THE MAIN GENERAL CONDITIONS ON THE ECONOMY OF INDUSTRIAL RESEARCH

1. ECONOMIC PROBLEMS OF LONG-RANGE PLANNING OF INDUSTRIAL RESEARCH

by

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The long-range planning of industrial research must, by the very nature of the work, contend with very many uncertainties. Many factors which are of importance to planning can only be considered as probability functions and may only be estimated with approximate accuracy. However, far more uncertainty and also confusion derives from a failure to prepare the long-range plans of industrial research.

In fact one of the most apposite examples for proving the superiority of a Socialist planned economy over the anarchistic order of production prevalent in a capitalist economy, is precisely the long-range planning of industrial research, with its attendant advantages for the people's economy.

A long-range plan of industrial research can only be based on the same plan for industrial development or rather, they must be considered in the light of their complex mutual effects. It is — for understandable reasons — only in the planned economy of a Socialist country that it is possible to draw up such a long-range plan of industrial development which embraces the whole of the people's economy.

A long-range plan of industrial research may thus be based on the various main targets of the long-range plan for industrial development, closely related to the latter, without which it cannot be prepared.

The appropriate concentration of all the necessary resources, both in respect to material expenditure and scientific workers, is a corollary of the long-range plan for industrial development. From it, conclusions may be drawn about the order of magnitude of the necessary means, the number of scientific workers, their degree of training, the planning of their suitable distribution, etc.

It is self-evident that these conditions can only be fulfilled by a Socialist planned economy, because capitalism lacks a plan for industrial development which is comprehensive of the whole of the national economy and it is, there-

fore, also impossible for a long-range plan of research to be based on it which would take the entire national economy into account.

All this takes place under capitalism with a great deal of overlapping due to competition between the various firms, and with a considerable deconcentration of the possible resources.

There can, at the same time, be no doubt that some of the large firms, the monopolies of the leading industrial capitalist countries have achieved and are achieving outstanding results — we might call them the firms' pinnacles of success —but the large-scale waste of available resources from the point of view of the whole national economy is also beyond any doubt. It is not sufficient — again from the viewpoint of the entire national economy — to concentrate on the most important subjects, to assure cooperation independently of the drive for profits and in pursuit of the interests of national economy to establish research aims in a coordinated manner, etc.

In the narrower sense any firm, in the broader sense the whole people's economy are prompted by both *externally* and *internally* effective factors to draw up long-range plans, in the course of which process both the external and the internal influencing forces must be subjected to a thorough scrutiny from the long-range point of view.

External influencing factors of this type are, for instance, changes in the domestic demand and in the requirements of the international market, the need to introduce new technological processes with respect to certain products, a decrease in the demand for other products, the obsoleteness of products, the need for introducing vertical integration in the course of manufacture, beginning from the purchase of the raw materials to the preparation and utilization of the end product (*e. g.* in the pharmaceutical industry), etc.

The *internal influencing factors* to be considered are mainly the advantages accrueing to the people's economy from the elaboration of a long-range plan of industrial research based on the same plan for industrial development.

The material of long-range planning of industrial research for the people's economy is compiled of industries, and in respect to the establishment of the appropriate proportions for the people's economy and of the order of precedence this plan therefore, in essence, reflects the aims of the various firms, moreover of the industrial research establishments formed to aid the research work of those firms, subject to evaluation and control by the higher industrial administration.

The following stages may be regarded as *the three main phases in the preparation of the plans :*

a) The suggestion of ideas for research subjects, and on this basis the elaboration of concrete motions for a plan.

b) The detailed examination and evaluation of these ideas and plan motions.

c) The selection of the plan motions which are the optimal ones from some points of view.

The plans may *originate* from very *different sources*. Such sources might typically be, for example:

a) An investigation of the process of production and of the requirements of production based on the initiative of the firms.

b) A consideration of the given circumstances of the branch of science and of the points of view of higher industrial administration, for instance, on the initiative of the research institutions.

c) The ideas, opinion and research strivings of the research workers.

Typical sources of information, therefore, that require research work are, for example, research on various means for discovering new or better raw materials, research tasks arising from the probable trend of the utilization of a particular product, research tasks arising from the present or expected future activities of the various competitors in the international field, conclusions which may be drawn from various economic phenomena, such as the trend of population, changes in consumer requirements, the development of consumer habits, etc.

Industrial long-range research plans may also be divided into two parts:

1. a general part, and
2. a specific, particular part.

