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PROBLEMS OF APPLIED INDUSTRIAL RESEARCH

in

DEVELOPING COUNTRIES 1/

by

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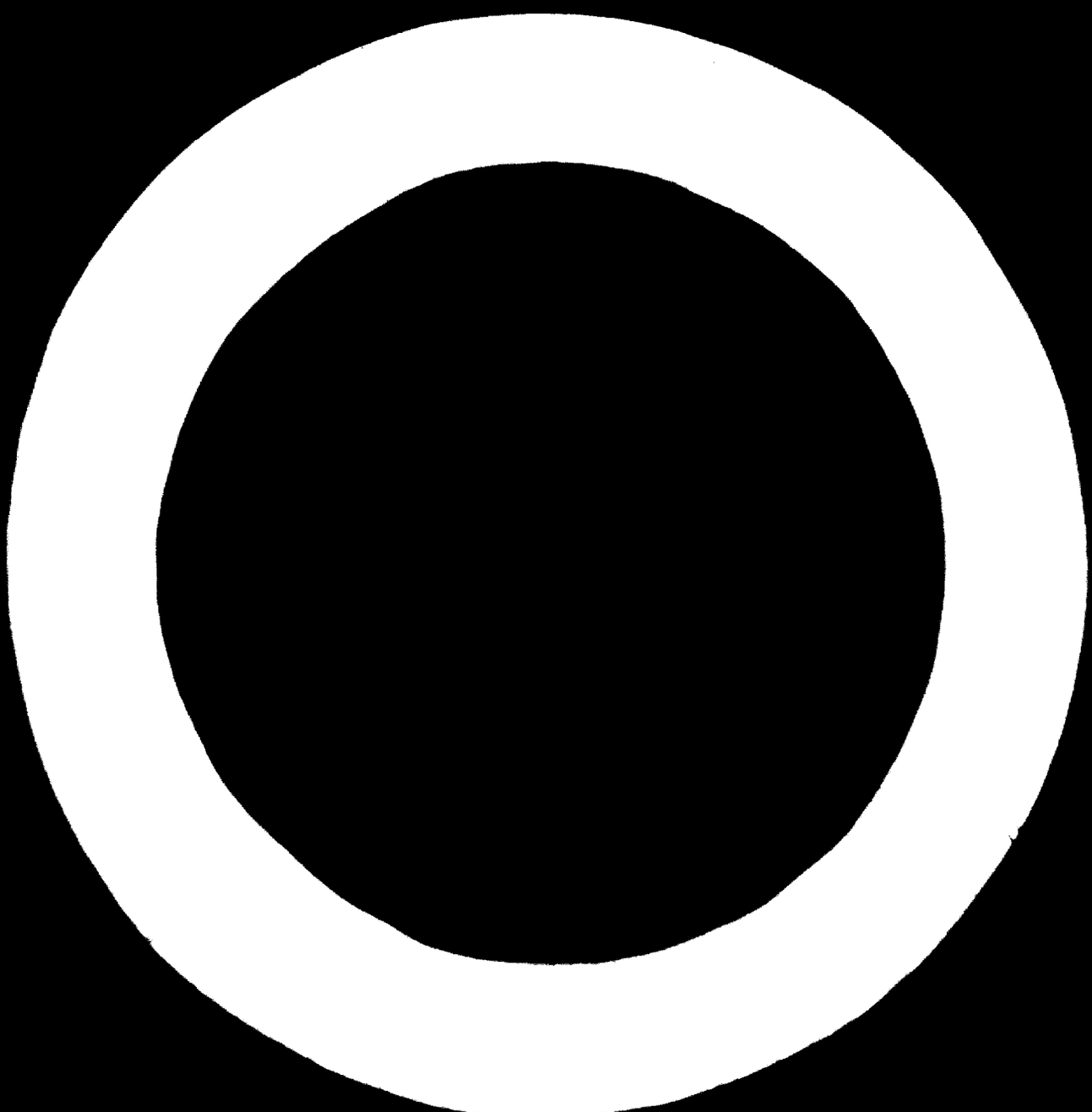


I INTRODUCTION

Each year the world, through increasing communication between countries and within countries, is becoming smaller, the people more confused and frustrated, and the general order of things more complex and often disrupted. For some countries the disparity between standards of living become greater, and the awareness of the disparities become more obvious, particularly to those with less. We are concerned not only with disparities between nations, but also within nations.

One of the keys, and only one of them, to overcoming poverty lies in the useful application of science and technology. Unfortunately there is no one set format for the effective application of technology to a country; often much time, effort and money is expended to little avail; sometimes the technological application serves only a small segment of the population.

A shift that is taking place to an increasing extent in most countries is the concentration of people or urbanisation. Not only in developed countries but also in developing countries, urbanization is creating new and intense problems, those of social impact. Many of the problems have arisen because of technology itself, and technology will be required to solve these as well as others in the future.

On one hand the developing countries are fortunate in that some technological pitfalls of the developed countries may be avoided; on the other, the developing countries have great distances to bridge in development. It is most important that full thought be given to technological planning in developing countries, at least in broad outline. Some of the more important factors and difficulties will be considered here.

In discussing the problems of industrial development as they relate to industrial research institutes (IRI's), four industrial research institutes will be referred to during the presentation: the Jamaica Scientific Research Institute (JSRI), which has been operating for twelve years; the Instituto de Investigationes Technologicas (Colombia) (ITT), also operating for twelve years; the Centre for Industrial Research in Israel (CIRI), now only in its fourth year; and B.C. Research (BCR), now in its twenty-seventh year. In the short time available for preparation of this report, a brief questionnaire was sent to the first three institutes seeking information bearing on the topic of this paper. To preserve anonymity, the names of the institutes will be used sparingly.

The inclusion of BCR with the other institutes may be questioned. This was done intentionally to include a small institute that had progressed to a stage or two beyond the others, to illustrate the problems that may arise at later stages of development of an IRI. Also, whereas BCR may be regarded as an institute of a developed country, it is in fact in a corner of Canada whose secondary industry is relatively underdeveloped.

