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THE INSTITUTE OF NATIONAL PLANNING

Memo. No. 617

PLANNING OF TECHNICAL PROGRESS IN INDUSTRY

Part II

Planning of temporal progress of research and development

by

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1.2.3.1 General problems

Determination of necessary working time for carrying out a certain topic of research mentioned so far[1] is considered to be a decisive prerequisite for entire managerial activity in research institutions. That means, it represents one of those fundamentals enabling managerial personnel of research institutions to distribute the single tasks of research activities between engineers, technicians and other employees on the basis of well-founded calculations. Up to now, however, only the quantitative and qualitative expenditures themselves have been considered. For temporally distributing the single tasks within different periods of time, i.e. year, quarter of the year, etc., some other calculations must be added. And this goes notably for the planning of temporal progress and fixing the terms of starting and finishing single stages of research work. This so, because only in such a way various tasks of one topic of research can be coordinated with each other so that

- successive and conditioning stages of research are tackled in a proper temporal adjustment,
- research institutions are loaded to capacity,
- research time as a whole is going to be shortened as much as possible.

Though there is a broad demand for many newly investigated products, developing countries should also try to follow more and more such a strongly organized system of conducting researches. This is the only way to keep up with technical progress and to close the gap between their present technico-economic level of production and that of the already advanced

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1) c.f. Planning of Technical Progress, part I, memorandum of the INP, Cairo, No. 617 .

countries. Sometimes, it seems to be a problem unable to be solved within a measurable space of time. Nevertheless, the tasks must be started tackling and a highly qualified planning of research and development can be estimated to be one of the crucial points on this way.

This becomes obvious when studying the conditions leading already to a speedy growth of national economy in emerging countries like the United Arab Republic, India, etc. Their economic development has been and will decisively be influenced by the fact that own research activities in many sectors of national economy have been pushed ahead in a planned manner -- in both the mentioned countries there are specific central research authorities and research plans are playing an important role within the frame of long-term plans[1] — as well as by taking over licences for starting a new production at a rather modern level.

Whatsoever the way may be, a comprehensive system of planning research from top to bottom and including all the activities up to their introduction into production has to serve as a guide. And the annual plans are to be based upon the briefly indicated planning of the temporal progress of research activities which, in turn, starts proceeding from the key tasks and main data of prospective plans as to this respective field.

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1) The development of research in the UAR is analysed, for example, by Abdel Fattah Ismail in, Current frends of science policy in the UAR, Impact of Science on Society, Vol. XII (1962), No.2

1.2.3.2 Parallelism in carrying out research

When carrying out researches, a lot of activities must be realized connected with each other in a manifold manner. This holds true with regard to a definite topic of research and different topics being in preparation in one research institution likewise.

Though realization of research work represents a continuous process of implementing successive and conditioning stages, they must not all of them necessarily be implemented one after another. If so, development of a new and difficult product would last more than 4 or 6 years. As a matter of fact, this space of time can decisively be shortened by organizing a high degree of parallelism within research work. That is to say, if there exist any technical possibility, single stages of research work should be implemented side by side. Hence, we have to take care of a high degree of parallelism within one topic of research and, at the same time, between various topics of research work, too. We would like to explain this more in detail.

Parallelism within single stages of research work means, for example, the graphic representation for newly drafted components are to be drawn immediately after having prepared them constructively. This is true to the fact that most of the products are composed of more or less independent units to be prepared separately by considering the connecting links between the different units.

Furthermore, there must be a high degree of parallelism between constructive and technological preparations. One is forced to tackle the problems at the same time as :

Firstly, the constructive determination of a new component or product is essentially be influenced by the foreseen methods of manufacturing the object under discussion. From the very beginning engineers of technological departments have, therefore, to answer the question whether the new constructive ideas are technologically solvable at all and whether this can be done technologically and economically effective.

Secondly, application of newly developed technologies requires certain considerations when designing the component or product constructively. That is, technical set-up must be chosen in a way allowing application of the new methods of processing. Thus, parallelism as to this kind of research activities forms not only a condition for shortening research time but, in general, an objective necessity for a high quality of research on the whole.

Parallelism between various and distinct stages of research is marked by problems similar to those mentioned before. Usually, one will find parallelism between such stages of research work as, for example :

- drawing of technical, graphic representations and their control,
- technological preparation and manufacturing of experimental or prototypes,
- manufacturing of experimental types and training of manpower for further production, etc.

Besides a shortening of whole time of research, a higher quality of technically preparing the subjects of research can be made sure. That is why such a collaboration of different departments engaged in drafting the new products or technologies should be fixed in a planned manner including internal and external collaboration as well.

Furthermore, this team-work has to comprise both technical and economical activities. The latter concerning, we have in mind

- determination of technical parameter and economic limits as concerns the new topic,
- determination of demand probably arising in home or foreign markets,
- economic limits of prime cost and price,
- choice of materials to be applied, etc.

These economic ascertainments must be considered necessary stages of research, too. This so, because only by means of their results those objectives can be formulated reflecting actually existing demand or limits for an economically effective production of respective goods. Proceeding from this, technology, for instance, can be set the tasks to surpass already known economic limits in order to increase economic benefit when selling the products.

It depends now upon the planner to design such an organization of research work forcing the various departments to a close collaboration. This is expected to be implemented, for example, by setting up advisory commissions composed of highly qualified experts and charged with checking up finished stages of research work according to set targets.

In result of this examination, it has to be decided whether the foreseen way of research should be followed in the future or whether some changings render necessary for the sake of keeping up with technical progress. To avoid unnecessary outlays of research capacity and economic losses, mentioned estimations are to be planned after having finished those stages of research supposed to be crucial points in entire research activity for solving a definite task.

Parallelism between different topics of research concerns also a very important problem of organizing research. The points under discussion are as follows :

- We are forced by the very facts to prepare more than one topic of research within one research institution.
- The capacity of research institutions is limited.
- The more topics of research are prepared at the same time and in one institution, the longer the time needed to accomplish a definite task.
- Scientific - technical personnel is specialized in various problems of technical development.