In the general part of a firm's long-range research plan it is necessary to come to a decision on the following main questions:

a) On the basis of the work done and the results achieved so far, it is necessary to establish for a nearer and a more remote date (*e. g.* 5 years and 10 years) *how the manufacture of existing products is to be developed*, in respect to both the expected technological and economic changes. In the course of this all the resources of the particular sphere of activity must be established, in material means as well as in the requirement for research workers.

b) The question, moreover, will have to be investigated as to whether, from the long-range point of view, the firm has any *special technical advantages or economic features* that may render it suitable for the production of a product that is particularly sought for on the home or the international market, but *cannot be produced elsewhere.*

c) On the basis of the previous point *b)* — but also independent of it — an investigation must be carried out, which *new products and processes it is necessary to introduce* over a long-range period, and the most appropriate research organizations for the purpose must be found, with an estimation also of the *economic results* of the new products or manufacturing processes to be introduced as the results of the research work.

d) It is necessary to consider — where the need arises — the possibility of backing up some of the main problems of applied research from the funda-

mental side and — in certain cases — also to establish the need for *maintenance services* where a product or process introduced on the basis of a research result may later require the participation of a research establishment to obviate faults that might arise.

In the general part the firms concerned must also set out the method to be employed in elaborating the plan.

One such *possible* method for elaborating the plan is, for instance, the following:

First, a detailed analysis must be made of the activities conducted hitherto and the aims to be pursued in the future by the firm which is engaged in the planning. This includes a survey of the past activities of the firm in respect to their research, technical (manufacturing) economic, and financial aspects.

It includes, moreover, using similar classifications, a determination and examination of the firm's main future aims.

Particular care must be given to the analysis of the extent to which the various plans prepared by the firm in the past — including those for research, technical realization, the financial aspects, etc. — were fulfilled in the course of time or why and to what degree they failed.

It is useful to set out these important facts, taken from the past — from which important conclusions for the future may frequently be drawn — wherever possible — in the *form* of appropriate *tables*, to be treated as documents for further planning work.

If the planned product participates in international competition it is also necessary to prepare an international situation report of the product (or process) as far as can be foreseen at the time of planning, with the international research results already achieved, the momentary situation of the product on the market, its future prospects, the expected behaviour of the competitors, etc.

The specific or particular part of the long-range plan of industrial research

A) must contain some method for *classifying the plans* according to the set aims. This may at the same time imply the order of importance of the plans;

B) it must, moreover, contain some method for the *evaluation of the plans* already selected and found suitable for research namely for checking them.

Re *A)* The research plans may be classified according to very many points of view. It is at any rate appropriate to undertake the classification according to an order which will also make it possible to evaluate them. Once the long-range development objectives of a particular firm have been established, it is desirable that the classification of the plan should also be done with due attention to these objectives and their related aspects. Research *plans may*, for instance, *be classified* according to the *following research objectives:*

the production of better raw materials,
the study of possibilities for saving power,
the expansion of the output of existing products,
decreasing the costs of existing products,
improving the quality of existing products,
the improvement of production processes that have already been introduced,
the making of new, more suitable equipment and installations,
research on new possibilities for the use of existing products,
the introduction of new products,
the elaboration of new, hitherto unknown manufacturing processes or technologies,
the elaboration of better methods for organizing industrial research,
undertaking fundamental scientific research from which useful applied scientific research follows within a shorter or longer time,
increasing foreign exchange returns, etc.

The further classification of the plans may be helped by specific problems which justify special treatment or an unusual procedure within the various aims enumerated above.

Further considerations of classification may be provided by the various problems concerned with the execution of the plans, *e. g.* whether they are long or short term, whether they contain fundamental scientific research or consist only of applied scientific research, on what level experiments are to take place (at the laboratory, pilot plant or manufacturing works level).

The method of classification according to *research objectives* above treated, can of course only be considered as *one possible* method, and may differ considerably according to the tasks, purpose, etc. of the research institution.

Re *B)* The evaluation of plans qualified as suitable for research.

Before the plans are evaluated, the various research plans may be gathered in to larger groups, and the groups may be arranged according to various points of view, as for example, groups of subjects containing tasks of a creative (intuitive), applicative (reproductive), systematizing (coordinating), etc. character. The very act of arranging the research tasks or the plans containing these tasks into groups may provide an indication for establishing the *appropriate proportions* or of discovering an undesirable lack of proportion in respect to the whole of the research program.

A further consideration in the process of arrangement can, for example, be a separate grouping of the short and long-term, or the research and development themes and possibly those containing designing work.

This arrangement too, can in the first place provide a picture of the suitable or unsuitable ratio of research and development projects.

The *evaluation* of the *subject plans*, once they have been arranged into suitable groups may, according to the given conditions and requirements, be *very different.*

One of these *methods of investigation*, that will provide an answer to important questions of detail right at the outset of the research work is the *periodic checking of the budgets of the research plans.*

Such checks will:

firstly, encourage, on the one hand, the preparation of more accurate and detailed research plans, and on the other hand, the devotion of constant attention to the progress of the plans and the comparison of plan and performance figures;

secondly, they may contribute to a better coordination of research activity;

thirdly, in some cases they may provide a warning that for some reason or other a new evaluation is needed with regard to the planned expenditure.

It is a natural consequence of the above procedure that it will force the leader of research not only to check his plans regularly, but also as the need arises possibly even to *revise* them. Two effects deriving from this are particularly noteworthy.

The one is, that the programme is not protracted through an unjustified length of time, and so cannot claim unjustified material means,

the other is that this regular control undoubtedly has also an incentive effect on the work of those engaged in the research.