II INTEGRATION OF INDUSTRIAL RESEARCH IN THE ECONOMY OF A COUNTRY

Figure 1 is a simplified schematic presentation of the technological interrelationships within a developing country. A government has the responsibility of providing technological facilities and services for many public needs; agriculture, fisheries, health and welfare, education, establishment of infrastructures, power development, water quality, possibly housing, birth control and, before long, pollution control. The industrial operations may be privately or government owned, or both within the same country. In any case the sales generated from the industrial operations provide a circulation of money to a portion of the population, provide support for government services through taxes, and provide a profit either to the state or to private investors.

Classically, in the older developed countries, industries have to a large extent both originated and developed within the same countries; in developing countries the cycle is shortened by the import of technological industries, usually as branches of operations in more developed countries. Technological know-how, investment capital and management are introduced, national people employed, taxes paid, and profits either reinvested in the country or exported (Figure 1). Whether or not the arrangement is equitable to the developing country is often difficult to assess. (Canada has been worrying about this for some time).

The IRI has a very real part in the technological chain. It must provide those technological services required by the industrial plants, such as physical, chemical, and biological testing; trouble shooting; feasibility studies; and later, more sophisticated services such as operations research, industrial engineering and productivity studies. The IRI has also a tie-in with government, for it must seek solutions to problems of social impact, such as housing, communication, transportation, and pollution control. The IRI is also often called upon to undertake standards evaluation and performance approval on products manufactured in the country or imported - an important foundation to a sound industrial economy. Usually, the IRI should not seek to become a true research centre for many years, until industry has developed to the point where research is demanded. In the early stages of industrial development, the IRI can give great service by undertaking techno-economic studies and analyses of new investments, such as have been successfully carried out by IIT, resulting in investments in Colombia amounting to 250 million dollars (U.S.).

The continuing success of industrial development within a country depends on the establishment of a suitable "industrial climate". Some of the main requirements are: stable and cooperative government, a stable and vigorous labour force, and the development of national managers. One of the IRI's reported that the greatest obstacle to industrial development in its country was political immaturity and social apathy; lack of technical know-how and lack of managerial ability were also important, but subordinate to the former two. The main force in the industrial development of a country will be the drive of its people; this has been pointedly demonstrated in the last twenty years by the industrial advance of Japan, a country with few natural resources.

III TIMING THE ESTABLISHMENT OF INDUSTRIAL RESEARCH SERVICES

The glib statement is often made that IRI's are essential for developing countries because these institutes automatically lead to industrial development. Not so. Premature or unsuitably planned IRI's may mean a loss of time, effort and money, and cause disillusionment in those industries and government departments which it should serve. If an IRI is set up when technological needs exist for it, and it has been designed to fit these needs, the institute will be a live and productive entity. If the timing and structuring are wrong, the IRI will be a frustration for its director and personnel, who will have to struggle every moment to establish a purposeful existence. This situation has occurred in a number of cases, not only in developing countries but also in developed ones. Often the IRI under such circumstances becomes isolated

from the industrial or applied world and lives for the scientific entertainment of its technical staff, a situation not too different from many universities in developed countries today.

In considering the timing and structure of an IRI, first attention must be given to the marke . An IRI may make three approaches to the market: ignors it, determine it, or develop it. The first may be fatal, as an IRI is dealing with a marketable commodity (or should be). The second is essential; the most expeditious way for the IRI to advance is to gear itself to the demands of the technical market. The third approach may be followed if the establishment of the IRI is premature, although development of specific sectors of the market may continue as part of normal operation. For example, a portion of the IRI staff time and talent may be devoted to in-house applied research projects leading to eventual participation by industry and to commercial innovation of new products or processes.

An important part of market evaluation is the classification of the industries in the country and a survey of their likely needs. Figure 2 sets forth a simple classification of primary and secondary industries with examples. The primary industries are essentially concerned with harvesting of raw materials and are to a large extent mechanical. Except for agriculture and fishing, which have biological aspects, the research dependency of the primary industries are relatively low. Most of the techniques needed are already available in developed countries, and can be applied in developing countries with little more than adaptive changes, often to climatic conditions.

The secondary industries have here been sub-divided into Simple Conversion, Simple Manufacture and Sophisticated. The technical service requirement and the research input for these is progressively greater. It is from the secondary industries that the greatest demand for services and ultimately for applied research will come. Figure 3 shows the need for different types of services relative to industrial development in a country. Figure 4 presents the stag s in the development of an IRI as it adjusts to these needs during the industrial development of a country. Interestingly, the demand for technical information is greatest for sophisticated industries, although much of it may be provided by the firms themselves (engaging highly trained personnel). In fact, it has been stated by one of the IRI's surveyed that the need for technical information service is highly overrated in developing countries.

Testing (biological, chemical and physical) must be provided by some agency in a country, not only for industry but also for government departments. At an early stage an IRI may provide all testing services; later government and commercial assay laboratories may handle the testing

needs and the activity of the IRI for this service will diminish. Likewise, the market for engineering services increases with industrial development and with the trend to industrial sophistication. As with the testing services, the engineering services and trouble shooting demand may be high for the IRI during the early years, taper off as independent engineering service companies become established. As the industrial development of a country advances both with time and sophistication, the market available to an IRI for technical services drops off and that for applied research increases. Ultimately the research, if it is good research, leads to innovation, either through client firms of the IRI, or satellite companies established by the IRI.

A seasoned word on applied research and its marketability. Technical research, because it seeks the unknown, is always a speculation. Very occasionally a project pays off handsomely; sometimes in a modest way; but most usually it is an economic failure. Under these circumstances most individuals or companies find more securely profitable ways to invest their capital. In the end, it is usually governments that fund research, either directly, or indirectly. In the United States of America most research is funded by government contracts although carried out in the laboratories of industry (industry accounts for only one-third of the R & D expenditures). It should be one of the main objectives of an IRI's in-house research to make potentially economic research ventures more marketable to clients by increasing their technical and economic feasibility. This does not mean completely solving the problems by using in-house funds, but reducing their risk factors.

Of the four IRI's consulted in this study, one is in Stage I (technical service) according to Figure 4, another is moving into the Stage II (limited research), another in Stage IV (limited innovation), and one is a premature birth, carrying on ninety percent in-house work and only ten percent contract (to government; none for industry).

None of the three IRI's contacted admitted to starting too soon, too ambitiously, or suffered from over-organization. The author feels all three disadvantages applied to his own institute. In Canada the timing of IRI's has often been very poor, since independent companies provide for general testing, approvals testing and a wide variety of engineering services. Most government research is done in-house and the research for the industrial companies is generally carried out in foreign countries, the site of their home offices.