When considering these factors, one will find that there are more or less contraditions between them. Hence it follows, no simple combination of the various components determining planning of research renders possible.

How to solve now these problems generally?

In any case, the main task consists in preparing a new product, technology, etc. highly effective from the technological and economic point of view. This demands for confining to those topics expected to influence a large scale of similar or related productive activities, for instance, so as to achieve a general improvement or to meet a certain kind of common requirements.

That is to say, research activities of emerging countries especially should not be limited to solving a strongly specialized task being of interest for a single researcher but be used for solving such problems of technico-economic development enabling them to reach a general break-through in their economic growth. The topics will be, therefore, quite different ones

within the single countries according to their natural or other peculiarities. Nevertheless, leading organs for research have to take care of not frittering away research potentials available on too many and distinct topics prolonging unnecessarily the time up to their accomplishment and leading only to improvements in a very limited sphere.

And this goes for research activities in one research institution, too. By taking into consideration specialization, qualification and interest of researchers, topics of research must be selected in line with above-stated general requirements. Since, however, nearly all the new and complex technical developments are composed of differently characterized partial task, a compromize renders possible enabling management to set the researchers in consistency with their specialization. To meet now specific requirements of national economy, results of single investigations are to be composed like parts of a box of bricks. This, however, can only be implemented as far as detailed topics have been derived from general objectives.

For ensuring the highest possible quality within the shortest space of time to be achieved under given conditions, research activities should be started from the very beginning on the basis of team-work being the only form for solving main problems of science and technique of today. As research institutions of developing countries are usually property of the society, this gives rise to forming a new kind of team-work based upon the common interest to serve the country in question. This will be of real help to over-come deficiencies in similarly called activities in private research institutions hampering their use to capacity.

1.2.3.3 Determination of chronological sequence of research activities

After having dealt with some general problems, we have now to answer the question of how the chronological sequence of research activities is to be planned in detail.

The general starting point must be given by long-term plans of technico-economic development showing, for example, the foreseen economic progress on the basis of introducing new technical inventions. Derived from this, general plans of set terms have to be shaped containing the main steps of research work of the single topics and the performances being expected. That means, they have to desribe in full :

- the exact designation of the respective topic of research,
- who is going to take part in this research (e.g. other factories, research institutions of universities or national research centres, etc.,)
- the expected performances of above-mentioned research institutions and the personal responsibility for it,
- the time probably needed in order to accomplish the single main stages of research,
- the terms set for winding up the main stages.

When drafting the general plans of set terms, these data are, of course, more or less rough and concern the main stages only. They have to be specified in connection with preparing short-term plans. This temporal specification includes, above all, the technical, or in case of processing industries, constructive and technological preparations. The single tasks of which have to be derived from the construction order or the order of technological preparations containing all the necessary activities to be carried out for technically preparing a certain component or product.

According to the applied system[1], necessary working time for implementing the single activities can be expressed in different ways. In case of using the method based on standard units of graphic representations, these orders may look like the following[2]: (Sketch 1 & 2)

To determine now the exact terms of starting and finishing the single activities, their mutual dependence and the necessary chronological sequence of their implementation must be analysed and demonstrated. This can be done by means of different methods, the most important of which are

a) application of process chards or master schedules,
b) network technique according to program evaluation and review technique (PERT)

a) Application of process chards or master schedules

Process chards for reflecting conditioning and successive stages of research work are based upon mentioned orders of research work and are drafted as follows:

The starting point is mainly derived from the date a new production is to be started. Proceeding from this, it has to be calculated back when the single and partial tasks must be accomplished and, therefore, also be started with so as to be able to wind up entire research in time. When co-ordinating now the single activities temporally , the connecting links between partial activities must be found out and determined first in order to make sure that implementation of one part will not be hampered by a lacking behind of another. This is very difficult a task and true to the fact that nobody is able to

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1) C.f. Memo. No. 617, Chapter 1.2.2.2.

2) On basis of : Typenmuster fuer die Organization des Produktionsab-laufs, Karl-Marx-Stadt 1961, Page 89

sketch 1

CONSTRUCTION ORDER

designation of research:	administrative declarations like number of order: set term of accomplishing:
customer or destination:	

technical parameter set by the customer	degree of technical difficulty of construction					number of graphic representations	time needed
	1	2	3	4	5		

stages of research work	time needed	number of scientific-technical personnel					number of working days				
		gr.eng.	eng.	tech.	draft.	typ.	gr.eng	eng.	tech.	draft.	typ.
1. technical offer											
2. technical outline											
3. construction and elaboration of graphic representations											
4. control of graphic repre - sentations											
5. technical documentation											
6. multiplying of graphic representations											
7. translation											
8. technical proof of prototype											

sketch 2

ORDER OF TECHNOLOGICAL PREPARATION

	number of components (as a whole)	degree of technical difficulty						standards of working time according to the degree of technical difficulty					
		1	2	3	4	5	6	1	2	3	4	5	6
planned													
actual													

expenditure of working time for technological preparations

stages of technological preparation	expenditure of working time			set terms			
	planned	actual	changings	planned	actual	changings	remarks
technological preparation as a whole							
technological outline							
determination of materials needed							
elaboration of process charts or route sheets							
technology of assembling							
elaboration of standards of work.time							
elaboration of master schedules of temporal progress of technological operations							
preparation and manufacturing of short-living means of production							

forecast all the possibly arising shortcomings and, therefore, deviations from the planned sequence of carrying out researches. Thus, a certain "stand-by capacity" must be included.

On the other hand, necessary space of time for research is to be shortened by applying a high degree of parallelism when carrying out the single activities. Sometimes, this may contradict each other in practice but must be solved on a well-founded basis of thoroughly considering all possible events. Needless to say, that respective alterations have also to be observed in the course of implementing research.

This shows once again that such a system of planning can only be realized at a high level by means of team-work based on common interest and by utilizing the experiences of all the employees within a certain research institution.