On the occasion of these periodic checks an account has to be given to the leader of research on the resources expended during the period under review and the results achieved during its course. A periodic budget check will also show whether some, at that time "fashionable" idea was not incorporated in the plan, whose subsequent evaluation, by science, has showed it to have been incorrect.

Finally possible overlapping items are also revealed, moreover, this is a "test" of the various research plans for precision, the requisite amount of detail and the establishment of the necessary measure of cooperation.

In the course of the preparation of research plans —apart from absolutely short-range development plans — it is generally not possible to arrive at a fully accurate estimate of the expected economic results of a research, or of the necessary expenditure.

Periodic checks show, from time to time, how far planning was realistic in this respect too.

It may also happen that important and urgent changes must be carried out in the plans for some reason or other. In this case a periodic check may draw attention to such a need.

Finally, checking the budgets of research plans, naturally, also prevents non-research expenditure from being represented as such.

Here, for example, are some items which may under no circumstances be included in research expenditure:

a) advice or services rendered by the research department of the firm to the manufacturing departments, relating to any work belonging to the normal process of manufacture;

b) non-research work devoted to the elimination of periodically arising faults;

c) the performance, in general, of all tasks that belong to the normal course of production;

d) possible experiments at the request of a particular customer with respect to a material or article which cannot hope to become an object of permanent consumption or of lasting interest for the firm or factory;

e) the cost of all kinds of routine tests which belong to the sphere of manufacture.

Naturally the evaluation of the research plans will be the more informative for being approached from more aspects, as each particular evaluation generally provides the answer to only one part of the questions to be clarified.

A method of evaluation which will provide the answers to a different group of questions is, for instance, an investigation of the scope of research subject plans and of the research capacity available. This investigation must primarily consider the number of subjects per scientific research worker during a particular period, moreover, the length of time that a research worker needs to work on a particular subject.

Naturally it is, furthermore, useful to carry out a critical survey of the percentage of research workers in the total personnel of a research establishment.

Apart from the distribution of scientific workers, it is also necessary in the course of the evaluation, to examine how the distribution of costs has developed among the various fields of research cultivated.

These investigations must in the last resort provide an answer to whether the scientific and economic importance of the various plans for research subjects, or in the particular case concerned in the economic returns, will be proportionate to the total expenditure devoted to the purpose (in research capacity and material outlay).

Further possible considerations in the evaluation of the plans may be the following:

a) To what extent may the research result, projected in the plan, be regarded as a hitherto unknown and completely original achievement? Before making the very costly preparations for original achievements, it should also be borne in mind that it is much cheaper to adopt something, than to establish it by research. At the same time very many results of research that has already been done are — though perhaps not secret — nevertheless, only available after a careful and prolonged search. Such a careful and prolonged search is,

however, often far cheaper than a research on "new results" of which it turns out later, that it could have been adopted.

b) The requisite *flexibility* of plans (opportunities for rearrangement and regrouping and the precision with which deadlines can be set).

With respect to the last consideration it should be noted that under certain circumstances the success of a particular research work might be endangered if the various phases of the plan cannot have precisely set deadlines, or if the phases cannot be completed in time and thus certain partial results — required for the next phase — are achieved too early or too late.

c) A very important consideration in the evaluation of any plan is the extent to which the *costs of the research work* that is planned, can be precisely determined beforehand. Very many plans of research are well-known which at the start — due exactly to unreliable calculations — seemed to require only modest resources but in the course of time they absorbed for ever increasing outlay, in return for very modest research results.

d) Finally a consideration in the evaluation of the plans can be, whether an "alarm signal" has not been sounded somewhere in connection with the research work that is planned, cautioning the project to be halted, or its plans altered. Cases in point might be, for instance the lose or acquisition of research workers with a special training necessary for the aim concerned, the availability of new information or discoveries with respect to the subject, an opportunity for obtaining equipment or installations, possible changes in the objectives of the firm, the results of new technical development affecting the plan etc.

In Western literature there are essentially two types of methods for the subject mutually at odds with one another; *the examination* and checking *of the efficacy of research projects.*

The adherents of *one method* use formulas and equations to arrive at their decisions.*

$IR =$ (N of the saving achieved through the research result in the first year + five percent of the sales value of the new product over five years + two percent of the sales value of the improved quality product over two years)

Accordingly, the value of a new product (N_p) for the firm may be determined by the following formula:

$$N_p = \frac{IR \cdot P}{C},$$

* In the capitalist world, particularly in the United States, it is mainly the larger industrial firms that engage in the elaboration of such formulas and equations. In the accounts they give these firms stress everywhere that their calculations are not, and indeed cannot be, of general validity, having been worked out exclusively on the basis of their own firm's experiences, to suit their own requirements and satisfy their own aims. As a matter of interest we may mention two such calculations. One was worked out for "Olin Industries", a firm quite well known throughout America, by the Head of its Research Department, dr. Fred Olsen. Previous to the actual calculation he first determines an Index of Return (IR).

where IR is the index of return as above, P is an estimated figure for the chances of success C is the overall cost of research.

