of labour was low and where the contribution of machine technology was primarily to allow more intensive cultivation rather than to save labour. Manufacturing methods can be labour intensive, using a very large proportion of local materials and a very small investment in capital equipment per workplace. According to the authors quoted previously, the modern Chinese economy has even discovered acceptable methods of manufacturing cement, fertilizers, chemicals and steel pipe in small factories. It would be very interesting to know how this is done, whether the techniques could be adapted for other countries, and particularly whether those designs and methods of manufacture of agricultural equipment which do not involve large capital investments can be adapted for use in small rural factories for seasonal operation in developing countries. Abu 'Uthman 'Amr ibn Bahr al-Jahiz, who died in 869 A.D. said, "Wisdom hath alighted on three things; the brain of the Franks, the hands of the Chinese, and the tongue of the Arabs." (Quoted in Needham, 1965, p.602). The first and last-mentioned have not so far succeeded in filling the bellies of the rest of the world.
It is the writer's recommendation that IDRC should consider whether there is any way in which it could co-operate with Chinese technologists in exploring the questions raised above.
4.2 - Manufacture of Consumer Goods and Small Capital Goods by Craft-Type Industries

Aside from agricultural machinery, there are many consumer goods, both durable and non-durable, as well as small capital durables, which can ideally be made in small workshops by labour-intensive methods. Such products can compete on financial and economic grounds with similar goods available on the world market if: they use indigenous raw materials and locally-available skills; they are serving a local market with distinctive tastes or requirements; or designs or fashions are changing too rapidly to allow capital-intensive competitors to take advantage of economies of scale. Some examples are included among the photographs accompanying this report.

Both the pottery and the metalwork are manufactured in the Kisakhani Bazaar area of Peshawar by labour-intensive methods. In the case of the pottery-works, the use of the potter's wheel has apparently almost ceased since the writer's first visit to this same workshop in 1958, because demand is now concentrated on objects which can more economically be made by casting in plaster-of-paris molds. In the nearby cloth bazaar, all of the hundreds of imported Pfaff sewing machines engaged in fancy embroidery-work are now equipped with electric motors, again in contrast to the position 15 years ago. The Thai fish-traps and baskets are primarily capital goods, which are sold in a bazaar which specializes in fishermen's supplies. They are manufactured almost
entirely by hand, although simple mechanical devices are used to facilitate preparation of the materials. Basketwork illustrates the precision and specialization which can be achieved when required by manual methods in series production. In Thailand hats are made in this way, with the wicker inner frame and the outer shell being supplied by two separate cottage or small factory industries to a third small industry where they are assembled. In Taiwan dozens of standard different types of baskets are manufactured for specialized purposes in establishments employing perhaps twelve or fifteen workers each, with almost no mechanical aids. Most dimensions are judged by eye during manufacture, yet the individual baskets of a given standard type nest perfectly and are for all practical purposes identical, even if they come from different workshops. The photographs of the canal-busses of Bangkok illustrates a combination of indigenous and imported technology. The engines and gearboxes of these particular boats are imported, but the motor is assembled in Thailand and the boat itself is manufactured there. (Trucks are handled in a similar way, again by labour-intensive methods.) A Thai manufacturer of engines does exist (Rewan, 1973), but his products are not yet being used in this type of application on large boats.
Among professional economists in the field of small industry there is a current of thought to the effect that industries in the modern sector are the only ones which are likely to survive, and that the traditional carpet-weavers, coppersmiths, potters, and basketry-workers of this world should be eased into other occupations as painlessly as possible. At least, the trend of thought of those associated with Latin American small industry is in this direction. For Latin American conditions they may very well be right. Yet in Asia in many places it can be seen that a slow process of modernization is, in fact, going on among these traditionalists, and they are surviving or even in some cases flourishing. The improvements in efficiency by motorization of sewing machines, by molding pottery instead of turning on a wheel, or by introducing new brass or copper or aluminum products were all made as a result of individual entrepreneurs' or craftsmen's decisions, based on their observations of their immediate surroundings including their market and economic milieu. Their incremental capital expenditures have been small and their operations are continually becoming more efficient at a rate which is, in fact, very sensitively adjusted to their local economy. It appears to the writer that there is little that IDRC can do in the way of research support which would assist such people directly. For one reason, there are too many of them. For another, no one can know their raw materials and markets better than they themselves do. They are the only ones who can
choose between the alternative technologies, materials, and products. However, they must have a basis of knowledge before they can make the choices with respect to methods and materials, and the Centre can help by assisting to provide the information they would need. The extension service operated through the Information Sciences Division appears to be a long step in this direction. It should prove of great value to the industrial sectors in the countries with which it is in contact. It is constrained to act through national agencies, and in any case could not hope to have the resources to deal directly with the multitudes of small industrial establishment in its area of interest. If individual small industrialists or craftsmen are to be made aware of the alternative technologies and methods available to them, from which they can choose in the light of their own intimate knowledge of their markets and milieux, the information must come in their own language and from their own national sources. The strengthening of national extension and information services may be the required next step by which IDRC can be of service to the smallest industrial establishments.
4.3 - Making the Most of Geography

"Western" and "Chinese" industrial science and technology developed, and continue to develop, primarily in areas of temperate climates and under a relatively limited range of geographic conditions, each in response to its own heritage and cultural environment. (There are, of course, other technological traditions and much borrowing among them all.) It would be interesting and potentially valuable to consider whether some developing countries or regions may have geographic endowments which would give them special advantages in some way, but which may not have been taken advantage of because of historical reasons or cultural constraints.

Some of the things which spring to mind are potential sources of energy. Many of the developing countries are of course richly endowed with direct solar radiation for much of the year and some for all of it. Winds, ocean heat and currents, and growing vegetation are some of the other obvious expressions of solar energy which have more restricted distribution but which are nevertheless abundant locally in developing regions of the world. Geothermal energy is also a geographic endowment many of the developing countries to a greater extent than in the industrialized countries, although the latter have so far taken greater advantage of its availability.
Research related to the harnessing of geothermal energy does not appear to warrant the Centre's support at the present time. The UN has for some years been conducting a program to assist those countries which require help, and the technologies involved are by now fairly well understood.