The master schedule drafted on the basis of such analyses may look as follows:

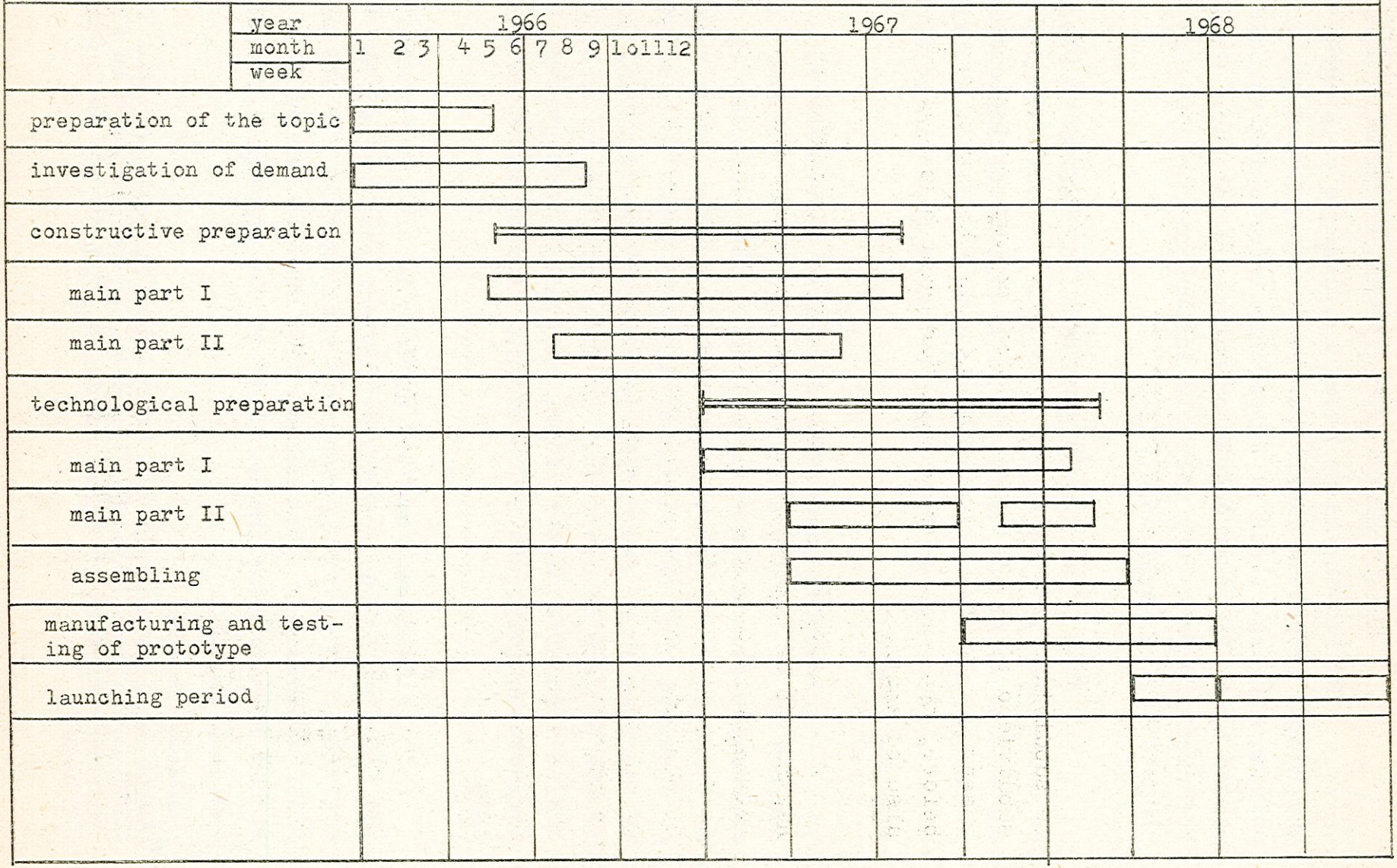
(C.f. Sketch 3)

Th-ough rather simplified, the main features are becoming obvious. They consist in the fact that the single stages of preparing a new product are not tackled one after another but in such a way that a new stage is started as soon as the inevitably necessary conditions and prerequisites are available. In the given example, for instance, technological preparation of the main parts starts at a point of time when constructive preparations are still in full swing. Such an interruption as concerning the technological preparation of part 2 may sometimes occur. But, for ensuring a continuous process, efforts should be made to overcome such deadlocks as they are hampering productivity of research personnel.

Finally, it should be added that similar chards are also to be drafted for the single components within main part 1 and 2 so as to be able to analyse their internal interlacement, too.

sketch 3

Chronological sequence for preparing a new product
(simplified representation)



b) Application of network technique according to program evaluation and review technique (PERT)[1)]

In recent years, network technique or program evaluation and review technique (PERT) has successfully been applied to solving distinct tasks of temporally interlacing various activities marked by a different degree of mutual dependence. Thus, network technique forms a very suitable instrument for planning temporal progress of research work, too.

When using now this method, any aggregate project has to be subdivided into its single elements. In our example, it must be subdivided up to the basic research activities implemented by one researcher or a research team and, like the method explained before, necessary working time for these basic activities must also be known.

Internal dependence of single activities within research has now to be demonstrated by using an arrow diagram. Every arrow represents such a research activity. The end point of the arrow, in turn, are used for marking certain events. As a rule, it must be observed that the number of the tail event is less than that of the head event expressing in this way the internal interactions of the project in question. By means of such an arrow diagram it can be demonstrated, therefore, what activities precede or follow a definite activity and which of them can be implemented side by side.

Finally, the drafted network is used for characterizing and calculating the so-called critical path reflecting those activities determining necessary working time for the whole project under discussion. That means, they must be, above all, accomplished in line with the schedule if the aggregate project shall be finished in time.

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1) As to this method, it has been taken for granted that features of PERT are knwon. They are repeated, therefore, only in brief. For thorough studies of PERT, Memo. No. 544 of the INP, Cairo should be used.

Let us consider now the practical application of network technique by using a simplified example.