IV GOVERNMENT SUBSIDIZATION OF IRI's

Although direct government subsidisation is essential and unavoidable in the setting up and early operation of an IRI, continuous

and full support by government carries the seeds of the ultimate destruction of the IRI, in its purpose and usefulness, if not in fact. Financial dependency weakens an IRI to the point of being unable to stand on its own economic feet. Under such circumstances the IRI invariably occupies itself with matters of relatively inconsequential industrial significance, or else becomes a basic research recluse. The latter tendency is ever present, since the classical training in universities emphasizes and perpetuates basic research to the subordination or exclusion of applied research. Only in the United States of America, where the job mobility of individuals between industry, univeraity and government is high, does a reasonable balance between basic and applied research tend to occur.

Indirect government subsidization of IRI's, although far less destructive than the direct subsidization, can also cause weaknesses in the IRI's fibre. Some IRI's in the United States of America have become so dependent on government contracts that industrial contracts have become almost non-existent. True, an IRI must maintain technical keenness to win government contracts, but it is essential to sound development of the IRI and its acquiring of self reliance for its own staff to conceive new products, improve processes, and develop new equipment or instruments to meet industrial market needs.

To date the record of achievement of IRI's throughout the world has not been outstanding in invention or development of new products or processes. The author feels that much greater accomplishments will be made during the 1970's and 1980's by IRI's, particularly by ones in the size range of two hundred to four hundred employees, and with specialization in few areas of research. Large IRI's, like large companies today, will not be the font of the outstanding advances in applied research. Again, government subsidization can assist or delay this development.

V PROBLEMS ENCOUNTERED BY IRI's

The problems met by IRI's relate to seven main requirements for successful operation. In descending order of importance, they are: a good market for technical services; good staff; freedom of action; sound in-house program planning; adequate financing; business-like approach; and continuing, active promotion. Failure of an IRI may be due to not fulfilling any one of these requirements, or to failing to meet a number of the requirements in part. The ramifications of these and elements leading to the breakdown of each are covered below.

1. Market for Services of an IRI

Unless an immediate market demand for the services of an IRI exists in a country or region, either from industry or government or both, one should not be established. In too many cases IRI's have been set up where the immediate market need was insufficient, only to have the staff of the IRI resort to general research projects with no likely application for many years, or to basic research studies with no practical objectives. This situation has occurred in developed countries, probably it is not unknown in developing countries. Success in most business undertakings requires good economic timing; this applies in full to IRI's.

To build, staff and equip an IRI in an adverse industrial climate either kills the initiative of the staff or else causes the institute to become introspective. The theory that an institute will create industry in a region where none exists is false. It can only assist industries that are established and encourage the establishment of new ones from abroad. As shown in Figure 4, an institute does not reach the stage of innovation until an advanced stage in its development.

2. Staffing

Once a favourable market environment for an IRI has been established the greatest single problem is that of staffing. The staff of the institute is, or should be, its greatest asset. A Director and senior program leaders with conceptual, managerial, and business abilities are difficult to find at any time. Unfortunately no country in the world today trains men in these skills for research managers and program supervisors. Scientific training in most universities has been academic, with emphasis on fundamental research and a disdain for applied research. On this point, the Jamaica Institute and B.C. Research reported unsatisfactory training of staff for senior positions; the Colombia and Israel Institutes reported satisfactory training of personnel. However, all four institutes claimed weakness of senior personnel in managerial capacity. One institute in a developing country stated that the removal of "internationals" would leave the institute in a very weakened state and that another ten years would be required for managerial training of the nationals to enable them to take over the entire operation of the institute. None of the four institutes expressed complete satisfaction with the outlook of their national employees towards industrial research and services. In two of the countries definite social apathy was mentioned and this was reflected in the lack of drive of institute personnel.

3. Freedom of Action

For an IRI to be successful it must have power of decision on such matters as its own in-house research programs, the course of investigation on contract projects, the hiring and releasing of staff, financing within budgetary allotments and general day-to-day operations. The IRI should not be a government department or placed under a government department but operated on an autonomous basis. The four institutes surveyed all stated that the political environment in their countries was favourable to the operations of the institute (although two institutes mentioned that political immaturity of their respective countries was the main industrial obstacle). It certainly is a case that some institutes in developing countries are subject to frustrating delays and red tape by their governments.

4. Program Planning

The ultimate success and destiny of an IRI depends on the judicious selection of its areas of technical service and research competence and on the sound selection of its in-house projects within these areas. The effectiveness of program planning will gain for the institute a reputation either of distinction or of mediocrity. This will be particularly so after the IRI has been in operation ten to fifteen years and a practical return is expected on the investment made in it. The importance of program planning to the success of IRI's in developing countries cannot be overstressed. The initial demand for services often does not absorb the full time of the staff, and it is the responsibility of the IRI to foresee those areas in which technical competence should be developed to serve industrial demands in the coming four or five years.

Faulty program planning may involve the following: deciding to undertake projects which, even if a technical success, would have no value in the market place (trying to find uses for wastes often fall into this category); undertaking basic research programs with the hope of valuable commercial spin-offs (these are usually long chances and an IRI can afford only one or two); failing to terminate projects when chances for technical and economic success are poor; failure to think specifically in considering the market for a project if technically successful, to the extent of designating specific clients.

5. Financing

A cooperative government attitude is essential to the successful starting of an IRI and adequate financial back-up by government is

necessary. However, government financing should be in the form of grants for capital outlays and of contracts for technical services and research rendered by the IRI. On the one hand, government departments should pay for all services provided by an IRI, on the other hand the IRI should be accountable in the matter of quality of service and reports. In the author's opinion, far more institutes have been ruined by over-financing by government, than by under-financing. Often lack of money is only an excuse on the part of institute directors for lack of sound, marketable in-house research projects and for lack of drive in promoting them. In addition, over-ambitious in-house programs including expensive pilot plant operations have led to over expenditure and thus to unreasonable requests for expanded government subsidization.

6. Business-like Approach

An IRI should operate in a business-like fashion with respect to meeting project schedules, issuing reports, planning its operations, budgeting its expenditures and making realistic charges for its services. The ultimate objective of the IRI should be financial independence. After all, it if believes that applied research is a remunerative proposition for industry, it should believe in it for itself.