Direct generation of electric power by taking advantage of the temperature difference between deep and shallow tropical ocean waters is another area which does not yet appear to be suitable for the Centre's support, in spite of the promising accounts which have appeared for many years in the technical literature (for example, Claude, 1930, and Othmer and Roels, 1973). A thorough critical examination of various schemes was done by a Canadian consulting engineering firm in 1968 for a private client which included sufficient design work to allow a cost estimate to be made. It showed that minimum costs and maximum benefits were achieved when distilled water is produced as well as electric power, and that the cost of production would depend primarily on the cost of capital and on the capacity factor at which the plant had to operate (essentially, the percentage of the time it operates). The reason for this is that operating costs are very low but capital costs would be very high, so that the fixed charges are the main financial burden which must be charged to the units of energy produced. The small differences of temperature involved (small, that is, in comparison with conventional steam turbine thermal power plants) result in very large
physical dimensions for several of the components, some of which would be unprecedented even if the sea thermal plant had as small a capacity as 7,000 to 10,000 kw. These sizes introduce new problems of design and erection and mean that there is little economic advantage in increasing the capacity of the plant. A rapid increase in unit costs occurs if the plant is made smaller than some unspecified lower limit (primarily because of the deep-sea intake pipe whose length is determined by the offshore site conditions and sea thermal conditions). Even without allowing for profit or for risks due to unknowns, and making the most optimistic estimates of interest charges and capacity factor, the costs of electrical energy and desalinated water would still be only marginal or worse, when compared with alternative available sources at the site in question. Since that study was done, there appears to have been no technological breakthrough of sufficient magnitude to make much difference to those results. (C. J. Brown and R. L. Gudgeon, Acres Consulting Services Ltd., oral communications.) It also appears that the site considered was close to the optimum that can reasonably be expected, so that there is little probability of finding a site where such an installation would be the most economical method of providing electric power and fresh water. This situation may, of course, change as world prices of fossil fuels continue to rise in the indefinite future (if not in the short term). Another possible future change would be the
commercial development of mariculture using the nutrient-rich cooling water brought up from about 1,000 m depth, after it has been warmed by passage through the power plant and ponding in sunlight. (Othmer and Roels, 1973, proposing revisions to a design and cost study, apparently the same as the one mentioned above but incorrectly attributed.) A demonstration plant to study the mariculture aspects is apparently being planned for installation in the Virgin Islands. If the results are favourable, they might have a bearing on the economics of the whole operation, as well as on the possibilities of other uses of cold deep-sea water, as discussed below. It is recommended that IDRC do no more than maintain a watching brief on these experiments.

A second possible use for cold water from ocean depths would be to cool and condense moisture from trade winds blowing across an island shoreline. It is estimated (Gerard and Worzel, 1967) that a condenser, 200 m long and 10 m high, through which the trade winds were allowed to blow, cooled by deep-sea water pumped by a windmill, might condense about 1,000,000 gallons of fresh water per day and supply about 30,000,000 gallons of warmed nutrient-rich sea water for mariculture as well as large-scale outdoor air conditioning for the region down-wind of the condenser. To the best of the writer's knowledge, no critical evaluation of this concept has been made. The mechanical problems and costs are, of course, much less severe than in the case of power
generation, since there are no enormous turbines to design and build. On the other hand, there are problems of heat transfer through the wall of the deep cold-water intake pipe, since it is of smaller diameter than what would be required for power generation, and there are many other engineering problems as well. One would suspect that here, too, there will almost everywhere be more economical methods of providing fresh water (but perhaps without outdoor air conditioning!). However, the economic value of mariculture products might be a deciding factor and once more it is recommended that the proposed experiments on this subject be watched.

Some mention has already been made of the need for small energy sources for water pumping duty in developing-country agriculture. The relation between energy input and agricultural output has recently been reviewed in the U.S. context (Pimentel et al., 1973). In U.S. corn production, for example, it is estimated that in 1970 about 2.8 kcal (in the form of corn at 1,800 kcal per pound) was returned for each 1 kcal of energy input in the farming system. This ratio is thought to have declined from 3.7 in 1945 to 2.8 in 1970. A very large proportion of the energy input is in the form of machinery and gasoline, nitrogenous fertilizer, and electric power. (The solar energy utilized by the plants themselves is, of course, not included.) The danger of this situation spreading to the developing countries is obvious,
in view of the increasing prices of fuels and the future genuine scarcities. It is imperative that the developing countries should not become dependent upon these very highly energy-intensive farming methods, and that alternative sources of energy be available to them, both for on-farm use and for central-station generation. Research on new technology for large central stations is not an appropriate subject for support by the Centre, in view of the large amounts of money being expended by others and the expertise already available (for example, National Science Foundation et al., 1972). India is reported (Energy International, Vol. 10, No. 8, August, 1973, p. 39) to be exploring the possibility of harnessing tidal energy at selected points in respectable amounts, but, judging from Canadian results, it appears probable that studies will show excessive capital costs in comparison with alternative sources.

In the matter of small decentralized power sources, however, there appears to be insufficient backing for research, in comparison with the needs. Some recommendation are made in this connection in Section 8 of this report.

The use of solar energy for other purposes than power generation or water pumping is being explored by several organizations. Brace Research Institute is known for its simple crop-drying and water-still designs and for its fundamental work on greenhouses. A recommendation in Section 8 of this
report relates to greenhouse engineering in coastal desert zones.

The situation of mineral deposits is also a geographical accident from which the developing countries may arrange to benefit. Most of the prospecting done in recent years has been done by large corporations using sophisticated electronic, chemical, and mechanical tools. However, there are techniques based on physical recovery of soil samples, often numbering in the tens of thousands, from large areas, which are labour intensive and can be used seasonally in some areas of the developing world. Improvement in these techniques to the point where they would be taken up and used by the mining corporations or by government survey establishments would be a useful contribution. This type of research, suggested by Dr. Mousseau Tremblay at CIDA, is discussed in Section 8 of this report.