There is newly to be developed a television set comprising 10 stages of research work, the implementation of which must be carried out in a definite sequence. The single stages or activities are marked by a demand of working time as follows[1]:

Activity	A	= 25	temporal units	
	B	= 125	" "	
	C	= 75	" "	(in this example,
	D	= 150	" "	one temporal unit
	E	= 50	" "	is considered to
	F	= 125	" "	be one day)
	G	= 25	" "	
	H	= 125	" "	
	I	= 75	" "	

The single activities must be tackled in a special order of succession. A and B can be started together. After having finished activity A, C and E have to be realized so as to be able to begin on the basis of finished activities B and C, activities D and F. Activity E, in turn, forms together with finished activity D the starting point for activities H and G, while F and G are needed so as to accomplish I.

This seems to be very complicated but will become more obvious when looking at the arrow diagram demonstrating mentioned conditions by means of a network.

For drafting this network, it is, to repeat this, necessary to know the time needed and the internal interlacement of single stages of research. It must, however, not necessarily be drawn to scale.

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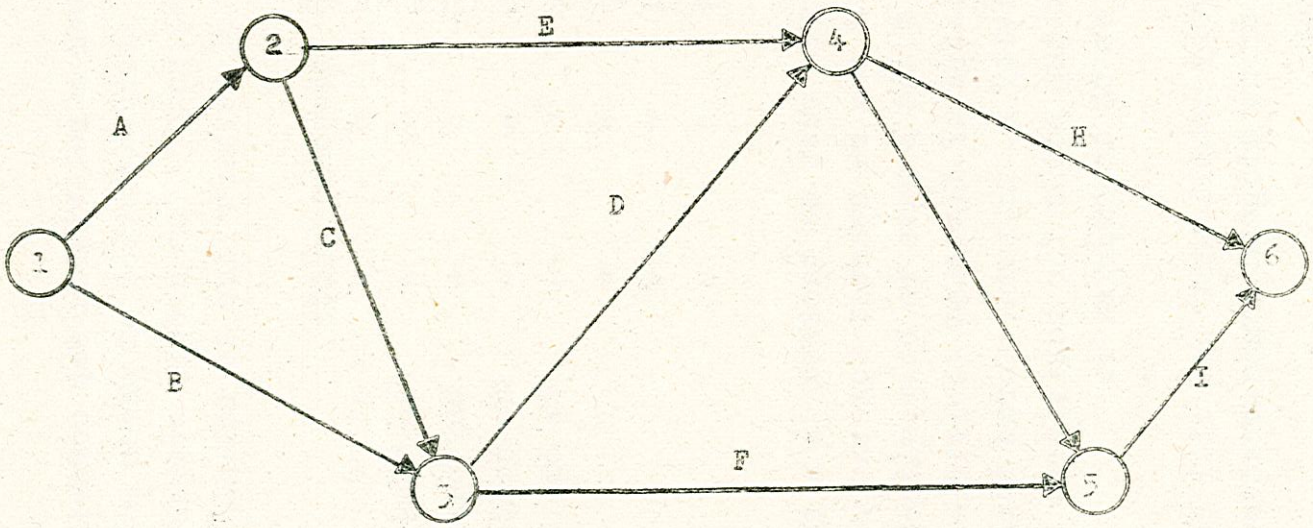
1) This example is partly based on Memo. No. 544 of the INP, Cairo.

Network diagram of research activities



The figures inserted there are reflecting the already mentioned temporal sequence of activities so as to accomplish a certain event. It shows, for instance, that event 4 is based upon finished events 2 and 3 and so on. Thus, for simplifying the further representations, we are able to neglect the description of single activities by only using inserted figures.

Now, the temporal progress of implementing single activities must be analysed more in detail. Let us assume, event 1 reflects respec-tive managerial activity for starting research and comprises 9 - 10 temporal units, i.e. days. Then, event 3 can be started after 10 + 25 days for A needs altogether 35 days. In case of activity F, it is required that B and C have been finished. For A plus C are shorter than B, starting point of F is determined by B and can be tackled 10 + 125 days after having initiated the project.

Concerning activity G, respective conditions are given by accomplishing activities E and D. Since D depends upon winding up of B, G can be started on the 285th days. The starting points for D, H and I are calculated similarly.

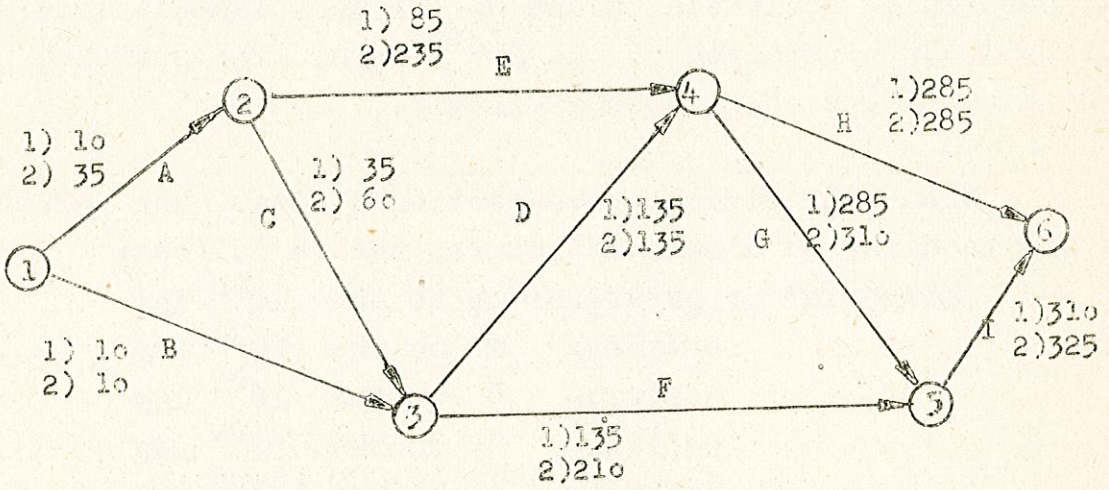
When summarizing above-mentioned ideas, the earliest date for tackling the single activities are as follows:

managerial preparations up to the 10th day
activity A on the 10th day
activity B on the 10th day
activity C on the 35th day
activity D on the 135th day
activity E on the 85th day
activity F on the 135th day
activity G on the 285th day
activity H on the 285th day
activity I on the 310th day

For finding out now the critical path, i.e. those activities determining necessary working time of the project, the latest permissible date for each activity must be calculated, too. This means concerning

activity I = 335th day (from the starting date of our project)
activity H = 285th day
activity G = 310th day
activity F = 210th day
activity E = 235th day
activity D = 135th day
activity C = 60th day
activity B = 10th day
activity A = 35th day.