Other capitalist firms in the chemical industry use the following formula for the *evaluation* of industrial research or development plans.

$$P_v = \frac{CS \cdot SP \cdot OV_a \cdot P \cdot L}{TC},$$

where P_v is the project value index,
CS is the chances for technical success on an arbitrary rating scale, say 0 to 10,
SP is the sales prospects, also on an arbitrary rating scale, say 0 to 10,
OV_a is the output volume annually,
P is the profit per manufactured unit in dollars,
TC is the total Research and Development cost in dollars,
L is life of product in years.

A further formula that used is, for the examination of the *returns* on research or development expenditure. This formula is as follows:

$$T = \frac{P \cdot R}{C},$$

where T is the time of return,
P is the probability of realization,
R is the arbitrarily estimated net return over five years,
C is the estimated expenditure on research and development.

(The two formulas have been published by O. Heyel: "Handbook of Industrial Research Management", Reinhold Publishing Corp., New York, 1959 p. 201.)

Adherents of the *other method* reject more or less formulas and equations — mainly because they are mechanical — and recommend decisions on the basis of the subjective judgement of appropriate experts, arrived at after a consideration of all the essential circumstances.

Which of the two decisive methods is the more appropriate also depends on the *nature of the plans*. Especially in the case of development plans where exact facts are available, the formulas and equations can be of definite help in making a decision, with regard to the economic results that may be expected. Neglect of the formulas and preference for decisions taken by appropriate persons or teams, is more suitable where the precise data necessary for a quantitative decision are lacking.

Both decisive methods raise a host of further problems. Examples which may be mentioned in this respect are the following:

First. To harmonize the opposed views of various types of people on decisions in matters of personnel and fields of research, necessitating the obviation of differences of opinion arising from human weakness, errors and different degrees of qualification.

Secondly. The difficulty of the suitable determination of the time factor, the possibly incorrect calculation or estimation of which may utterly change the value of a particular plan.

Thirdly. The presence with respect to the estimation of various facts of many probability variables, which not infrequently may cause the outcome of the calculations to be of doubtful validity.

Fourthly. The difficulties in general terms of *formulating joint opinions as a team* due to the need to overcome the divergences arising from the differences in technical and economic considerations and of the opinions of research and production experts. Within a particular firm very many kinds of consideration have to tally *e. g.* the firm's financial strength, its technological capacity and preparedness, the various requirements arising from the development of domestic demand, conclusion drawn from the competition on the international market, etc.

Some very noteworthy findings on the *examination of the economic efficiency of scientific research work in the Socialist countries* were published by FÁTH.*

In essence, FÁTH recommends the carrying out of *four kinds of investigations* to check the efficiency of scientific research work, including industrial research. These investigations are to be carried out according to the following considerations:

a) Successful, unsuccessful and incompleted subjects.

b) Expenditure.

c) Duration.

d) Economic results.

Re *a) Successfully completed* subjects are those items of research work, which *according to the opinion of the research team* may be regarded as having been successfully completed and whose results may be adopted either within or outside the institute. Furthermore, those results which have within or outside the institute have by authoritative persons been stated as being ready for adoption but have not been applied in practice yet and finally those research results which have actually been applied in practice. Those results which have already been applied, may appropriately be divided into narrow or broader spheres of application. *Unsuccessful* are those items of research work which have on instructions from higher authorities or on the institute's own initiative been interrupted or abandoned at any stage short of completion, moreover those subjects which have not led to a result through the use of the methods applied hitherto, but where research may be continued by using different methods and possibly also different aims. It is appropriate to call this last group of subjects *incompleted subjects*, to distinguish them, from the completely unsuccessful ones.

Having defined the concepts of successful, unsuccessful and incompleted subjects, the investigation should, according to Fáth, be extended to the following questions:

* FÁTH, J.: *Über die Analyse der Tätigkeit wissenschaftlich-technischer Zentren.* Nach einem Vortrag des Autors auf dem V. Internationalen Kolloquium an der Hochschule für Elektrotechnik Ilmenau, vom 24. bis 28. Oktober 1960. Fertigungstechnik und Betrieb ....

1. What is the ratio of the number of successful subjects to the number of unsuccessful ones?

2. What part of the cost is devoted to incompleted subjects?

3. What are the expected economic returns of a completed research work?

Re *b)* In the course of investigation according to expenditure, it is useful to raise the following issues:

1. The distribution of costs among the successful, unsuccessful and incompleted subjects.

2. The expenditure devoted to unsuccessful subjects, per Ft. 100,— devoted to successful subjects.

3. The expenditure devoted to incompleted subjects, per Ft. 100,— devoted to successful subjects.

4. The distribution of expenditure on the successful subjects, according to various points of view, which may be selected according to the differing characteristics of the subjects.

5. The distribution of expenditure on the unsuccessful subjects, according to various points of view, which may be selected according to the differing characteristics of the subjects.