7. Promotion

To be a vital part of an industrial community, an IRI must communicate with those it intends to serve, both in industry and government. This is best done by personal contacts, augmented by news sheets, brochures, annual reports, displays, open-houses, radio and television. The promotion of an IRI's services is part of the duties of its staff. This applies not only to advice to prospective clients on what the IRI can do for them but also to follow-up on projects that have been completed for clients.

VI PROBLEMS ARISING DURING TWENTY-SEVEN YEAR HISTORY OF AN INSTITUTE

Although BCR is usually considered as located in an industrially developed environment, most of the industry in British Columbia classifies as primary (harvesting) and simple secondary (simple conversion) (see Figure 2). Only in recent years have simple manufacturing operations been established with extensive markets outside the Province, and to date only one or two complex manufacturing operations exist. Consequently many of the problems associated with BCR since its inception in 1944 might be

similar to those confronting IRI's being established in the developing countries. Some of the problems met with at BCR as it has passed through one stage to the next in its development over the past twenty-seven years are set forth here as a forewarning to other research directors.

BCR has passed through Stages I, II, and III and now is entering IV (Figure 4). These development stages are difficult to define in terms of specific dates, as they merge from one into the next. Each represents a different emphasis in the technical activity of an institute, and each presents different problems.

Stage I - Technical Service

The most serious single mistake made by those responsible for planning and setting up BCR was failure to determine the market for contract technical services. In part this is understandable, as the organising group and the subsequent first Board had no representation from industry or business. This resulted in an institute being established when there was no immediate industrial need for many services, particularly those involving laboratories. Although initial government subsidy was adequate, the understanding was that it would not be substantially increased later and that the institute would be required to earn most of its operational cost within the first five years. This placed the director in a very unrealistic financial position.

Another serious detriment to the institute in the early years was the use of many advisory committees and project sub-committees whose purpose was ostensibly to advise what research studies should be undertaken and, to a large measure, how they should be carried out. These committees, which were in operation during the full period of Stage I from 1944 to 1950, wasted the time of the technical staff and were completely ineffectual. It was not until after 1951, when these committees were abolished and the responsibility for developing sound programs and for carrying them out was placed squarely on the shoulders of the full-time technical staff of the institute, that progress was made.

The activity during Stage I included chemical and physical testing (no biological), trouble-shooting particularly in emergency situations ("panic research"), non-sponsored surveys, approvals testing, technical information and grants-in-aid for research, particularly in university departments. (The last of these was a heavy financial drain which was not plugged until near the end of Stage I). The contracts carried out were for small amounts, usually under $500 and most commonly under $100.

while the costs on individual projects usually were far in excess of the charges made. This was not always the result of unrealistic bookkeeping; frequently the sponsors were unwilling to pay realistic prices. This again illustrates the premature establishment of the institute.

During Stage I the institute had a very heavy staff turnover. This in part was due to maladministration, but also caused by the obvious futility of trying to make something work in an economically adverse environment. Inappropriate selection resulted in the engaging of senior men with great devotion but little or no industrial background or applied research inclination. This mistake restrained the progress of the institute in many of the ensuing years. In retrospect, most of the early problems of the institute arose from lack of an adequate market for industrial services and from the involvement of people with an academic rather than applied, industrial outlook, both within and associated with the institute. Financing and freedom of action were not problems.

Stage II - Limited Research

This covers the years roughly from 1951 to 1954 during which the institute undertook more sophisticated testing, initiated economic studies and operations research and began to undertake projects in the range of $1,000 to $10,000. During this period the divisions of Chemistry, Engineering, and particularly Applied Physics, which was doing a large volume of work in physical testing, were the groups meeting industrial demands. This stage may be looked upon as the "increasing growth phase", at the end of which the annual rate of increase in volume of research contracts reached $50,000 (and this has continued to the present time).

Probably the greatest mistake made during this stage, which led to problems both with staff and research programs later, was the lack of longer-term program planning. Most of the technical divisions became so involved in short-term testing work that they failed to establish research competences in specific fields that might be associated with the development of the Province. The technical divisions became heavily staffed with people prepared and able to undertake small, industrial problems on request, but unable to conceive areas of applied research which would lead to expanding industrial demand.

During this stage a substantial amount of the in-house funds were devoted to two large basic research programs and, although these flourished and were successful, they were inappropriate for an IRI and brought no industrial contracts.

Stage III - Extensive Research

This stage covered the years 1955 to 1962 and was characterized by increasing emphasis on the deliberate use of in-house projects to build up areas of specific technical competence of value to the industries of the province. In the Applied Biology Division three areas of technical competence were established: marine borer control, biological leaching of metal sulfides, and water pollution. In the Division of Chemistry the areas of technical competence were odor control of kraft pulp mills, the bleaching of kraft pulp and the synthesis and use of organometallic compounds. A number of processes were patented during this stage and an income from patent royalty started. This stage also saw the termination of the two basic research programs that were started in Stage II and on which substantial in-house funds had been spent. When these two groups left for environments more appropriate for basic research, the institute essentially lost all that it had invested.

A difficult problem during this stage was the need to bring in people with conceptual ability appropriate for selecting areas of technical competence. For this purpose the technologists and many engineers who had been so valuable during Stages I and II were inappropriate. Furthermore, with the establishment of sophisticated commercial analytical laboratories and engineering consulting firms, these people had become redundant. As a result, this stage involved a change-over of about 25% of the staff.

By this time the individual projects had increased in value up to $50,000 and the main source of earned income was industrial contracts from British Columbia which had increased from $61,700 in 1949 to $459,000 in 1959. (See Figure 5). In 1959, $459,000 (or 84%) or the earned income was from industrial contracts within British Columbia, $44,500 (8%) from industrial contracts outside of British Columbia and $45,000 (8%) from government contracts. It was soon to become apparent that one of the problems was that the institute had essentially exhausted the local market for technical services and research contracts. Overtures were made to the local government for more subsidy financing, but were refused. This probably was a blessing in disguise, as it forced the institute to look beyond provincial boundaries for further marketing of its capabilities. During this stage the internal accounting system was improved to obtain a realistic return for services rendered under contract and an increasing emphasis was placed on promotion. In previous years the publications from the institute, including a monthly news sheet and the Annual Report, had not been designed with potential industrial clients in mind. Appropriate changes were made. To increase industrial communication and participation in the institute the proportion of industrialists in the Board of Management was increased so that by the end of Stage III half of the members of the Board were representatives from industry.

Stage IV - Limited Innovation

From 1962 to the present, BCR has been in the stage of Limited Innovation whereby it is deriving a modest but significant income as royalty payments from commercial application of technical accomplishments. Royalties are now being derived from the following: marine-borer control systems; oxidation and scrubbing systems for kraft black liquor; sonic testing of marine pilings; a fire-retardant coating; a wasp trap based on a non-poisonous attractant; an underwater coating for steel; and a continuous monitor for sulfur-containing gases. A fire-place log machine, a self-disintegrating oyster cultch and a number of other processes and products are nearing commercialization.

Figure 5 shows that by 1969 the institute's earned income from industrial contracts with B.C. firms was about the same as that for 1949. The increase in income from industrial contracts with firms outside B.C. increased substantially from 1959 to 1969 so that it constituted one-third of the earned income in 1969. Similarly, government contracts have increased over the past ten years and now account for 22% of the earned income. The increase reliance on both the industrial and government contracts from outside British Columbia has imposed increased cost and time for contacts with potential clients at greater distance from the institute. Over the years one of the difficulties has been to have technical men in the various disciplines establish and maintain contacts with clients hundreds or thousands of miles away.

Over the twenty year period from 1949 to 1969 the government subsidy remained remarkably constant in effective dollars, rising from $260,000 to $320,000. Despite this modest increase in government subsidy, the institute did well in Stage IV and was able to accumulate working reserves of over half a million dollars by the end of 1967. Use of most of these reserves for covering part of the cost of a new office-laboratory complex and a tight money situation in both Canada and the United States have temporarily imposed financial restrictions on the institute. However, these will probably be transient and the outlook is promising. Problems throughout the years at this institute have not been basically financial; rather they have involved acquiring effective staff, particularly people with creative ability and business acumen. With the increasing number of new processes and products coming from in-house research, the trend towards financial independence should continue and the institute eventually move into Stage V. This essentially will have been achieved when the royalty income of the institute has reached about $300,000 annually.

As indicated from Figure 5, the income from industrial contracts from B.C. firms is not likely to increase substantially in the future; the increase in earned income will have to be derived mainly from contracts with industrial firms outside B.C. and from government contracts. With the increase in emphasis on problems of social concern such as pollution, transportation, housing, and communication, the greatest expansion is anticipated from government contracts.

Comparing the situation at BCR with that of an institute in a developing country, I would say the latter has the advantage over BCR during Stages I, II and possibly III, in that it can serve technical needs for a longer period before coming into competition with independent testing and engineering companies. On the other hand, because of its closeness to more highly developed economies with attendant more sophisticated markets and particularly that of the United States of America, BCR has a chance to move more quickly into Stages IV and V, those involving innovation and returns from processes and products it invents. With regard to the most valuable asset of the institution and the one about which most problems arise, its staff, all IRI's suffer from the failure of teaching institutions throughout the world to train enough competent people for technological jobs. The disadvantage is greater for IRI's in developing countries where there is no opportunity to acquire men with the benefit of industrial experience after university training.

VII SUMMARY AND CONCLUSIONS

1. The rapid industrial development of developing countries is primarily dependent on the importation of risk capital, technical know-how and managerial ability, acting in an environment that is conducive from the standpoint of politics, work force, and natural resources. An IRI can assist the establishment of new industries by economic and feasibility studies, the operation of established industries by providing technical services, and, at a later stage, the setting up of new industries through applied research.

2. An aspect that is often given insufficient attention is the timing of the setting up and the structuring of an IRI in relation to the immediate market demands for its services.

3. Government subsidization of an IRI is essential at the start, but the initial plan should call for the IRI eventually becoming largely, if not entirely, self supporting through charges for technical services and research contracts, royalties on its own inventions, possibly income from satellite companies.

4. The main problems encountered by IRI's relate to markets, staffing, freedom of action, program planning, financing, business-like approach, and promotion.

5. The main problems experienced by one IRI operating in a primary industrial environment of a developed country over a period of twenty-seven years have been the market for technical services and research, and technical staffing.

6. The conditions under which an IRI operates are affected by many variables. These include the internal tensions associated with research on technical problems that are often ill-defined or elusive, sudden shifts in technological emphasis in the country, labour unrest and changes in government policies and economic conditions. As a result an IRI, more than most organizations, is always in a state of flux, and the constantly changing administrative situation calls for a high degree of flexibility in management.