This shall again be illustrated by a sketch.

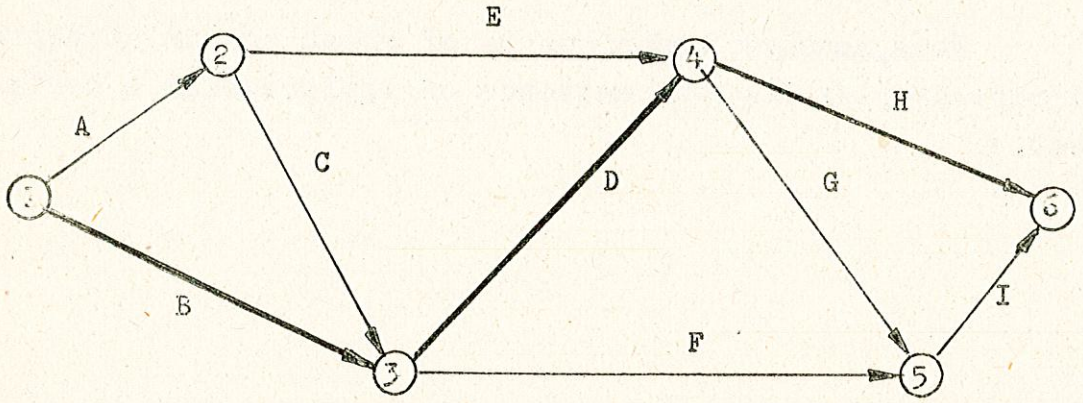


1) earliest possible date 2) latest permissible date

Proceeding from this, the critical path is generally determined according to the following rule:

If the earliest possible time of starting an activity equals the latest possible for accomplishing the project in time, then that respective activity lies on the critical path.

As to the chosen example, this goes for the activities H, D and B representing, therefore, the critical path of the project under discussion and determining duration of research work. Thus, observance of their time limits must be given prominence and continuously controlled.



Needless to say that this method leads to very exact figures regarding the temporal sequence of research activities and it enables management to shorten entire cycle of research activities up to their indispensable necessary space of time. Moreover, while in our example respective figures could be calculated by hand, in case of more comprehensive networks, possible deviations from the planned time have to be included and computers must be applied. This, however, forms the contents of special studies and is to be neglected in our outline.[1)]

1) Application of computers for PERT is dealt with in the IBM General Information Manual, E-20-8067-1.

To accomplish this, it should be noted that network technique can also be used as far as the date of finishing a certain project is fixed and serves as starting point. Then, the date of finishing or starting an activity can be obtained by calculating back from the given finishing date which shall equal zero. By using the figures of our example, the single activities must be started as follows:

I must be tackled at least 75 days before zero

H must be tackled at least 125 days before zero

G must be tackled at least 100 days before zero

F must be tackled at least 200 days before zero

E must be tackled at least 150 days before zero etc.

Thus, network technique is of great use in either case of temporally planning the sequence of implementing a certain project.

1.2.3.4 Calculation and balancing of capacity in research institutions.

Determination of chronological progress of materializing topics of research forms only one prerequisite for drafting annual plans. Before fixing the definite data for starting the single activities, capacity of the research institution must be calculated so as to be able to estimate wether the most suitable temporal sequence of carring out single topics of research is in line with capacity available.

Since machines are hardly applied for research activities, except of copying graphic representations, typed technical documentations or manufacturing of prototypes, calculation of capacity has to proceed from the number and structure of employees available and the planned working hours of each of them. Thus, working time fund is reckoned by multiplying the number of employees of a certain group of qualification by problable working time in the forthcoming year. For example :

X_1 graduated engineers x Y_1 working hours = Z_1 hours working time fund
X_2 engineers x Y_2 working hours = Z_2 hours working time fund
X_3 technicians x Y_3 working hours = Z_3 hours working time fund
X_4 draftsmen x Y_4 working hours = Z_4 hours working time fund

When balancing working time with the time needed to accomplish planned research activities, we have to take into consideration losses of working time caused by illness, leave, participation in training courses, etc.

Furthermore, as to small research departments without constant working teams, time needed for research work has directly to be balanced with the working time of scientific-technical personnel available. The instruments are given by

the planned temporal sequence of single topics of research or the drafted network based upon the actual temporal conditions (terms of delivery, etc.) and the subdivision of single stages of research into different activities of engineers, technicians, etc. as mentioned, for instance, in the construction order.

Proceeding from this, a balance sheet can be drafted which may look like the following :

(Sketch 7)

Though the sketch is a little bit simplified, some of the main problems can be revealed. One problem consists in balancing the working time of engineers and technicians. This so, because technicians are able to start their work only after the highly qualified members of the research institution have drafted the features of the new product or technology. As this process can hardly be subdivided, there is no continous flow of work to the following stages of research work undertaken, for example, by technicians and concerning, for instance, the design of the single components, short-living means of production, etc. in detail. Usually, the same holds true with regard to the division of labour between technicians and draftsmen.