Some of the developing countries are endowed with types of soils which are not commonly encountered in the industrially developed regions, again for reasons of geography. Both agricultural and civil engineers recognize laterite and related soil types. There are also "collapsing" and "swelling" soils with which civil engineers have to contend far more often in the developing countries than elsewhere. The civil engineers' techniques of testing and treatment were developed primarily in north temperate latitudes, and even
standard elementary classification procedures are sometimes inadequate when used elsewhere. There is also an increasing amount of information available in many of the developing countries on agricultural classification and distribution of soil types which the civil engineers are often unable to use for various reasons. The purposes and concepts of agricultural and civil engineering soils classifications and tests are, of course, different, so that some kind of interpretative correlation procedures are needed. Some small amount of work that has been done (for example, Ackroyd, 1963) suggests that good results could be obtained, which would be particularly useful in the field of road design and construction. At the same time, soil mechanics techniques and knowledge from the civil engineering field might be of value to pedologists and other workers in agricultural sciences. In Section 8 of this report, some recommendations are made for work in this interdisciplinary field, following suggestions made by Mr. Raúl Lopez of Acres Consulting Services Ltd. The urgency for fuller understanding of tropical soils, particularly laterites, becomes greater as larger areas of forest are cleared every year. The recent announcement (Novedades, Mexico, 16 December, 1973, p. 3) of the completion of the first trace of the Transamazonian Highway in Brazil is relevant.
There are some developing countries with considerable seasonal temperature variations (and, of course, many industrialized ones as well) where any method of long-term heat storage would be extremely valuable. Some studies of heat storage have been done in connection with energy conservation problems. However, the writer knows of no research on the possibility of seasonal storage. The possible value of such research is suggested by Mr. Tom Lawand of Brace Research Institute.

4.4 - The Construction Industry

Heavy civil construction can in principle be done by machine-intensive or by labour-intensive methods, and this is the field one thinks of first when the question of labour-capital substitution is discussed. Indian and Chinese feats of dam construction by labour-intensive methods are probably the most widely-known examples. Less spectacular but much more common is the exclusive use of manual labour for construction of secondary roads, canals, and so on in many developing countries. Building construction is a relatively labour-intensive operation almost everywhere, but in industrialized countries the trend is for machines to be substituted as much as possible, which usually means less employment of unskilled labour with little change in the requirement for skilled labour. The enclosed photographs include two re-
lated to labour-intensive building construction in the modern sector in Asia.

Heavy construction in the modern sector is biased toward the use of machines by financial considerations. A large structure, such as an irrigation supply dam, might cost US $20 million, for example. If the financing is through loans at 10 per cent per annum, a change of one year in the date of completion is equivalent to a change in interest payments of US $2 million. This amount is the actual saving or the additional outlay of the owner during the actual construction period merely to service the loan. (The figure is not precise, because at the beginning of the final year the whole amount will not have been withdrawn, but it is close enough for purposes of this discussion.) At the same time, such a change in completion date affects the users of the structure. In the case of an irrigation dam, a year's storage of water would be lost if completion were delayed. In the case of a power dam, a year's delay of power production and sales would result, with consequent effects on the date when net cash flows begin to be positive and, therefore, a detrimental effect on the present value of future earnings and on the economic feasibility of the scheme. This type of consideration (greatly oversimplified in this discussion) is one of the main factors militating against the use of labour-intensive construction methods on large projects in all parts of the world.
However, there are many items of work on a large project which do not enter into the determination of the total duration of the job. They are not "on the critical path". The critical path method (CPM), or similar methods of scheduling large construction jobs, is now commonly used. It involves estimating the time required for performance of each of the (perhaps thousands) of individual tasks required to complete a project. These tasks are then arranged in time sequences - the access road must be built before the tunnel excavation can be started, before the concrete tunnel lining can be placed, before the unfilled voids behind the lining can be filled by grouting, and so on. There are many such time sequences branching from one another, and each branch has a duration attached to it. The total duration of the path, mentioned above, from the beginning of access road construction to the completion of tunnel grouting might be, say, 5 years. A different path, leading through access road, river diversion tunnel, coffer dams, dam foundation excavation, dam construction, and filling of the reservoir, for example, might total 4 years. In this case the tunnel sequence would be the one which controls the total duration of the job. It is "the critical path" which must not be allowed to stretch. The other path, however, involves one year of "float" time. An increase in duration of up to one year does not affect the duration of the total job. In grossly oversimplified form, this is the concept of the CPM of project construction planning. The resulting very
elaborate network is used for checking progress during construction, essentially in order to make sure that the items on the critical path are being completed in their allotted times, and that items not on the critical path are completed before the expiration of their "float" times. (Of course the process is not as simple as this summary suggests.)

The point of this discussion is that there may be ways of designing and scheduling parts of a project to allow the use of labour-intensive construction methods without incurring financial penalties due to early starting or late completion. This would be possible if the chosen parts of the job are those which are not on the critical path. Of these items, only some will prove to be amenable to labour-intensive methods. Others might be amenable to redesign (perhaps stone masonry instead of concrete, etc.) within limits. The labour-intensive methods would usually require an earlier start on each item, in order to allow completion within the allotted float time, and such rescheduling has a deleterious effect on cash flow. However, the use of less capital equipment has a favourable effect, in view of the long lead-times required for purchase and shipping of heavy construction equipment (as was pointed out by R. Lumsdon of Acres Consulting Services Ltd.). The balance between such items would vary from project to project.

This whole subject is a very interesting one from the point of view of job-creation and the economics of the public works sector of many of the developing countries. In Section
8 of this report a project is recommended to investigate the implications.

Basic information is needed if such considerations are to be applied in practice. It is necessary to know what the financial costs are of various degrees of labour-capital substitution in different construction operations. Some studies are underway on this subject (International Bank for Reconstruction and Development, 1971. International Labour Office, 1973, P.8) but it is doubtful that generalizations will be useful. It will probably be necessary to estimate the duration and the cost of different methods of performing each operation in each project in each country as the need arises. This would enormously complicate the job of estimating the cost of construction projects, but such estimating will always be a very small fraction of the total work required on big projects.