This investigation makes it possible also to reveal the *reasons of the various findings*. Thus, for example, it is possible to examine for what reason the expenditure share of an incompleted subject is too large, or for what reason there is a large expenditure share for those subjects, which may according to the research workers be regarded as having been successfully competed, but whose results have not yet been adopted. (Reasons of this kind may, for instance, be: an incorrect choice of subject, the unjustified reluctance of factories to adopt a project, insufficient efforts by the institute to propagate the results, research results which are open to disputs, reluctance, in general, to accept new ideas, etc.)

Similarly an examination may be made of the reason why certain results have been adopted but not applied in practice, or why a result has been applied only in a narrow field, whereas it seems appropriate for widespread application, etc.

Re *c)* FÁTH, in connection with his method of investigation attributes great importance to an examination of the *duration* of research projects. The significance of the duration is mainly to be found in the fact that with the passage of time even valuable research results may lose their value by still newer results being born. In this respect he also points out that it is frequently very difficult to establish the exact period when the research on a subject was begun and when it was terminated. For example, research workers will declare of very many results that they are completed and reeady for application, though the manufacturing plant or utilizers might still have to modify them,

of have them modified. These jobs may be done within the institute, but they may also be done outside it, and it is necessary to weigh all the attendent circumstances when determining the period of the beginning and the completion of the research. The author recommends the determination of average research durations as a criterion of the overall activity of the institution. With a view to the differing import of the various subjects, however, such an average duration will not provide very much information obviously.

Use of the expression

$$\frac{C_s}{C_0}$$

is recommended for evaluating the time necessary for a successful research result, where

C_s is the total cost of the successful completed research subjects for a certain period of time (*e. g.* 1 year),

C_0 is the average value calculated from the total costs devoted to unsuccessful research work during the same period.

Re *d)* The *evaluation of the economic results* almost appears as the summary of the evaluations of answers to the previous detailed questions. The definition of the concept of economic results requires *in each case* separate consideration and deliberation. They may, for instance, consist of a decrease in costs, an increase in output, an improvement of quality, a growth in foreign exchange returns, etc.

In this respect the extent of the difference between the economic value of the *nominal* and the *actual research results* must not be left out of consideration. A research result achieved in the laboratory or pilot plant may undergo very considerable modification in both the technical and the economic respects till its practical application.

An investigation according to economic results consists essentially of performing a *quantitative* and a *qualitative* examination.

The *quantitative examination* may extend to absolute units of measurement (*e. g.* the numbers of plants or factories using the results, the annual quantity of product manufactured by using the research result, the sales value of that quantity of product, the distribution of the products for domestic consumption and export, etc.), moreover for the establishment of ratios (*e. g.* the ratio of the actual sphere of application of the research result to its possible sphere of application or to the existing requirement, etc.).

The *qualitative examination* is, in the first place, directed towards the *kind of economic result* that involves the utilization of the research result, *e. g.* whether it increases the existing choice of goods, decreases the present cost of production, makes work easier or safer, and last but not least, whether it leads, in general, to an expansion of our knowledge of the laws of nature.

The qualitative examination must, moreover, cover the significance of the research result in comparison to the previous technical *inland level* and also to the *highest international level.* It must also provide an answer with regard to the extent to which the research result satisfies the growing requirements of society. These questions depend in fact on the use, the applicability and patentability of the research result.

The use of the research result is, for instance, that it decreases production costs, opens up a new field of utilization for the product, improves the quality of the product, or by, for example, changing the product, increases its utility and thus the demand for it, this increases output, provides an opportunity for the acquisition of important foreign exchange, etc.

The applicability of the research result is mainly a question of the extent to which the concerned result may be applied in the firm which produced or acquired it, with due attention to the trained research workers, material resources, possibly special raw materials, special technological process or equipment required to apply it, and not least of all, to the magnitude of the subsisting requirements, etc.

The patentability of the research result, particularly its international patentability, may also give numerous important items of information on its economic value.

The result of the investigations described in sections *a*, *b*, *c* and *d* above, provides an answer on the extent of economic effectivity of the research result, which may in essence be *derived from a collation of the proceeds* derived from the research result concerned and previously defined according to some standard, *and of the necessary expenditure required to achieve those proceeds.*

* * *

In the *long-range plan of the people's economy* for industrial research, it is specially necessary to consider as one of the most important tasks of long-range planning of industrial research, which is the *determination and satisfaction* for 10—15 years ahead of *the requirement* of research workers of a high level of scientific training and of other *experts.*

In order properly to accomplish this task it is of fundamental importance to pay attention to *the most important development trends of the new relations between production and science,* because these trends shed light — among other things — on a number of tasks relating to the provision of the necessary research capacity, and particularly on what needs to be radically changed in this sphere in the future with respect to the methods of the past, in order to secure the efficacy of industrial research work.

Professor NOTKIN has written the following on this matter, in a 1958 issue of the Vestnik Akademii Nauk: "The whole system and organization of production will be transformed to a scientific basis. The traditional empirical

methods which have been accumulated during the development of earlier large-scale manufacture, will be present as a background. As a final result scientific research will become an organic part and an indispensable condition in the development of production."

According to György D. SZAKASITS, *two types of main trend are valid* with respect to scientific research work.*

The one is the acquisition of a social character by research work, in that as a very significant result of the revolutionary change that has taken place in the past decades and is still in progress now, a new, specialized branch of social labour, that of applied scientific research has come into existence.

The other is the trend of science and production to interweave the result of which is an increase in the role of scientific research work and its active effect on the development of production, with a simultaneous *constant growth in the requirement for the participation of highly trained experts, skilled in research work, in production.*

The above trends are substantiated by a wealth of statistical figures. SZAKASITS cites sources to show that at the beginning of the twenties about fifty thousand people were engaged in the sphere of scientific research throughout the world, of whom the number of leading research workers may be estimated to have been about fifteen thousand. In 1960, in scientific institutes and universities all over the world, about 650 000 people were engaged in research work. Thus, the number of research workers who have also been concerned with the problems of production and have been doing applied industrial research, has very considerably increased in the last 30 years.

The expenditure of resources devoted to research work has also increased intensively. Examining the increase in the sums devoted to research and development in the two leading industrial countries, it may be established that whereas in the United States in 1950 some $ 2500 millions were devoted to research and development, and in 1959 $ 9300 millions (an increase of 372%), in the Soviet Union the 1950 figure of 8100 million rubles rose in 1959 to an expenditure of about 39 500 million rubles (which corresponds to a 475% increase)**. Considering the percentage of investments, the Soviet Union has devoted about 20%, the United States 15% to research, as percentages of output value the figures are about 3,6% for the Soviet Union and 1,8% for the United States.

The increase in *research and development* costs and in the numbers of *scientific workers* may also be seen from the following Table for three countries — the Soviet Union, the United States and Great Britain — for 1959.

* An intensive treatment of this question is given in D. SZAKASITS: *A tudományos kutatómunka átalakulásának főbb tendenciái* (The main trends in the transformation of scientific research work), a discussion syllabus for a session of the Industrial Economics Committee of the Hungarian Academy of Sciences, 1961.

** *ibid.*

Table 1

Country:	Costs of research and development in $ 1000 million (without investments)	Nos. of scientific workers (1000-s)	No. of people with scientific qualifications per 1000 of population
Soviet Union	9,8	284	57
United States	9,3	220	45
Great Britain	1,1	47	28

Development in respect to the increased role of industrial research in the preparation of *new products* has also been intense and forceful. An investigation conducted in the United States in 1956 showed, that *over fifty per cent of the industrial products in circulation had been produced as the result of research activity in recent years.*

Thus a special, new field of labour has come into existence, which both in its form and content has become more and more alienated from the traditional methods of scientific research and has increasingly *assumed the traits of industrial productive labour.*

Socialist long-range planning must devote attention to these considerations, both in the planning of the industrial research institutes, as places of work of a new type, and also generally in meeting the planned requirement for industrial research personnel.

This new type of planned, collective industrial research work also requires the establishment of institutions with up to date equipment, reminiscent of production plants, where plant-scale experiments to promote the industrial applicability of the research results, may also be carried out. It implies moreover, that the requirement in experts of the research institutes be supplied through long-range planning. The requirement is closely related to the development of the various branches of industry, moreover to the long-range aims of industrial administration.

The minimum training period for research workers is ten years, of which five years may be stipulated for university training and five years for the acquisition of the minimum of research practice. It may thus be easily seen that the preparation of highly skilled industrial research workers takes about 15 years, moreover that the requirements which can be fulfilled by such prolonged preparation must be very thoroughly considered beforehand.

The facts contained in a detailed study issued by the Organization for European Economic Cooperation tend to show that the leading capitalist countries were mostly — precisely because of their unplanned economic order — unprepared to adequately supply their advanced industries with research workers and specialists.

Of the two following Tables, the first shows the lack of research workers in the fields of science, the second in technical branches in the German Federal Republic, France, the United States and Great Britain.

Table 2 *

Science

Country	Biology	Chemistry	Physics	Geology	Mathematics
G.F.R.	lack	lack	lack	surplus	equi-librium
France	slight lack	slight lack	slight lack	great lack	some lack
United States	general lack in all spheres				

* *ibid.*

Table 3

Technical research

Country	Mining	Metallurgy	Nuclear techniques	Miscellaneous
G.F.R.	lack in metal ore research	lack	lack	lack in timber industry and oil drilling prospecting engineers
France	General lack in all spheres			
Gt. Britain	lack	lack	—	—
United States	General lack in all spheres			

To secure the requirement of experts for industry and industrial research, very valuable facts may be furnished us by the planning activity and *the large-scale development that has commenced pursuant to it*, which was undertaken in the Soviet Union during the last decades.

Most recently, KOMAROV** has dealt exhaustively with the problems of the coverage and development of the requirement in experts in the Soviet Union. According to his view the following factors have a fundamental influence on the numbers of scientific workers and technical experts needed in industry:

a) The technical standards of the necessary work. The higher the level and the more complex the work that is to be done, the more the use of ma-

** Экономическое основы подготовки спепиалистов для народного хозяйства. — (Economic fundamentals of the preparation of specialists for the people's economy). Publishing House of the Academy of Sciences of the Soviet Union, 1959.

chines and apparatus increases, the more will the number of research workers and experts necessary, also grow.

b) The number of workers necessary for the work to be performed. An increase in the number of workers engaged in production may in some cases also involve a growth in the number of technical experts concerned with the management of production.

c) The degree of complexity of the product manufactured (or in the branches of industry engaged in winning raw materials, the various geological or other conditions of production). It is obvious that the more complex a product, *i. e.* the conditions of work, the more experts may in a given case be necessary, even having an identical number of workers.

d) The increasing role of science and up to date techniques in industry. It requires no further explanation to state that the industrial application of a new scientific result, or the enhanced introduction of new technologies require an increase in the number of specialists.

e) Finally, the organization of industrial administration. The more rational the organization of industrial administration is, the fewer experts will be needed in the administrative branches and as a result the requirement for experts will also decrease.

As a result of the trend towards the interweaving of science and production, a consideration of the basic factors enumerated cannot be omitted when preparing the long-range research plan for industry or taking measures to provide a planned satisfaction of the requirement in research workers, albeit the factors listed do not weigh equally in the case of the supply of research workers for the long-range industrial research of various industries, or even with various firms.

Table 4*

Development of the number of graduated specialists who have left the institutes of higher education of the Soviet Union between 1929 and 1955

Year:	Total No. of graduates	Graduates from ordinary courses	Graduates from correspondence courses
1929—1932	170 000	170 000	—
1933—1937	370 000	370 000	—
1938—1940	328 000	304 000	24 000
1941—1945**	302 000	286 000	16 000
1946—1950	652 000	561 000	91 000
1951—1955	1121 000	874 000	247 000

* *Tájékoztató a tudományos kutatás tervezésének, igazgatásának és szervezésének irodalmáról.* (Information on the literature of the planning, administration and organization of scientific research.) Publication of the Hungarian Academy of Sciences, 1961.

** war years

KOMAROV also stresses that *the appropriate long-range planning of scientific and technical experts is one of the most important, and at the same time the most complex and hardest task when planning for the people's economy*, for which there are special planning bodies in the Soviet Union. These bodies, in the course of their work, consider the immediate aims and long-range tasks of social production, and, therefore, also its expected structural changes. They consider, moreover, the conceivable and ponderable development of science

Table 5*

Number of post-graduate students at the end of the year

	1940	1950	1955
Total No.	16 900	21 900	29 400
At institutes of higher education	13 200	12 500	16 000
At scientific institutes .	3 700	9 400	12 600

Table 6**

Distribution of post-graduate students according to faculties at the beginning of 1956

	At institutes of higher education	At scientific institutes
Total No.	16 744	12 588
Engineering sciences	4 562	4 796
Physics and mathematics	1 983	872
Agronomy and veterinary science	910	1 654
Philology	1 736	428
Medical science and pharmacology	1 624	540
History and philosophy	1 432	632
Political economy	1 295	515
Biology	583	843
Chemistry	483	835
Geology and mineralogy	504	756
Pedagogy	765	272
History of art	333	97
Jurisprudence	274	93
Geography	212	147
Architecture	78	108

* *ibid.*
** *ibid.*

and technical progress, and keeping all these points of view in mind they prepare the five-year and the 15-year long-range plans for scientific workers and technical experts.

The long-range planning of scientific workers and experts assures *an uninterrupted supply* of research workers and technical experts for the industrial and scientific organizations of the Soviet Union.

Development is characteristically shown in the following Table, which *shows the growth in the number of graduated specialists who have left the institutes of higher education of the Soviet Union between* 1929 *and* 1955.

Table 5 shows the *increase in the number of post-graduate students*, while Tables Nos. 6 and 7 show the distribution of post-graduate students and scientific workers according to faculties at the beginning of 1956 and the beginning of October 1955 respectively, in the Soviet Union.

Costs for the training of experts is a considerable item of expenditure in the budget of the Soviet Union. Table 8 shows the order of magnitude of these costs.

Table 7*

The distribution of scientific workers according to faculties in the Soviet Union October 1st, 1955

	Scientific workers	Percentage of total	Nos of those with post-graduate degrees	
			Doctors of science	Candidates
Total Nos.	223 893	100,0	5 460	77 961
Engineering sciences	61 107	27,3	1 855	20 653
Medical science and pharmacology	25 326	11,3	2 775	12 436
Physics and mathematics	20 077	9,0	825	5 364
Philology	17 743	7,9	248	4 062
Chemistry	16 435	7,4	626	4 639
History and philosophy	15 305	6,8	325	6 987
Agronomy and veterinary science	15 135	6,8	736	6 021
Pedagogy	11 478	5,1	74	1 923
Biology	11 009	4,9	946	5 544
Political economy	8 247	3,7	203	3 762
Geology and mineralogy	5 653	2,5	480	2 262
History of art	4 000	1,8	61	617
Geography	3 381	1,5	144	1 347
Jurisprudence	1 607	0,7	91	1 027
Architecture	876	0,4	31	376
Other	6 514	2,9	20	941

* *ibid.*

Table 8*

	Specialists with university qualifications					Specialist with intermediate qualifications				
	1940	1946—1950	1951—1955	1956	1957	1940	1946—1950	1951—1955	1956	1957 years
Expenditure on the training of specialists, million rubles	2876,8	31555,3	44453,9	10723,0	11105,8	1841,1	20268,2	25440,3	6193,4	5825,4
Annual average no. of students in thousands	811.7	1049,4	1591,4	2001	2099,6	974,8	1255,4	1658,2	2011	1941
Annual average training costs for one student in rubles	3544	5061	5600	5358	5030	1889	3230	3068	3080	3001
No. of trained specialists in thousands	126,1	652	1121,4	259,9	266,5	236,8	1278,5	1559,4	510,1	504,0
Average cost of the training of one specialist, thousand rubles ...	22,8	48,4	39,6	41,3	41,6	7,8	15,8	16,3	12,1	11,6

In the Fourth and Fifth Five-Year Plan of the Soviet Union, the average costs of the training of one specialist and university studen respectively, developed as shown above. (Specialists here comprise engineers and technicians.)

* V. E. KOMAROV: *op. cit.*

During the development of science and technology, beyond the trends of development already pointed out by SZAKASITS, the contours of a *new, important trend of development are appearing* with ever greater distinctiveness, according to which, *theory must come closer to practice, science to life* and applied research to industry. Corresponding to this latest trend in development the Soviet Union is increasingly raising the numbers of workers with plant experience, to participate in university or college training. These university or college students who have already had experience in production will, on successfully completing their studies, bring a considerable qualitative change in comparison to the skill of those specialists who are ignorant of production and practice, and who had gone to university straight from school.

In order to satisfy the quantitative demands of the requirement for experts, ever increasing *evening and correspondence* courses are being set up at the universities and colleges of the Soviet Union. The extraordinary popularity of this form of education is shown by the fact that in the Soviet Union today, about half the registered university and college students are enrolled in evening and correspondence courses. It is only by raising the numbers at the day courses and establishing further evening and correspondence courses, that the extraordinarily expanded requirements of the Soviet Union for experts can be satisfied. At the same time the employment on an ever wider scale of women in production, also helps substantially to meet requirements for experts.

Table 9 which follows, shows the percentage ratio of women among the students at all the institutes for higher education and the technical colleges of the Soviet Union.

Table 9*

	Women with graduate qualifications	Women with technical college qualifications
Percentage ratio of women among all specialists	52,0	65,0
Of these engineers and technicians ...	29,0	40,0
Agricultural experts.....	38,0	40,0
Economists.....	50,0	74,0
Health workers.....	74,0	91,0
Teaching staff and cultural workers	65,0	80,0

* V. E. KOMAROV: *op. cit.*

Finally in Tables Nos. 10 and 10*a*, a comparison is made of the development of specialist training in the Soviet Union, the United States, Great Britain, France and the German Federal Republic. The Tables show the total

Table 10*

	Soviet Union			United States			Great Britain			France			German Federal Republic		
	1940	1950	1955	1940	1950	1955	1940	1950	1955	1940	1950	1955	1940	1950	1955
Total of experts trained by institutes of higher education .	126 100	176 900	245 800	186 500	331 900	292 900	—	24 400	23 500	11 700	—	17 300	15 300	18 500	18 000
No. per million of population	660	931	1 229	1 429	2 133	1 789	—	500	475	279	—	403	221	370	346
No. of engineers trained	30 000	36 000	66 000	15 000	53 000	23 000	—	3 200	2 800	2 000	—	3 600	2 000	2 800	3 400
Percentage ratio of engineers of all experts trained ...	24	20	27	8	16	8	—	13	12	17	—	21	13	15	19

* V. E. KOMAROV: *op. cit.*

Table 10a*

	Soviet Union			U. S. A.			Gt. Britain	France	Austria	Italy
	1940	1950	1956	1940	1950	1956	1956	1955	1951	1951
No. of graduate engineers in thousands	290	392	721	156	316	400	78,5	91,8	12,6	44,4
No. of engineers per 1000 of population	15,1	25,9	36,0	12,1*	20,8	23,3	15,4	21,2	18,3	9,5

* in 1937. V. E. KOMAROV: *op. cit.*

numbers of experts trained per million of the population, and separately also the number of engineers per thousand inhabitants.

These very interesting and valuable figures — if transposed to the corresponding situation and requirements — may also be well used in planning the requirements of experts for other Socialist countries.

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