Additionally, working time of scientific-technical personnel of research departments of enterprises cannot only be used for implementing new topics of research. At the same time, improvements of the current production must be prepared and introduced into production. The share of capacity needed for this kind of research and development is a very different one within single factories. It depends mainly upon the kind of production, the quality of its technical preparation and the data of its introduction. That is to say, a current production requires the more improvements the longer ago it has been started with, in order to keep step with technical progress.

sketch 7

working time needed for / topics of research	graduated engineers			engineers			technicians			draftsmen		
	J	F	M etc.	J	F	etc.	J	F	etc.	J	F	etc.
No 118-1966	60	55		150	300		600	600		500	900	
No 120-1966	150	150		400	300		100	200		200	200	
No 121-1966	100	100		100	50		-	100		-	100	
No 10-1967	100	100		-	-		-	-		-	-	
added amount	410	405		650	650		700	900		700	1200	
capacity available	400	400		600	600		800	800		1000	1000	
difference ±	-10	-5		-50	-50		+100	-100		+300	-200	
corrections												

When balancing now the different demands for research capacity and capacity available, very often it will happen that they are not in line with each other from the very beginning. There will rather be a lot of bottlenecks which must be brought to light so as to be able to redetermine chronological sequence of research activities and redistribute capacity available as well. If needed, such stages of research must be redistributed, above all, which do not affect the accomplishment of a certain topic of research as a whole in time. That means, those activities are to be redistributed being outside the calculated critical path of carrying out an aggregate research project.

In as far as they are inevitable, necessary redistributions must be implemented in close collaboration between planner and scienticic-technical personnel charged with realizing these tasks. This so, because the latter know best whether planned time limits are supposed to be very confined ones and whether by introducing special measures single activities could be finished within the available space of time. Such measures may concern, for example,

- shortening of necessary working time by means of a new type of team-work in research institutions of public sector;
- competition between cooperating working teams,
- granting of aiming bonuses or other material incentives,
- etc.

Thus, is it up to the management to find out such solutions, in close collaboration with the employees, making sure that planned projects will be tackled and accomplished in time.

When planning capacity and its utilization, however, in research institutions organized on the basis of working teams, some additional facts have to be taken into account. Under these conditions, balancing of working time and requirements has to be based on working teams, too, i.e. working time available and time needed to accomplish a certain stage of research have to be determined in the same manner. The problems arising out of such a way of planning are the following :

From the technical point of view, the working teams are composed according to the general features of technical problems to be solved. For these tasks and problems are variable, structure of the working teams has to be adapted adequately. These corrections, however, should be defined to a rather small extent in order to attain a genuine team-work of these working groups.

Another problem concerns the structure of qualification and quantitative composition of the single working teams, on the one hand, and the different degrees of technical difficulties with regard to various topics of research and development, on the other. Usually, respective requirements will differ from each other with every topic of research. Since the composition of working teams cannot be changed similarly, we have to find out a so-called optimum formation following the general trends of research activities in the respective field. Arising bottlenecks in the one or other direction should be met by means of time balances of the whole team and, if needed, by means of special and temporally limited agreements with single members.

To reveal now the burden of each member, it becomes necessary to elaborate detailed time balances based upon the demand of working time for a certain topic of research

expressed, for example, in such figures as mentioned in connection with the construction order. Such a balance of working time may look as follows:

(Sketch 8)

From this time-balance, the distribution of various orders of research between the members of a working team and the interlacement of activities between engineers, technicians and draftsmen can be seen. For ensuring a high degree of certainty, actual conditions must be reflected as regards such factors as planned leave, business trips, visit of fairs, leave for studies of corresponding students and so on.

Moreover, the time-balance, mentioned above, should not be used for planning only. At the same time, it can also be applied to follow-up. By registering the working time needed in order to accomplish single activities, planned and actually used up working time can immediatly be compared. Hence it follows that the time-balance represents a good fundament for both analyses and future planning of working time and for elaborating standards of working time for special kinds of research as well.

1.2.4. The efficiency of research and development

For research and development have no end in themselves, their efficiency has to be analysed from the very beginning. That is a very difficult problem and has not been solved in all details for the time being. When comparing the experiences of different countries in this matter, one will find, therefore, different opinions and solutions.

sketch 8

department group	Balance of working time of a working team																				
name	profes-sion		January				February				March				April				May		
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Mr. A	grad. eng.	plan	order A				order B					fair		order E					leave			
		act.																				
Mr. B	engineer	plan					order C								order F							
		act.																				
Mr. C	engineer	plan				order A					part time study							order B				
		act.																				
Mr. D	technic.	plan	leave				order C								part time study							
		act.																				
Mrs. E	drawer	plan					order A											order C				
		act.																				
etc.																						

In spite of difficulties possibly arising in this context it must be stated that calculation of efficiency of research work has to be considered an indispensable part of every research activity. This holds true for industrially advanced and emerging countries likewise. This so, because only by such calculations it can be disclosed what are the most favourable topics of research to be given prominence in a certain stage of economic development. And that is of importance for developing countries especially forced by the very facts to speed up their economic development and to close the gap between their technico-economic level of production and standard of socials life and that of the advanced countries. Otherwise, i.e. without thoroughly estimating efficiency of research, a lot of money and research will practically be used for less important topics and, therefore, more or less be wasted as they are not devoted to solving the most urgent needs of the country in question. Thus, all the possible dissentions notwithstanding, we have to find out an appropriate solution acceptable by economists and scientific-technical personnel as well.

At first, basic research has to be considered separately. It is unquestionably true that efficiency of basic research can usually not be determined by quantity. But, there are methods to measure it by quality. To give an example. When investigating a new method of rooting out the cotton worm, the result will be a higher cotton quality and a higher crop. This new quality can be ascertained without being forced to estimate the exact changings regarding the amount of higher crops, etc. In most cases, such a calculation could be sufficient in order to demonstrate efficiency of basic research.

Applied research, however, is expected to solve a special task. Technical parameter and economic limits are usually fixed either by the customer directly or by other consuming institutions like foreign trade organizations, etc. Thus, it must be compared whether the objectives of a new research will lead to the targets set. The foreseen topic and way of solving the problems should be defended by those charged with implementing the tasks. And for that, the efficiency of the new research forms one of the most decisive criteria.

Needless to say that such a critical estimation cannot be given by one engineer or economist. But the new topic of research must rather be defended against a commission composed of highly qualified experts in the respective field and coming from one's own or other institutions as e.g. the already mentioned intra-branch working groups.[1)]

In this context, we would like to stress that by taking into consideration all the problems connected with calculating efficiency of research, it is more useful to spend a certain amount of money for these purposes than to neglect them at all. The latter is the most uneconomical way to go and leads, of necessity, to speculations and a incorrect planning. State authorities in developing countries have, therefore, to put pressure on researc institutions to take over new topics of research only if the probable efficiency has been proved in advance.