Figure 1

TECHNOLOGICAL INTER-RELATIONSHIPS IN A DEVELOPING COUNTRY

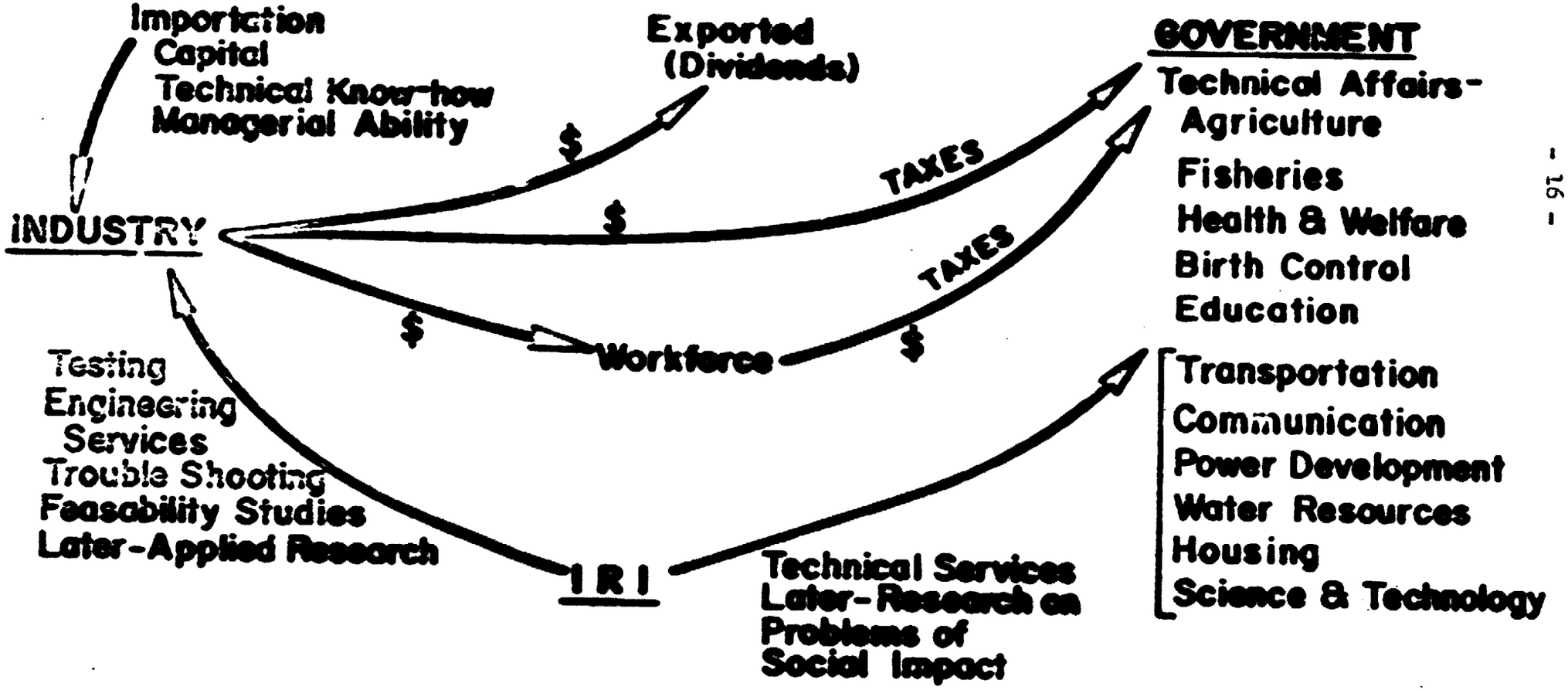


Figure 2

PHASES OF INDUSTRIAL DEVELOPMENT

PRIMARY (Harvesting)	SECONDARY Simple (Simple Conversion)	SECONDARY Intermediate (Simple Manufacture)	SECONDARY Sophisticated (Complex Manufacture)
Fishing	Fish Processing	Metal Fabrication	Electronics
Agriculture	Food Processing	Industrial Chemicals	Pharmaceuticals
Logging	Pulp, Paper, Lumber	Automotive	Aeronautics
Mining	Smelting of Ores	Construction	Atomic Energy
Oil and Gas (Wells)	Refining of Oil	Transportation	Computers
Water Reservoiring	Hydro-electric Power	Industrial Coatings	Plastics
RESEARCH DEPENDANCY			
Low	*Moderate*	*High*	*Very High*

Figure 3

PRIORITIES FOR TECHNICAL SERVICES AND RESEARCH AT DIFFERENT STAGES OF INDUSTRIAL DEVELOPMENT

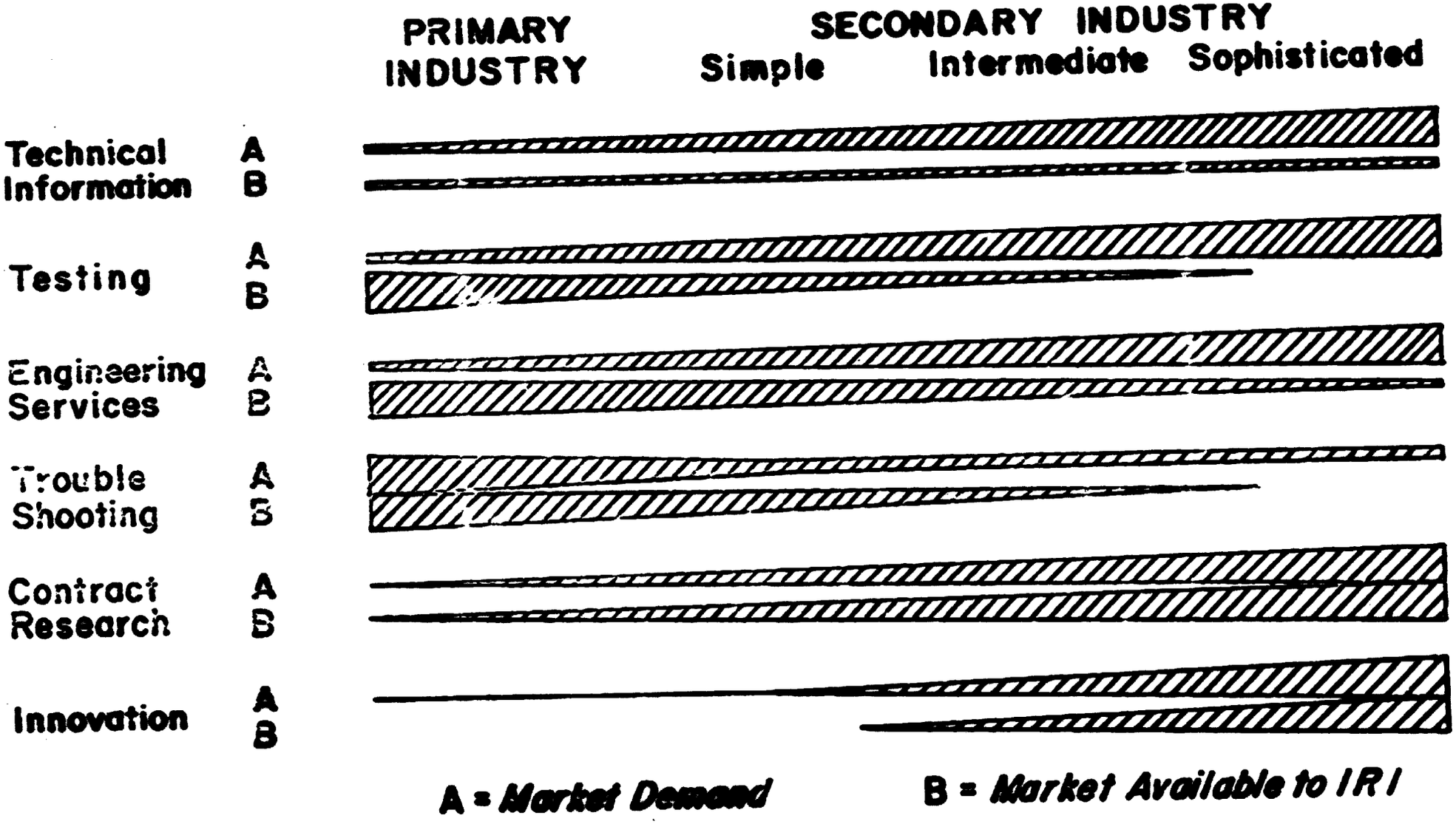


Figure 4

STAGES IN THE DEVELOPMENT OF AN INDUSTRIAL RESEARCH INSTITUTE

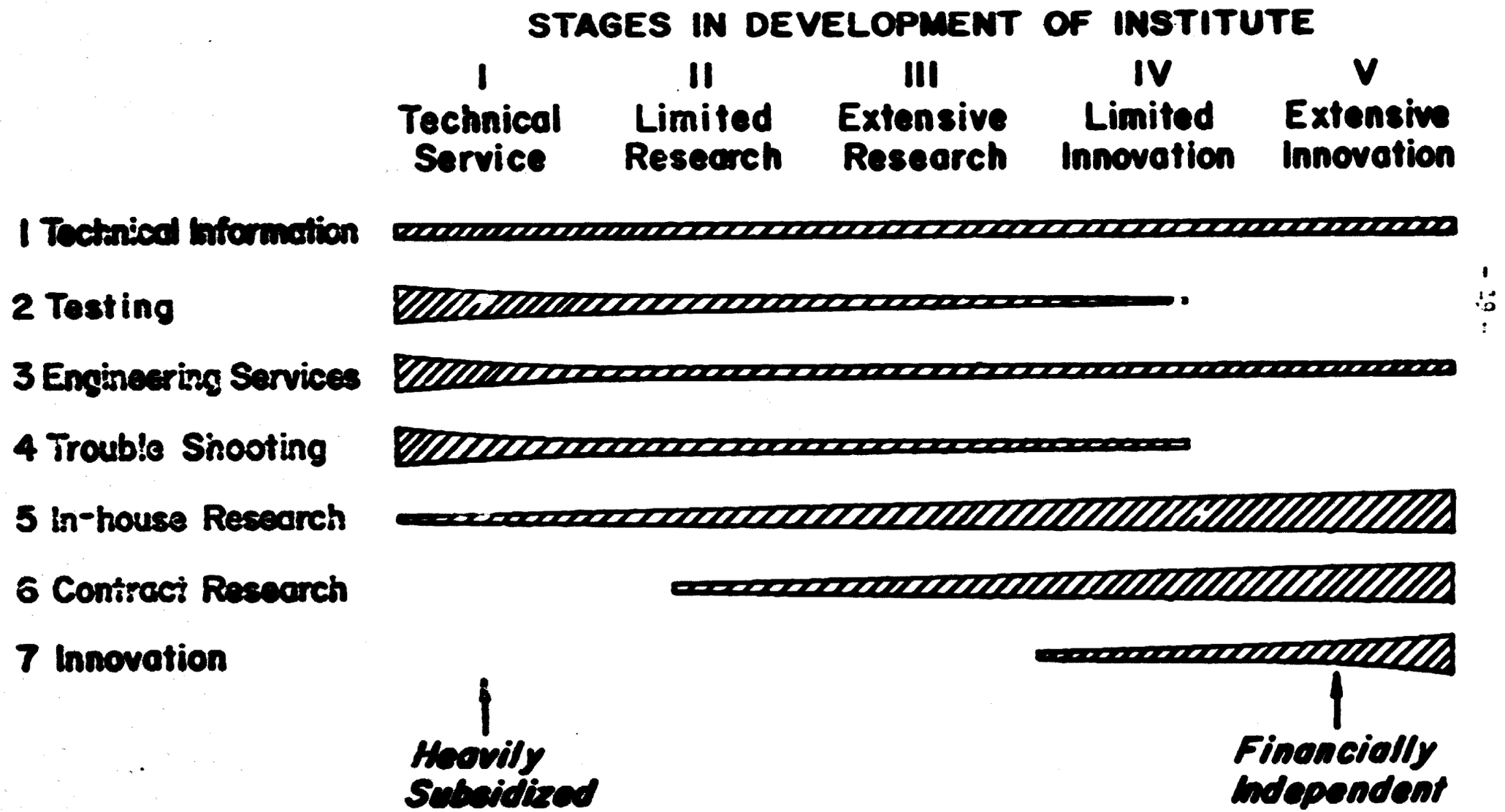
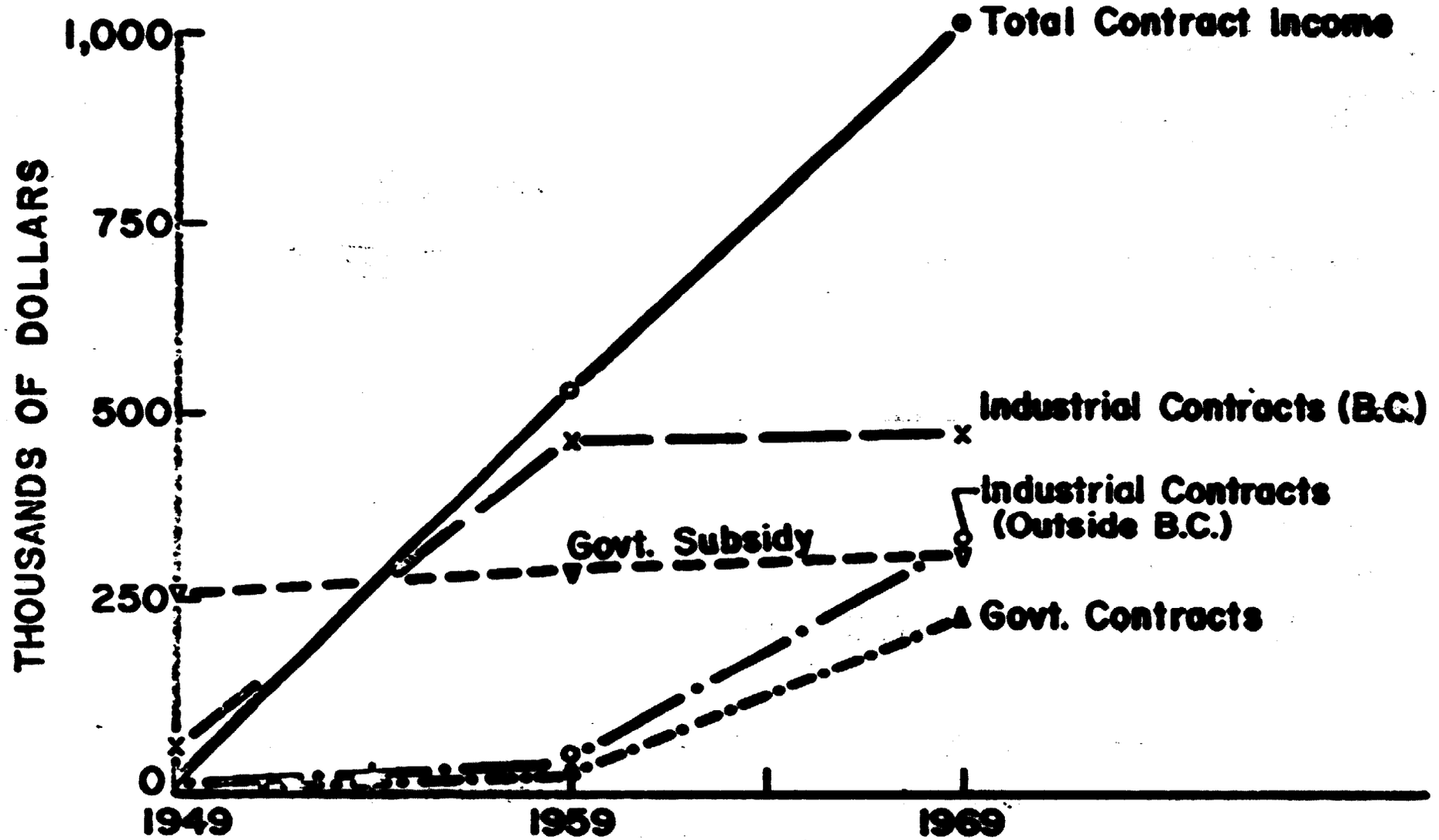
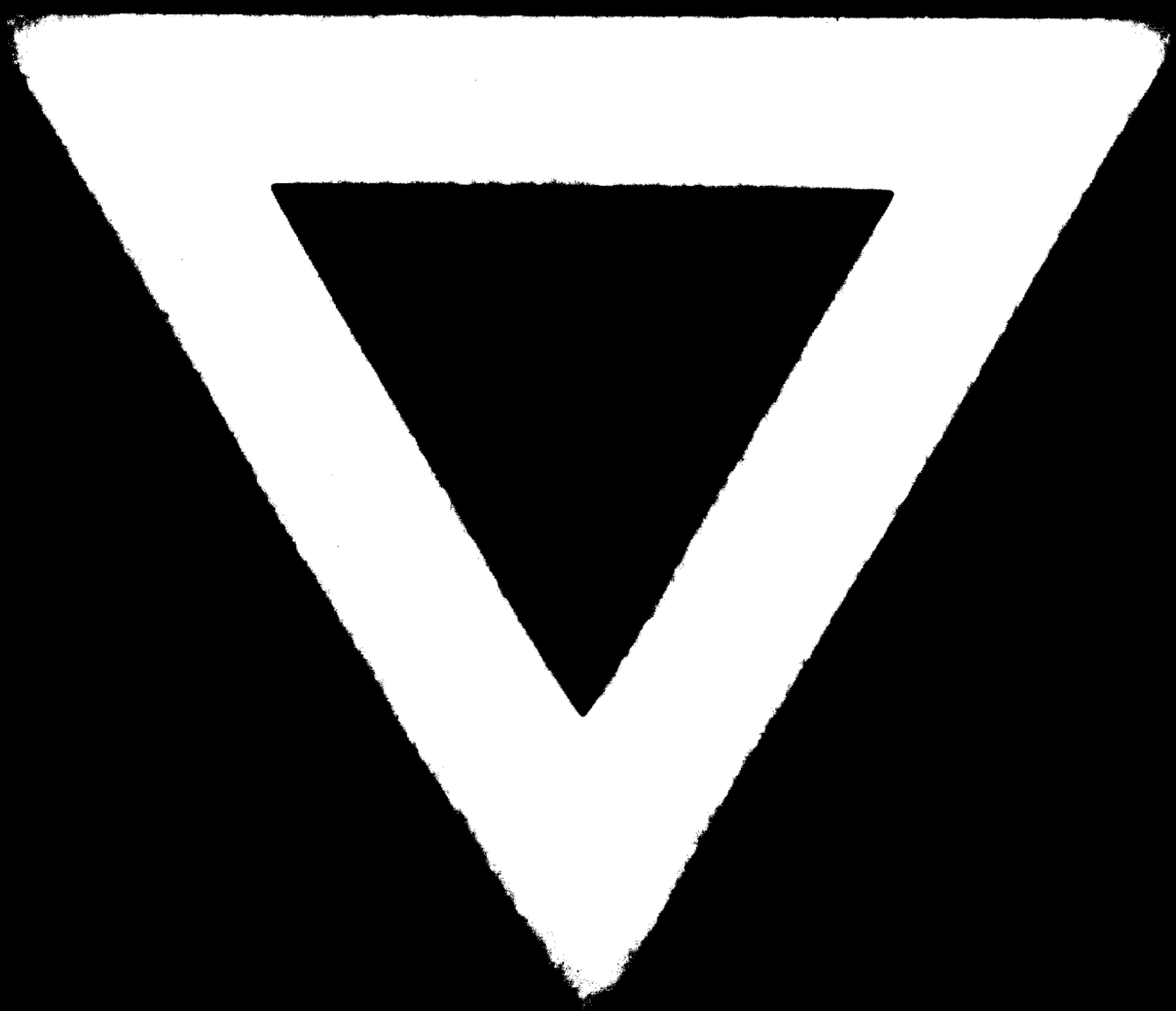


Figure 5
SOURCE OF RESEARCH CONTRACTS AT B.C. RESEARCH
1949, 1959, 1969
(Expressed in 1969 Canadian Dollars)





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