Additional problems arise from the nature of the international contracting system which applies to most big construction jobs in developing countries. International civil construction contractors generally prefer capital-intensive construction methods even when labour-intensive methods are equal in cost and quality of product. The reason for this preference is that labour costs in many countries are less predictable than machine costs, and in most cases the contractors are required to bid for the work on the basis of competitive
unit prices five years or more before the work will actually be completed. In order to protect themselves, they will include in their prices an undisclosed allowance for future cost increases during the construction period. In the case of a labour-intensive construction operation this hidden allowance would be large if the contractor believed that wages were likely to increase substantially. Thus, the owner's insistence on labour-intensive methods being used for a substantial part of the construction would often result in a high capital cost, even though the actual cost to the contractor might be equivalent to machine intensive construction.

There is a whole complex of considerations involved here. How to provide the safeguards which will reduce or eliminate this practice of hidden allowances for contingencies; should the risk be transferred from the contractor to the owner as a material expression of the meaning of the term "shadow wages"; what type of contract to use, and what specific phraseology to insure that the contractor actually uses the methods specified - these and more such questions could be usefully explored in a research project.

An additional important one, which is more sensitive in the political sense, arises from the nature of the contractual relation between the developing country agency or government and the source of funds, in cases where large projects
are partly funded by overseas loans or grants. Where such funding is to be used only for the foreign exchange costs there is a strong disincentive to press for labour-intensive construction methods. This is one of the hidden reasons (in the writer's opinion) for the resistance to labour-intensive construction methods which developing-country officials sometimes exhibit. This would be a difficult subject to investigate, but could perhaps be attacked by a funding agency through examination of its own practices and of the results of different types of loan agreements.

Many smaller-scale research projects on the construction industry are needed as well. Standardization of methods of testing materials, such as timber, could be undertaken by government laboratories in many parts of the world. Some comments on this subject (suggested by T. M. Wardle of Acres Consulting Services Ltd.) are included in Section 8, as a typical example.
5 - TYPICAL INSTITUTIONS

5.1 - Industrial Research Centres

Industrial research centres sponsored by governments in the developing countries can be identified in listings such as the WAITRO Directory (World Association of Industrial and Technological Research Organizations, 1973). However, many of those listed do not actually perform research themselves. One which does was visited during this study. It is Applied Scientific Research Corporation of Thailand (ASRCT). It is about 9 years old and is under the jurisdiction of The National Research Council of Thailand. At the time of the visit its staff included Mr. Martin Bell from the Science Policy Research Unit at the University of Sussex, so in a sense there was a connection with IDRC through that route. A discussion was held with Dr. Kassem Balajiva (Director, Technology Research Institute), Dr. Narong (Agricultural Research Institute), Dr. Phipit (Economic Studies Group) and Dr. Bell. The writer had the impression that all these gentlemen are competent in their fields of specialization and that Dr. Kassem, in particular, has thought a great deal about the place of his Institute in Thailand's future.

Since ASRCT was set up the nature of the Thai economy has changed, with the growth of an industrial sector heavily concentrated in the Bangkok area, increases in production of irrigated crops, and in many other ways. The staff now
question whether the original terms of reference and emphasis are still adequate and suitable to existing conditions, and they have no way of answering this question, either affirmatively or negatively. They feel an urgent need to find out where the Thai market for their services is. Their work is financed by contracts (mostly with government agencies such as The National Energy Authority and National Economic Planning Board) and to a small extent by royalties from products they have helped to establish (mint extract for the production of menthol for cigarette manufacturing was mentioned), so that their future financing depends to a great extent on their being equipped to handle the types of research in which such contracts are likely to be offered. They suspect that there are many areas where they could offer their services and equip themselves, both in facilities and in professional specialists, but they lack the data base. They say that no complete adequate up-to-date survey of Thailand's industrial establishment yet exists and survey of research needs has not yet been started, so that they do not know in what directions they should be preparing to specialize in order to meet future demands.

This is a problem common to many research centres. For IDRC it raises several of the policy issues discussed by the President last year in Bogotá (Hopper, 1973). The Centre's mandate "to assist the developing regions to build up the
research capabilities, the innovative skills and the institutions required to solve their problems" would have to take precedence over its other objectives if it were to award research contracts to such institutions in fields with which they are not already familiar. The Centre would have to consider the possibility of assisting such institutions in determining what the research needs of their own countries are, by means of national surveys of the type which these ASRCT staff members desire to do, which would be contrary to usual Centre practice. In the field of industrial engineering and technology there will arise many cases where a need is, indeed, confined to one nation. For example, if Thailand were to establish a steel industry of any size, there would be a larger market for research in refractories technology, using indigenous Thai resources to produce a group of products primarily for this industry. It is unlikely that the results of this specialized research would be immediately applicable to the problems of other countries. Indigenous Thai capital is unlikely to finance such research because the equivalent products can be imported, and yet it is probable that Thai capital would interest itself in the refractories industry, if the necessary industrial research had been done and other conditions were appropriate.

In other cases research results would be more widely applicable. If the Central Power Research Institute in Bangalore were to
undertake research on wind-powered generators, as they are reported to be doing (Energy International, Vol. 10, No. 8, August 1973, P.39), then their results may be widely and internationally applicable and there may be less reluctance on the part of the Centre to support such work.

5.2 Agricultural Research Centres

There are an increasing number of such centres, with which Officers of the IDRC are well acquainted. The writer's visits to two of them were concerned only with the industrial engineering aspects of their work. One of them, The International Rice Research Institute (IRRI), is physically located in a developing country, and the other, the Brace Research Institute, is in Canada. Both are doing excellent work in different parts of the field of interest, and both would be worthy of Centre support on the basis of solid results achieved, if there were no other considerations. Under certain circumstances support of industrial and engineering research and development work at both of these centres (and at similar ones) could also be justified in aid of all four of the objectives listed inside the covers of IDRC publications (for example, International Development Research Centre, 1973, p. 104)
5.3 - Universities

There are specialized technical universities and polytechniques in many of the developing countries, as well as graduate schools such as Asian Institute of Technology and Middle East Technical University, many of which contain the experts and the facilities for certain types of relevant research. Each application would have to be judged on its own merits and those of the institution from which it comes. However, provincial universities have not received much attention and they are worth considering as a class of institution.

In at least some Asian and African countries (to a lesser extent in Latin America) university staff may find themselves with a considerable amount of time free from teaching duties each year. In one southeast Asian country a few years ago, the national university had semesters totalling almost exactly half the year. It was assumed that professors of science and technology would do research for most of the remaining half-year, and there were some funds available for equipment, etc., to support such work. This university is in the national capital of a country which evidently values higher education enough to invest heavily in it. Professors were allowed to undertake only very limited industrial consulting work, and their rates of pay were at least adequate to make such restrictions financially acceptable.
In contrast, in a few Latin American countries in which the writer has lived there is very little opportunity for personal involvement in research on the part of most of the university staff, although many supervise research performed by students. The staff themselves are busy with professional practice or consulting work.

In both of these cases the teachers are more fortunate than the average staff member of a provincial university in a developing country in Asia. With time available, he finds himself able to obtain neither support for research nor part-time remunerative work, which increases the difficulties of those who must support their families at the usual low wage scales. In order to gain an impression of the capability for useful research which might be hidden away in such places, the writer visited two of them: Peshawar University in Pakistan and the University of Science, Penang, Malaysia. These proved to be good fortuitous choices, as they probably illustrate almost the two extremes of the scales of both need and capability in provincial universities in Asia. One is a bustling, new institution in the process of rapid expansion, staffed with a large proportion of relatively young and bright people from various cultures, most of them with a large workload and claiming to do as much research as the present staff and facilities can support. The other is an older established institution which is also increasing in
physical size and capability (under the guidance of a new and energetic administration) but which concentrates almost exclusively on its students and devotes little of its energies to research, for lack of resources as much as for any other reason. Both have in common that many of their students are from rural or non-metropolitan backgrounds and remain in touch with their home areas.

At the Universiti Sains Malaysia the writer met the Vice Chancellor, Professor Tan Sri Hamzah Sendat, who was kind enough to grant an interview on very short notice. The university is only a few years old, although it is affiliated with the older institution at Kuala Lumpur. It had about 240 teachers and about ten times that number of students, of whom 40 were working for higher degrees for which theses are required. Most of the university funds come from the government budget and from fees, but the university accepts research contracts within the limits of its capabilities, which are growing rapidly. It is working with the University of British Colombia on collaborative research in marine science and with UN-IBRD support at a fisheries research station. Among the other areas of applied sciences in which they are doing or hope to do research are: in physics, solar energy; in chemistry, rubber technology, palm oil, paper, textiles, plastics, phytochemistry and pharmaceuticals. They also have an active group in social sciences, and a School of
Housing, Building and Planning, which will concentrate its research efforts in the field of low-cost housing. The research is done both by staff and by students under supervision and guidance. Supporting research at this university would contribute to several of IDRC's objectives, and one comes away from a brief visit with the impression that results would be obtained within budgets and probably even on schedule.

At the University of Peshawar the writer met and talked with three professors individually. Prof. Mohammed Jan Khan is head of the physics department of the affiliated Islamia College. Prof. Abdul Matin is in the Department of Economics and is former Chairman of the Board of Economic Enquiry for the Northwest Frontier Province of Pakistan, while Dr. Jamal Khan is Professor of Mechanical engineering and is reported to be about to rise to higher responsibilities. All are obviously active and intelligent men, and are reported to be experts in their respective fields. The Vice Chancellor of the University, Dr. Abdul Ali Khan, is said to be a dynamic personality who has made many changes since he assumed this office. The university is undergoing a building boom, as is the region around it which, when the writer lived there in 1958 - 1959, was a farming district outside the city. (It is located beside the road from Peshawar to the Khyber Pass, leading to Kabul, so it has never been really isolated.)
The University has about 400 staff members, many of whom would be free of teaching duties for almost half of each year. However, the opportunities for productive research are few and, indeed, probably only a handful, such as Professors Abdul Matin and Jamal Khan, would be capable of doing productive independent research at a high level in subjects of possible interest to IDRC. (Professor Mohammed Jan Khan is not being slighted in this assessment. His professional interest is in theoretical nuclear physics, which is not a field of research the Centre is likely to support. This guess is, in any case, only the uninformed estimate of a layman.) Students are not required to present theses for higher degrees, so little or no research is being done in this connection. Few staff members have any experience of preparing research proposals. In many subjects the University lacks basic documentation, bibliographies, and journals. Nevertheless, Professor Abdul Matin has done a few co-operative research projects in socio-economic fields with multi-disciplinary teams.

At the present time it appears that research work of high quality could be done only by a very few of the University's staff. Outside sources would have to provide documentation services, part-time expert guidance, and financial help. The requirements would, of course, vary from subject to subject. It would take some time for experience to be accumulated in the course of one or more projects in each special field.
before capability was developed for independent research work by a significant proportion of the staff. (This remark, of course, excludes the handful who already have this capability.)

On the other hand, the University has several advantages. It is staffed to an important extent by people who were born and brought up in villages or provincial cities in its own province. They are acquainted with local problems and are interested in them. Their students are also primarily from Peshawar and from the NWFP. Finally, there are many "researchable" problems waiting for attention. Here and in similar institutions is par excellence the opportunity for IDRC support "to assist the developing regions to build up the research capabilities, the innovative skills and the institutions required to solve their problems". The secondary benefit of improving teaching capability of the University is also appreciable.

There are many types of projects which could be undertaken by such universities. At Peshawar, for example, multidisciplinary teams from agricultural, economics, and engineering departments could probably undertake work related to agricultural implements and equipment, brick and concrete products, kacha (adobe) construction, soil properties related to agriculture and civil engineering, and many other areas requiring low cost equipment or equipment, such as
standard strength-testing machines, which the departments already have. Outreach programs to the bazaar industries in the nearby cities would be feasible, given money and backing, as well as feasibility studies for new industrial ventures.

It is difficult to imagine any type of program which would be more difficult to administer than such projects at such institutions. In comparison with the efforts expended, research results would be few for some years, and effects on the local economy would be even slower to manifest themselves. In the longer term, however, these could be very productive programs since so little has been done along the lines of the provincial university in its provincial setting. It is recommended that the Centre give serious consideration to both the advantages and the disadvantages of coming to grips with support of industrial and engineering research at such places.

5.4 - Government Service Laboratories

This phrase designates the laboratories of the Ministry of Public Works, the Ministry of Agriculture, the Meteorological Office, the Ministry of Health, etc. Most developing countries have at least the organizational framework for such laboratories, and in many there are fairly elaborate labora-
tory facilities for a few departments which happen to have had important roles to play in the past, such as the Roads and Bridges Department of PWD or the analytical chemistry laboratory of the Public Health Service. In some cases, as in Canada, provincial governments will also have some of these facilities.

It is quite common to find that a government laboratory is run by one or a few competent but overworked scientists or engineers, assisted by as many unskilled or semi-skilled labourers as they can use, but with an extreme scarcity of skilled technicians. As the Centre is aware, technicians are among the rarest of birds in most developing countries. From land surveyors to river gaugers, from agricultural extension workers to outboard-motor mechanics, their value is often not recognized and few incentives are provided to induce people to become technicians in many countries. The government's departmental laboratories suffer very seriously in consequence, and financial support will not, at least in the short term, help them to solve this problem. This must be kept in mind when considering the support of research in such laboratories. This said, however, it appears to the writer that serious consideration should be given to the fact that many of these laboratories could, under certain circumstances, do valuable research and development work in addition to their routine duties. Because of the shortage of
technician-level employees, they often contain equipment which is underutilized. They are often headed by competent people who are well acquainted with their region's needs and who have thought for years of ways of attacking particular scientific or engineering problems. In many cases the addition of one technician and a few instruments might produce disproportionate results, provided they were reserved for innovative work. It is recommended that, particularly in the field of standardization of materials testing (timber, soil mechanical properties), consideration should be given to this type of support for this type of institution. The writer can make no suggestions on how to penetrate the hierarchy involved in reaching the heads of such laboratories, who are often relatively low on the civil service ladders.
6 - ACKNOWLEDGEMENTS

Many people were consulted directly with requests for advice. Some of this advice is incorporated in this report and some is not. In many cases its omission is due merely to a lack of ability on the writer's part to evaluate it. The writer assumes full responsibility for the interpretations he has placed on advice from others, and regrets if any contributors have been inadvertently omitted from the following list.

IDRC
J. H. Hulse, Ottawa
N. Kappagoda, Singapore
E. Tono, Bogota
L. Wong, Singapore

CIDA
S. Free, Ottawa
M. Tremblay, Ottawa
L. Bailey, Bangkok

IBRD, Washington
A. Churchill

IDB, Washington
H. Schwartz

ADB, Manila
T. C. Mesmer
Brace Research Institute
T. A. Lawand

IRRI, Los Baños, Philippines
N. C. Brady
J. K. Campbell
B. Duff
F. E. Nicholls

ASRCT, Bangkok
M. Bell
Kasem Balajiva
Dr. Narong
Dr. Phipit

Universiti Sains Malaysia, Penang
Hamzah Sendat

University of Peshawar
Jamal Khan
Mohammed Jan Khan
Abdul Matin

AIT, Bangkok
G. Chang
H. E. Hoelscher
S-L Lee
UN-ilo
C. Baron

UNRISD
W. Scott

UNIDO
I. Krestovsky
J. Levitsky
B. R. Nijhawan
H. Schwoerbel

Acres Consulting Services Ltd.
C. J. Brown
P. J. Denison
G. Gardner
R. L. Gudgeon
W. G. Lockett
R. Lopez
R. Lumsdon
I. W. McCaig
R. A. Pillman
S. L. Sunnak
T. M. Wardle
REFERENCES (Publications referred to in the text are listed. Many others were consulted.)


References (Cont'd)


References (Cont'd)


8 - PROJECTS

8.1 - Industrial Extension Service

There appears to be a need for a service, with similar objectives to the one now being operated by the Centre in Singapore, to serve the smaller Latin American countries. A Mexican government agency has made a tentative beginning, and it is recommended that IDRC explore the possibility of co-operation with a view to extending and strengthening this service. An alternative or additional possibility is the proposed Latin American Commission for Technology Applied to Small and Medium Industry, which is mentioned in subsection 3.1 If the sponsors should succeed in establishing such a commission, it too could serve this function, and it is recommended that IDRC observe and offer assistance.

It is recommended that methods be explored of strengthening the national industrial extension services in each country in order to provide to small industrialists the knowledge upon which they can base intelligent choices as they adjust their products, techniques, and materials to their changing markets.
8.2 - Agricultural Machines for Local Manufacture

It is recommended that the experience of the IRRI machine development program be critically evaluated, particularly the aspect of user acceptance and the spectrum of socio-economic effects, including changes of employment on farms and in factories. It is anticipated that data will soon be available from which some tentative conclusions can be drawn. IDRC might then consider whether to support a similar program for the design and development of equipment for crops other than wet rice. Such equipment would be intended to improve cultivation practices for higher yields and greater cropping intensity, rather than for saving labor. It should be simple enough to be manufactured in the kinds of facilities likely to be found in small cities, rather than in the metropolitan areas. Since such simplicity is likely to imply a lack of adjustability, a variety of small manufacturers in a variety of centres would be encouraged to produce it for sale, making whatever minor modifications their local market conditions demand. IRRI machines now being manufactured by at least some, if not all, of the Philippine firms involved in that program are proving financially competitive with imported equipment for the same purpose, where such equipment exists. The Centre's own experts will be better able to recommend what specific types of machines might be considered, for what crops, and where the research might be done.
Consideration should be given to the inclusion, among the models considered, of modern Chinese types of simple agricultural machines, in order to broaden the cultural base and eliminate some of the unconscious assumptions of machine designers of the Western tradition. If adaptations of such machines should prove to be suitable for use in other areas and conditions, they might prove to be appropriate products for small seasonal rural workshops and factories (see 8.3), especially if the major parts can be made of wood.
8.3 - Rural Factories and Seasonal Manufacturing

An attempt should be made to examine Chinese experience in the field of small rural factories manufacturing both capital goods and consumer goods by labor intensive methods. In particular, it would be valuable to know whether their methods of manufacturing cement and fertilizers on a small scale are adaptable to other countries' conditions. It would also be valuable to know whether any of the small industries involved have low enough capital equipment requirements to permit their use only seasonally, in order to provide alternative employment during slack agricultural periods.

It is recommended that, if IDRC should decide to make contact with Chinese engineers in order to initiate a sharing of experience, informal guidance be obtained from Mr. Carl E. Rufelds of the Trade Commissioner Service, Department of Industry, Trade and Commerce.

For a recommendation regarding modern small Chinese agricultural machines, see 8.2.
8.4 - Awareness Services

There are several fields of science and technology in which advances are rapid and which will soon, or are already, producing knowledge and techniques which could be of great interest to some developing countries. Existing and proposed methods of deriving energy from the sun and from winds are examples. Remote sensing of geographic data is another. It will soon be possible, at least in certain geological circumstances, to predict earthquakes. These applied scientific subjects will probably all experience breakthroughs in the next few years. IDRC should consider whether it can assist the developing countries in setting up bureaus which would undertake to keep abreast of current developments in these and similar fast-moving fields, and to inform corresponding bureaus in other countries of news of interest to them. In order to sharpen perception and to improve judgment, as much as to produce research results, such bureaus probably should have research institutes attached to them, specializing in research in the particular subject in which the bureau is interested. In some cases it might be more efficient to work from an existing research institute to the information service, rather than vice versa.

This suggestion originates with Mr. Tom Laward of Brace Research Institute.
8.5 - Solar Energy for Prime Movers

Aside from the awareness service in solar energy developments recommended in subsection 8.4, there appears to be a need for small power sources which can operate remote from power lines and, if possible, without fossil fuels. One typical duty would be pumping water from wells. Solar energy would be a suitable source in many areas, but relatively little attention is being paid to small-scale development for farm users. Solar energy in the form of wind is one possibility, and units are already available in suitable sizes, although costs are still out of reach of most developing country farmers (see 8.6). Direct use of solar radiation needs additional study.

It is recommended that the Centre support research on integrated systems (prime mover plus pump plus linkage between them) for water pumping duty, making use of the difference in temperature between cool groundwater and solar-heated collectors as an energy source. Efficiencies can be low, and solar ponds could be considered for heat storage, which might permit overnight duty. Heat engines of the Rankine or Stirling type, using external heating, could be considered. The efficiencies of solar ponds can be increased by inducing density gradients to prevent convective cooling and probably also by dyeing the water to increase energy absorption.

Large scale power generation by harnessing solar energy stored in sea water of contrasting temperatures has been
advocated for many years. There is evidence (subsection 4.3) that this cannot yet be an economically competitive technique. However, recently proposals have been made for combining this with mariculture which would produce additional revenues, and pilot studies are being planned. No activity on the Centre's part is recommended, other than remaining aware of developments in this field.
8.6 - Wind Power Feasibility Study

An economic feasibility study is recommended to estimate the market potential of small wind-power devices in 1-2 and 5-10 hp ranges for such duties as water pumping. The worldwide geographic and temporal distribution of low-level winds would be surveyed, initially by use of existing detailed data. Attention would be paid to sea breezes related to shorelines. The number of potential users would be estimated for different selling prices and the manufacturing costs estimated for various scales of production. If preliminary studies of this type show that economies of scale could be important enough, then further pilot plant work could perhaps be promoted under other auspices.
Mr. Tom Laward of Brace Research Institute suggests that environmentally designed greenhouse complexes could be developed which would use a minimum of electric power and fresh water, for siting in parts of the 20,000 miles of coastal deserts of the world. The greenhouses should to a large extent be controlled, closed-cycle systems, probably utilizing carbon dioxide enrichment from external sources. Several lines of investigation would be required, including the needs for fertilizers and other agricultural chemicals. The bulk of the research would be that of engineering adaptation of known technology, but original scientific research will also be required.

According to Mr. Laward, a complex of this general nature has been operating for several years in Abu Dhabi, which performs a technical function but has had indifferent socio-economic impact. Guidance from related previous experience is thus available to assist the researchers.
8.8 - Scheduling Construction for Labor-intensive Methods

The object of this study would be to use the critical path method of construction scheduling and planning to increase the labor intensity of heavy construction projects in selected cases. To avoid unnecessarily prolonging the construction of a project, with consequent financial and economic penalties, those parts of the construction operations which are not on the critical path would be selected. The financial penalties of prolonging individual operations would be compared with the financial benefits of avoiding early purchase of heavy equipment. The possibilities of redesign of structures to facilitate and to take advantage of labor-intensive construction methods would probably also have to be explored. The subject is discussed in greater detail in subsection 4.4.

The use of the critical path method (CPM) or similar methods is now accepted practice in scheduling and managing large construction projects, but it is likely that no attempt has been made at optimization from this point of view. Such a study should be correlated with a parallel study on contractual implications (subsection 8.9).
8.9 - Contractual Methods in Large Capital Projects

The loan agreement as a form of contract between the borrowing developing country and the international lending agency would be a difficult but possibly rewarding subject for research. There are provisions in many such agreements which provide incentive for the borrower to prefer as capital-intensive methods as are available for construction in order to economize on domestic expenditures.

The international contract tendering system also has a built-in bias which promotes capital-intensive construction methods. The general types of construction contracts which are commonly used are:

(a) Time-and-materials contracts
(b) Unit-price contracts
(c) Target-type contracts
(d) Turnkey contracts.

There are some variations and combinations. Case studies could be done of typical examples of each of these, perhaps taken from the files of a lending agency or a co-operating international contractor or consultant, analyzing the incentives that would have been required in each case to induce the contractor to employ more labor-intensive methods. This would probably lead to consideration of methods of assuring contractors of stable wage bills for the duration of a construction operation, perhaps including a review of current
practices in Canada and their possible applicability to developing country conditions.
8.10 - Secondary Effects of Artificial Lakes

Man-made lakes for storing water, for irrigation or hydroelectric use, have secondary economic effects which are difficult to predict and are in any case different in each case. Mr. T. Mesmer of the Asian Development Bank suggests that there are very few studies of existing cases which express their results in economic terms and that such studies would assist project appraisers, both in developing countries and in funding agencies, in evaluating the total economic costs and benefits of proposed reservoirs. The project would include a review of such ex post studies of this type as exist, and would select one or more additional cases for investigation. Reservoirs with a variety of economic consequences should be chosen, if possible, including effects on sedimentation and erosion, ground water levels, fisheries and forestry, public health and occupation, and so on, and the economic effects of the changes caused by the existence of the reservoir would then be rigorously evaluated.
8.11 - Labour-intensive Prospecting for Minerals

In recent years, an increasing amount of literature has become available on the subject of trace-element content of common minerals and of minerals associated with ore deposits. In some cases, there are peculiarities of chemical composition of the common minerals which might serve as guides in the search for ore deposits. Some of the common minerals persist in soils derived from the parent rocks in which the minerals were originally formed. In such cases, analysis of the soil, and particularly of selected mineral fractions, can be used as one of the tools in prospecting. Samples of soils obtained from a grid of stations spread over the area of interest (which may be very large, measureable in hundreds or thousands of square miles), would be treated to concentrate the mineral species of interest, which would then be analyzed to determine its trace content of the indicator element. The collection of samples is a labour-intensive operation which could be done seasonally. The separation of the mineral of interest, and particularly the chemical analysis, are operations requiring sophisticated technology, and they would be done in a small laboratory working all year.

Somewhat similar (but much less refined) methods of geochemical prospecting have been known for twenty or thirty years, but are now less widely used because of the increasing
cost of labour as well as the increasing availability and capability of geophysical methods. Dr. Mousseau Tremblay of CIDA is of the opinion that refinement of the geochemical methods along the lines suggested would probably result in their greater use, with consequent increased employment in the dry season, by mining companies and government mineral surveys in parts of Africa and perhaps in other areas. The first step in studying such methods would be to review and summarize existing information which is in several languages. Such a review could perhaps best be done at one of the West African universities or government survey offices.
Traditional disciplinary boundaries have resulted in divergence of interests and a proliferation of systems of classification of soils for agricultural and civil engineering purposes. From the civil engineering point of view, there appears to be a wealth of soils information collected but unavailable to the civil engineer because of his usual lack of familiarity with the implications of the agricultural classifications, testing methods, and objectives.

The significance of the various soil types shown on regional soil maps is thus lost on the civil engineering profession. However, within civil engineering practice, many of the required properties of soils (permeability, shear strength) can be deduced from more easily observed properties (gradation, density), and it is probable that they could also often be deduced from the parameters which are used in agricultural classifications and mapping of soils. The correlations would vary from place to place and it would probably be impossible to generalize over large areas. A series of local studies, by co-operative groups in limited areas, would be needed, with regional and finally international exchanges of experience. Other co-operative efforts would also be valuable. Such interdisciplinary studies would probably also result in improving understanding in both disciplines, as each has experience in soil mechanics, physics and chemistry which is not easily accessible to the other.
Mr. Raúl Lopez has reviewed this subject at the request of the author, and has made detailed comments upon which the above statements are based.
Machine methods of classifying structural timber have been developed which permit a considerable saving of materials, as compared with manual quality control. The machines are simple types and need not be confined to use in industrialized countries. Apparently, there are no designs available for use with hardwood structural timber. Consistent methods of classification would enable less over-conservative designs to be used for timber construction, with consequent economic effects which would probably include the choice of timber over competitive materials in more cases in both developing and industrialized countries. The adaptive design of such machines for use with many species of hardwoods in developing countries might thus have important effects. The Centre has available to it the expert advice of Mr. John Bene, and the writer recommends that his opinion be solicited.

Once structural properties have been determined, then measures could be taken to promote the use of timber construction by making available to engineers and architects such things as performance design codes, design aids, standard designs and specifications for each country where there would be significant benefit in promoting timber construction. Since the harvesting of timber can be a seasonal occupation, the effects on employment should be considered a positive contribution, at least in predominantly agricultural areas. Such work can probably be undertaken in government
standards institutes or testing laboratories.

This suggestion was made by Mr. T. M. Wardle of Acres Consulting Services Limited.
An attempt has been made here to present to IDRC a selection of possible projects from a variety of disciplinary fields, all having in common the promotion of industrial development of the less developed countries. Emphasis has been placed on the labour-intensive sectors. In the foregoing, there has been a certain concentration on projects related to natural resources, particularly energy. However, there are many others where contributions would be equally valuable.
Fig. 1 and 2. Traditional technology, Thailand. Basketry fishtraps and baskets and the market where they are sold in Bangkok.
Fig. 3 and 4. Traditional technology, Pakistan. Metalwork bazaar in the city of Peshawar.
Fig. 5 and 6. Mixed technology, Pakistan. Pottery factory in the city of Peshawar. The products offered and the molds which have replaced the potter's wheel.
Fig. 7 and 8. Mixed technology, Thailand. River boats at a "bus terminus", Bangkok. Power units are imported, shafts and propellers are locally made, and boats are traditional but use imported decorative elements.
Fig. 9 and 10. International Rice Research Institute, Los Baños, machine design program. Machine shop and prototype unit being assembled.
Fig. 11 and 12. IRRI, Los Baños. IRRI-designed agricultural machines.
Fig. 13 and 14. Building design for labour-intensive construction. Above, the monument to Qaid-i-Azam Mohammed Ali Jinnah, Karachi, faced with polished marble blocks. Below, scaffolding covering walls of commercial construction in Bangkok is for manual finishing of external surfaces.