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1) c.f. memo No 617 of the JNP, Cairo, page 25 .

Mentioned demands coincide basicly with the ideas of the UN Organization for Industrial Development when saying:[1)]

> "Industrialization to us is much more than the establishment of new factories. It includes also the efficiency of operation of both new and old factories. It includes the full utilization of existing capacities . .... Above all, however, we believe that industrialization, to be really effective, lasting and self-sustaining must be securely based in the institutions, policies and capacities of the deceloping countries."

Since industrialization will depend in an ever growing scale on the efforts of the developing countries themselves, the demands for a high efficiency must be raised up already at the very beginning, i.e. at the point of time of starting research.

State authorities have to take care of meeting these requirements and this should, above all, be done through economic means. For example, financial means for research are limited in all the countries. They are to be allotted, therefore, by the state, state bank or respective superior authorities according to the efficiency of research for the present of future national economic development as a whole. Only in doing so, the economic results per unit of financial means spent for research can be increased.

With regard to the main contents of research and development in industry, calculations of efficiency have to the worked out for

- completely new factories[2)]
- products newly to be developed;
- improvements of products produced at present,
- new or improved technologies.

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1) Statement of UN-Commissioner Dr. I. H. Abdel-Rahman at the opening of the African Industrial Symposium, Cairo 1966, published in conference materials, page 5

2) Since these problems are surpassing the boundaries of this topic, they are to be neglected in here.

Calculation of efficiency of a new product

To start with, calculations of the efficiency of a product newly to be developed must, at first, be a qualitative one. That means, properties of the new product have to be compared with similar goods supposed to be the most advanced in the respective field. Technical parameter and economic indicators of these products should serve as basis of reference, no matter, whether they are manufacturd in one's own or in foreign countries.

It depends now upon the stage of research, the calculation is carried through, and the significance of that product for home or foreign markets in which details these critical analyses are going to be undertaken. As to a lot of goods of general demand, i.e. consumer and durable goods of daily life, it is very often quite sufficient, at least for a certain period, to reach a level which corresponds to the averge requirements of the population and their purchase power. And that, because an unnecessary increase in quality will make research more costly and production more expensive without having a really higher effect. Sometimes, taking over of licences will in such a case be cheaper than own researches enabling the country to concentrate research capacities on its special tasks of socio-economic development. But this is another question and must be decided upon in any case under discussion separately.

If, however, a new research is aiming at determining world top level in a certain field being of particular importance for entire economic development of the country in question, mentioned parameter and indicators have to be analysed and compared more in detail. On the one hand, the already reached level of most advanced products has to be studied by taking into consideration their most likely trends of technical development in the forthcoming years.[1] On the other hand, we have to investigate

1) c.f. memo No 617 of the INP, Cairo, chapter 1.1.1.

the development of demand[1] as the probably saleable volume of the product in question depends mainly on both the reached technical parameter and the price. This, in turn, requires a thorough study of efforts of competing capitalist factories or countries which, of course, do not intend to give up their position but rather to strengthen it by keeping up with technicl progress, too. In case of competing factories in socialist countries, respective problems should be negotiated upon in order to solve them in the long run.

Thus, for being able to come to well-founded decisions regarding the effectiven-ess of a new topic of research, respective analyses should be carried out in a very comprehencive manner by including all those institutions of the country which can give a word to the problems under discussion.

Furthermore, another problem comes into the fore and must be taken into account in developing countries especially. Over against private firms in capitalist countries, the benefit for the national economy as a whole must be put in the centre when calculating effectiveness of research in public institutions. It renders possible that, sometimes, a certain topic of research may only be in favour of national economy, for example, development of a few supplementary materials necessary for a highly effective main production of the country concerned. If so, additional material incentives are to be given by superior authorities so as to make sure that this topic will not be neglected by the research and productive department of the enterprise in question. In general, however, every topic of research is expected to guarantee a higher economic efficiency for both the producer of the new goods and the future consumer as well.

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1) c. f. memo No 597, part II, of the INP Cairo

Calculation of efficiency is not bound up with one stage of research only. The first estimations are to be prepared in connection with determining the topic of research itself. When defending the topic over against superior state authorities, these analyses play a very important role. Of course, at that time they may only contain rough figures. Hence, they must be detailed and specified in the course of realizing new stages of research work. That is to say, calculations of efficiency are to be elaborated or refined after having finished the following stages of research :

- determination of the topic of research,
- designing the proto-or experimental type,
- manufacturing of pilot lot.

In doing so, the new quality of the development in question and its actual efficiency can be proved continuously. It is worth while discussing the problems several times so as to avoid that time and money are spent for topics of research technically or economically outdated because new products are already produced in other countries at that time and they are representing the same or even higher quality than the product in preparation.

This underlines once again the very significance of exactly extimating trends of science and technique, research work in other countries, probable technical and economic parameter of a certain product in the future and the development of demand.

It goes without saying, furthermore, that every estimation of a new research from the technical and economic viewpoint depends first and foremost upon the product itself. Thus, the following remarks can only cover very general features to be specified according to the product in question.

As to the technical estimation, such general features are :

1. the technical parameter of the new product,
2. the degree of mechanizing and automizing processes to be carried out by the new product,
3. the simplicity of operating the product, e.g. machines, appliances, etc.,
4. the degree of mechanization and automation of processing the new product,
5. the use of standardized components or parts of other products manufactured in the same factory,
6. the rational use of available raw materials, etc.

From this it appears that both the technical features of the new product and its processing must be considered.

The economic estimation regarding, there are similar and quite different factors as concerns producer and consumer goods. General items are, above all:

1. necessary outlay for the research, on the one hand, and
2. prime cost, price, returns of the new product as well as
3. financial outlay for introducing the new product into production, on the other.

Besides this, special calculations must be carried out in case of producer goods so as to estimate the economic effects when applying, for instance, the new machine. To say it in other words, effectiveness must be considered from the point of view of the employer, too. And for that, the following factors should be ascertained, for example :

A new machine will be an economic one if the possible reduction of prime cost by using it is higher than the purchase price itself.

$$P_P < (p_1 - p_2) \times p_y \times l_y$$

The signs stand for :

P_p = purchase price
p_1 = prime cost before applying the new machine
p_2 = prime cost after applying the new machine
p_y = pieces per year
l_y = expected period of useful life of the machine

Furthermore, the new machine will economically be employed if the period of useful life of the machine is longer than the period of recupment (P_r)

$$l_y > P_r$$

The period of recupment is calculated as follows :

$$P_r = \frac{P_p}{(p_1 - p_2) \times p_y}$$

On the basis of this, savings of prime cost during the period of useful life are to be determined :

savings of prime cost $= (l_y - p_r) \times (p_1 - p_2) \times p_y$

Since the main fields of applying a new machine are usually known such calculation render possible. The effectiveness, however, is linked up with the technology of processing. Thus, one will find more and more that new machines and technologies are developed simultaneously by considering these close interactions.

Calculation of efficiency of an improved product

The calculations of efficiency of research's aiming at technically improving products already produced is decisively influenced by the fact that respective and comparable figures as technical parameter and economic indicators are available. In this case, authorities to be entrusted with are able to compare them directly. Generally, the following factors have to be considered:

- financial outlay for research and development in order to improve the product in question,
- necessary expenditure in order to lead up the improved product into production,
- planned volume of production and savings of the factory to be reached when manufacturing the improved product,
- savings outside of the factory, i.e. in employing enterprises or national economy as a whole.

Necessary expenditure of working time and financial outlay for these improvements are calculated like th-ose for new topics of research and development. The results are very often and suitably expressed in a balance-like manner containing such items as :

	old product	improved product
technical parameter period of useful life efficiency of higher durability prime cost price volume of product etc.		

Obviously, it depends upon the particularities of the improved product what kind of factors are to be used for estimating its new quality. In any case, the problem consists in taking into account possible savings when producing the improved product and necessary expenditures for the improvements themselves. Then, one will find that sometimes researches in order to increase quality of existing products are less effective than a new development aiming at reaching a completely higher technical standard of the product in question. That is why very exact calculations are necessary before starting improvements at all.

Calculation of efficiency of technologies

The calculation of the efficiency of a technological process to be developed newly depends mainly upon its field of applicability. That means, the broader the field of applicability the more difficult an exact estimation of possible savings.

If only a definite method of manufacturing certain goods is concerned, one will be able to calculate the efficiency expressed by savings, increase of productivity, etc. in all details. On the other hand, there is no possibility to calculate economically, of course, the effectiveness of such a new technology as "metal-gluing-technique" applied, as a matter of fact, in all the branches of industry. In such a case, the expenditure for exactly calculating possible effects may be higher than the efficiency itself. Thus, out of three main factors determining efficiency as

- financial outlay for research and development,
- time of applicability of a new technology,
- direct economic effects of the new technology,

two urgently needed are more or less unknown.
The most complicated problem concerns the possible time of applying the technological process . It depends, for instance, upon the time the products manufactured by means of this new technology will remain in the market. On the other hand, new articles can be found or be developed using this highly productive technology in the future. This shows very evidently that no comprehensive and exact computations of effectiveness render possible.

How should this problem be solved ?

Generally, two possible solutions are given :

1. If the technological process in question depends mainly on a definite product, the time of applicability should be calculated according to the foreseen time of manufacturing it.
2. If the new technological process is to be used generally, the time of applicability must be calculated according to experiences. That means, there are to be analysed equal or similar processes and their time of applicability expressed in years by considering possible changings in the field of application. This serves as a basis for the calculation of efficiency, mentioned above. Moreover, the branch or association of industrial enterprises should form the scope of such kind of analyses for both the time of applicability and the efficiency of the process under discussion.

To give an example .

At first, the effects of the new process are calculated within one year and within the branch. Later on, this amount has to be multiplied by the years of applicability by including those fields of application covered with a high degree of certainty in the future. It goes without saying that these figures concerning the effects of the new technology are very often rough ones expressing only, for instance, an average percentage of time or cost reduction.

Finally, it depends upon the problem itself how thoroughly it must be calculated. In any case, due attention must be paid that the expenditure for calculating the efficiency does not pass over the efficiency.

The ideas given in connection with the calculation of efficiency of research and development represent first experiences as to this subject. It should be noted that big efforts are made by economists of socialist and capitalist countries in investigating new methods and possibilities without, for the time being, however, getting results to be considered as final ones. It remains the tasks of economists also in developing countries, therefore, to study very thoroughly all the experiences and to make full use of them for their own country's purposes.

After having accomplished all the mentioned activies, the annual plan of research and development can be drafted in a comprehensive manner so as to compare it with the other necessary activities of the factory or branch in question and to submit it to the superior authorities for being checked and if necessary being approved. Respective data can be combined by means of the following forms:

PLAN OF TECHNICAL PROGRESS
Survey on topics of research

ministry :
organization :
factory :

No	topics (abbreviation)	main data start	main data end	stages of research in plan year: stage	date	stage	date	stage	date	financial means required: total	up till now	plan year	remarks

number of topics	new	to be finished I	II	III	IV	financing	source of financing: budget	other sources
total: out of them: central: ministry: organiz.: factory :						total financial outlay plan year: amount for pure research: amount for experimental stage: amount for equipment: investments for starting regular production:		

place and date: signature:

PLAN OF TECHNICAL PROGRESS
Research and Development

ministry: organization: factory:	remarks:

research institution:

responsible engineer:

topic of research:

contents of the topic, way of solution, national economic importance, working program:

main data of implementing the topic:

start of research:

finishing of research:

required financial outlay:

finishing of stages of research and required financial outlay:

1. stage: amount:
2. stage: amount:
3. stage: amount:
4. stage: amount:
5. stage: amount:

main data of experimental stage of research:

number of experimental types:

number of products of pilot lot:

value of experimental production:

necessary equipment for manufacturing and testing experimental production:

start of regular production:

1. year : number:
2. year : number:

necessary investments :

place and date: signature: