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Strategic Planning for Research and Development

Th. Bemelmans*

This paper examines the need for and the difficulties in implementing strategies for planning the research and development activities of a company. The author does not accept that research planning reduces creativity, though he is of the view that planning's exclusive concentration on economic aspects of a company's activities, such as turnover or profit, can lead to erroneous decisions in the research and development field. This paper outlines a number of specific and explicit research strategies which can be followed, and relates them to the company's strategic objectives. Furthermore, the author explicitly categorizes different types of research and comments upon the relevance of strategic planning to each.

Introduction

Products become obsolete, not only from a technical but also from an economic point of view. Existing products are superseded by new or improved products. The same applies for production techniques. If a firm does not follow this technical trend, competitive strength will diminish continuously, affecting turnover and thus continuity. Naturally, every firm will try to prevent such a situation by renewing its assortment and its way of production in due time.

A way to safeguard continuity is the development of new products by either own research or outside research. In both cases these activities should be carefully planned because the available resources are limited and the development time for new products appears to be often long.

There are serious doubts whether or not research can be planned. Some people believe that research planning may reduce creativity, resulting in a smaller profitability of successful innovations. We do not share this opinion, though we find that the exclusive concentration on eco-

nomical aspects, such as turnover or profit, may lead to erroneous decisions in the research field. The importance of research and the appropriate planning is different for each firm. If a firm wishes to be leading in the technical area, a strategy often called 'first to market', research will naturally play an important role in the whole business climate. Such a strategy is asking again and again for new products with a high innovation value. These products will give the firm the technical lead over its competitors, resulting in high turnover and profit opportunities.

On the other hand there are also disadvantages. The search for products with a high innovation value generally leads to both high costs of research and great risks of failures. An alternative of the 'first to the market' strategy is that of 'follow the leader'. In this situation the firm is not primarily oriented toward the development of products based on completely new technologies, but its aim is to follow as quickly as possible a technical leader by using already existing technical know-how. The costs of research and the technical risks of failure are then very often much lower.

On the other hand it will be obvious that such a policy may also result in a skimmed market with lower selling prices and higher market introduction costs.

Categories of Research

Research can be divided into several categories, namely:

- ☆ basic research: research with the objective to enlarge purely technical know-how without aiming at a specific commercial application. There is no relationship between this research and the operational goals of the firm;
- ☆ applied research: research with the objective to enlarge technical know-how in such a way that a specific commercial application can become a reality;
- ☆ development: a systematic use of available know-how oriented toward the introduction of new or improved versions of products or production techniques.

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In literature about this subject more sophisticated classifications are mentioned. Mansfield and Rappoport, for example, give the following description:

Following the procedures of the Panel of Invention of the Department of Commerce, as well as our own previous work, we classify the work leading up to the first commercial introduction of a new product into following stages: applied research, preparation of product specifications, prototype or pilot plant construction, tooling and constructing of manufacturing facilities, manufacturing start-up and marketing start-up. Of course, there is no presumption that these stages do not overlap or that they must occur in any particular time sequence. (ref. 5, page 1381).

In this description nothing has been said about basic research, either, since it defines activities for a commercial application. In our simplified definition the preparation of product specifications and the construction of prototypes or pilot plants are part of the development phase.

From the definitions it appears that basic and applied research are intended to enlarge technical know-how, this in contrast with development. However, it is unjustified to conclude therefore that development would be much simpler and more controllable. In quite a lot of cases the opposite will appear to be true.

In the previous part we have stated implicitly that planning of research is useful and possible. However this statement is not valid for basic research which is in fact science for science's sake. In our opinion it is impossible to evaluate the benefits of this type of research because it is not related to any particular goal of the firm. The same opinion has been formulated in literature such as 'A wise manager does not select projects in the area of basic research'. In practice decisions are unavoidable about the major guidelines regarding basic research. First of all one has to decide which amounts will be available for this research, if it is found necessary. An often used rule of thumb is to reserve a certain percentage of turnover or profit for this purpose. Secondly one has to indicate what kind of technical instruments and what kind of people will be available. This decision more or less indicates the course basic research can take. However, once having defined the setting of basic research, it is wise to do no further attempts to select specific projects according to economic criteria.

Decision about the R & D Budget

Many studies have been carried out to discover how a firm decides on the R & D budget. From empirical investigations in 69 Swedish firms, the following appears:⁸

In our opinion no firm is likely to use only one of the above mentioned methods. However, the conclusion is justified that in most cases the single projects are the dominant factor in determining the R & D budget.

Therefore one should have an insight into how projects are evaluated in order to be able to judge about the whole

Table 1. Methods for determining an R & D budget

Method	% of occurrence
(1) A percentage of actual or expected turnover	17
(2) A percentage increase of the R & D budget in previous year (years)	9
(3) Same costs as those incurred by the principal competitor	1
(4) Analysis of individual projects	62
(5) Other methods	11

budget. These project evaluation models will be discussed further in subsequent paragraphs. Here it is sufficient to conclude that the profitability of the single projects, a criterium that is part of all evaluation models, apparently determines the whole R & D budget to a large extent. Some relationships between profitability of projects and the amount of money reserved for R & D are mentioned in American studies on this subject.

If the total R & D budget were completely dependent on individual projects, one would be facing the risk of a budget, fluctuating strongly from year to year. However, a research organization once created cannot be enlarged or reduced *ad infinitum*. So factors such as budgets in previous years and the maximum fluctuation allowable within the organization, will play an important role in the determination of the R & D budget as well.

How is the total budget divided over the several research categories? Mansfield concludes from statistical data that on an average only 4 per cent of the whole budget is spent for basic research. Applied research and development are consuming successively 20 and 76 per cent of the whole budget. The foregoing is in concordance with the fact that the main part of an R & D budget within a firm is spent on projects with a relative low risk of failure. Apparently the enlargement of technical know-how, which usually entails high risks, is mostly left to thirds whereas the firms themselves invest relatively high amounts in the introduction of new products on the market.

At the end of this paragraph the reader will find some figures about total innovation costs per project and the R & D part in it. Based on an extensive analysis of 38 new inventions in 1960 in the United States in the branches: chemicals, machinery and electronic industry, Mansfield makes an estimate of the average innovation costs per project and the division of these costs over the several phases.⁹

On an average, total innovation costs amount to \$2.3m with the same standard deviation or spread. We can conclude that there are enormous fluctuations in these costs. We have summarized the Mansfield data in Table 2.

From Table 2 it appears that the costs of research are hardly half the total innovation costs. Next, we see that development requires much more money than does

Table 2. Percentual division of total innovation costs per project

Phase	Chemicals	Machinery	Electrical industry	Total
(1) Applied research	17	3	4	10
(2) Development				
—product specifications	13	4	3	8
—prototype/pilot plant	13	41	44	29
(3) Production investments, start-up production and marketing	57	52	49	53

applied research, certainly in the machinery branch and the electronic industry. Also here we have to mention the enormous spread around these averages. Mansfield gives a number of explanations for this very large spread, e.g.

- The importance of the invention, measured in turnover terms. The research part of the total costs are increasing accordingly as the invention has a higher innovation value.
- The experience and know-how of the firms in a certain technological area. The greater this experience is the lower the R & D costs will be as a percentage of the total costs.
- The size of the firm, again in terms of turnover. Larger firms are initiating most of the time projects in which a relatively high percentage of total costs are spent for R & D.
- The total innovation amount. The larger this amount, the lower the R & D percentage. In the case of big projects mostly the non-research costs are dominating such as production and marketing costs.
- The necessity of the construction of pilot plants/prototypes. From Table 2 it appears that the construction of pilot plants and prototypes requires quite an amount of money. One would therefore expect the percentual part of R & D to be high. On the other hand it has been proved that pilot plants/prototype construction mostly occurs in big projects, thus in those projects in which especially the non-research costs are dominating [see argument (d)].

Keeping in mind the previous statements something additional could be said about the indirect benefits of basic research. It will be clear that basic research is surely not a kind of jackpot of new inventions but it enriches the experience of the R & D organization with a number of technologies that may appear to be relevant in the future. It has been pointed out that this experience is a significant aid to the local innovation costs of a project. From this point of view basic research means both an anticipation of future propositions and an investment in technical know-how which will be necessary anyhow on a longer term when concrete projects are to be initiated.

R & D Planning in Relation to the Overall Planning

Research planning cannot be separated from all other planning activities. Apart from research as an essential

activity there are more opportunities for a firm to maintain continuity and the corresponding operational goals on a longer term. In Figure 1 research planning is inserted as part of the overall planning process. In the strategic planning phase possible goals and missions of the firm are evaluated and more clearly defined. This phase is to be finished with a so-called Strategic Plan. A plan is always the result of a planning process, thus a choice out of all possible alternatives.

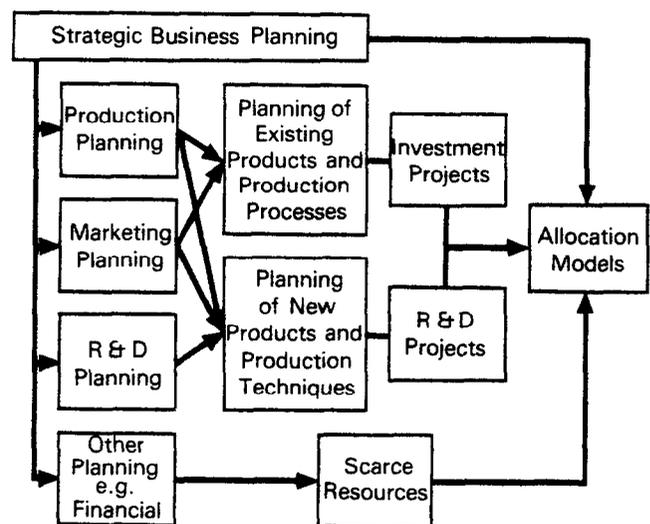


Figure 1. Research planning and overall planning

Starting from the strategic plan one has to define a number of sub plans. In Figure 1 we only mention a limited number of plans. Looking at those products or production techniques that are already available from a technical point of view, the following could be said:

- ☆ production planning is to indicate which production resources (equipment, labour, capital) could be used for which products and what the consequences would be;
- ☆ marketing planning is to make an inventory of possible product/market combinations and to evaluate the effects of those combinations that are in line with the firm's principal objectives;
- ☆ the integration of production and marketing planning is to indicate possible policies and actions. Each action may contain one or more investment projects.

For the planning of research the same reasoning as mentioned before will be valid. One has to realize however, that here those products and production techniques are to

be discussed for which additional research should be carried out. Result of this planning process will be a summary of proposed R & D projects, combined in a research action to be taken.

By the fact that resources are limited, one has to set priorities between the projects. Useful aids in determining those priorities are the so-called allocation models which are taken up in Figure 1 as the crowning piece. This does not imply that these models would have an absolute value in selecting projects. Normally they show in a more structured way what consequences could be expected from several actions. Such an output is essential to indicate how the planning process should be recycled due to inconsistencies or unacceptable results. The evaluation of research projects by using models has to be split up into three main phases, namely a general investigation phase, a phase of the project evaluation and allocation decision phase.

In the following paragraphs we will pay somewhat more attention to these phases.

The Phase of the General Investigation

Research is oriented toward the future. Therefore it is obvious that this phase will start with a (technological) forecast.

Elements in such a forecast are:

- (a) an investigation of future needs (needs-analysis);
- (b) an investigation of future means (means-analysis);
- (c) environment-analysis.

Studying the environment with the aim to get a global idea of what future possibilities are relevant for the firm, is very often a starting point (scenario-writing).

Based on such global scenarios the next step will be the definitions of needs that are already relevant or will become relevant for the firm in the future. Naturally those areas with which the firm is already familiar will get special attention. A complete change to new areas of needs or technologies will in most cases lead to a fundamental set-up of the necessary know-how with all the resultant enormous expenditures required.

We define a technology as a specialistic sub-area of a certain technical science, for example the technology of gas turbines, fuel cells or diesel engines. The previously mentioned method of need-analysis is the well-known normative approach. One is reasoning from a normative future to the actual world of today to discover which technologies should be used and explored further.

Alternatively to the normative approach we have to mention the explorative way of forecasting. Here the actual technical know-how of today is a starting point for setting up a philosophy on what possible needs could be fulfilled in the future, given certain technological trends.

Explorative forecasting is very speculative because one attempts to describe the whole range of future technical possibilities without limitations from the needs-side.

The latter aspect certainly is a real disadvantage of the explorative approach. However, in a sound business climate one knows how to balance both techniques and the effort involved, without trying to describe future possibilities where only the sky is the limit. In our opinion normative as well as explorative forecasting have to be applied parallel to each other in order to have a check on the results of both techniques.

The outcome of the previous phases is a global insight for the firm as to what future possibilities are open. Such a prognosis will mostly indicate so many alternatives that the evaluation of all these alternatives would ask for an endless planning process. Therefore it is necessary to cut down the number of alternatives. We have indicated already such a selection by stating that only areas with which the firm is already familiar, will seriously be proved. In fact such a selection should be based on the strategic missions, explicitly stated in the strategic plan. Such missions are the general setting in which several alternatives should be tested.



Figure 2. Elements of technological forecasting

In Figure 2 we have presented the foregoing with, additionally, the still lacking feed-back between the several stages. We suggested the strategic plan to be representative for the general setting for the planning process. On the other hand one should realize that technological forecasting is often an eye-opener for this strategic plan, because such a forecast is somewhat clearer as to what opportunities the firm will have in the future. Technological forecasting has at least the power to adjust a formulated firm's mission.

Finally we want to make two remarks regarding technological forecasting:

The first remark concerns the belief of a lot of people that technological forecasting will predict the future in very concrete terms. It will be clear that such a belief is completely wrong. What technological forecasting can present, are only *conditional* technical trends and market opportunities.

Technological forecasting can evaluate in other words 'what-if' situations without the power to reduce the if-statements to only one, or to decide which will be the real one.

The second remark is in concordance with the first one. As stated before, the aim of technological forecasting is to get an insight into possible future events. Next to this, an analysis of all the 'if' assumptions is certainly equally important. If these assumptions are changing in the course of time in any essential aspect, then the forecast should be adjusted as well. Next, if one introduces assumptions with a low degree of realism, then exactly the same will be true for the forecast.

The forecasting model is then contradictory to reality and not vice versa as model builders sometimes pretend.

The Phase of the Project Evaluation

After having defined the future scope of the firm, it will be necessary to make this more concrete. First of all one has to define which kind of products and production techniques are relevant for the firm. Additionally product specifications must be made. In all these activities, the future attitude of competition, as far as known, plays an important role. At least one will be looking after a product with such price/feature ratios that it will be competitive with other products on the market.

After making an inventory of relevant products to be developed, one has to define more into detail the several research projects. These projects should be evaluated against several criteria, to discover whether each project will be a winner or a loser. The two major parts in such an evaluation are the technical and economic evaluation.

First step in the technical evaluation will be the inventory of all relevant technologies.

Second step is the identification and selection of technological parameters in such a way that the state of art of each technology can be described (for example pressure or temperature parameters). Defining such parameters is a very serious problem in actual practice. Such definitions must be carefully chosen so that it is possible to describe the technological trend in spite of the fact that more technologies may overrule each other. A fragility parameter could say something about the trend in fragile material but nothing about unbreakable material. Choosing a parameter that is too strictly related to one specific technology will mostly lead to an incomplete description of the technological trend. The consequences of this are that it can hardly be indicated which improvements will have to be done.

Once having chosen adequate parameters one is able to transfer all product specifications and wishes into values of the technological parameters concerned.

Third and last step of the technical evaluation is the identification of technical bottle-necks by comparing the values wanted and actual values of the technological parameters. The larger the discrepancy between actual values and values wanted, the bigger the technological development and mostly the higher the research efforts.

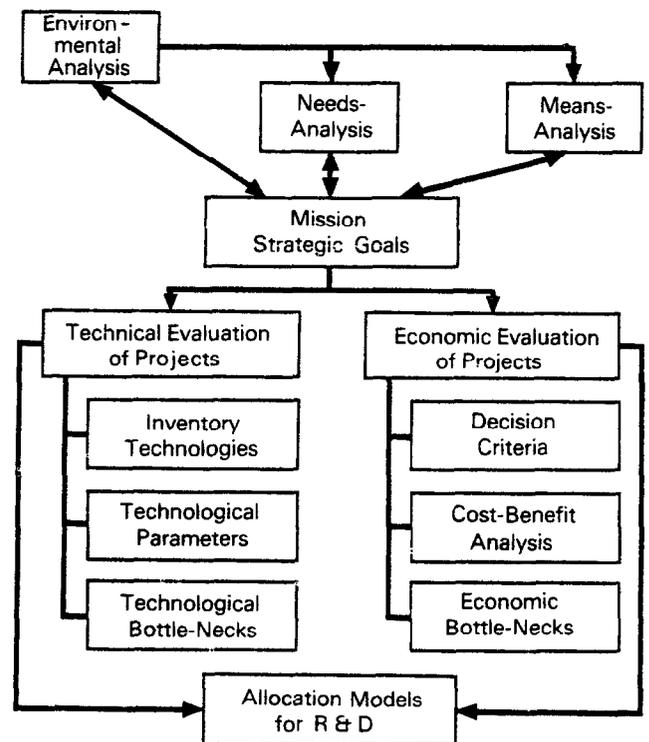


Figure 3. The research planning process

The three mentioned steps are indicated in Figure 3 in the blocks: inventory technologies, technological parameters, technological bottle-necks.

The foregoing alludes that the process of technical evaluation is a very logic and rational step-to-step process. Principally it is a process of creativity, mainly coordinated by technical people. I have seen situations in which only technical people were involved in this process with the result of marvellously new products, excellent examples of technological know-how but unmarketable. Also the opposite occurs: R & D simply waiting for a full-detailed and defined specification sheet of a new product, leaving all thinking and creativity to marketing people. Without doubt such a process will be mostly a very expensive way dominated by the main wish of marketing people: 'Copy as fast as possible what competition already has'. One thing is then for sure: the firm will face the same failures as competition does.

Parallel to the technical evaluation one should take care of an economic evaluation.

Step one will be the selection of criteria that should find their background in the strategic plan.

The second step is the set-up of a cost-benefit analysis indicating also the uncertainties involved. Interrelations with other projects should be explicitly stated as soon as the data are hard enough to do so.

The last step in the economic analysis is the determination of economic bottle-necks by making an inventory of what means and what people are desirable or available.

Between the several steps in the technical and economic

evaluation a continuous stream of feed-back should occur. Technical and economic aspects are not separate but interlinked items of the same problem, reason why the output of one of the steps could also influence the approach of the other.

The Allocation Decision

The results of the technical and economic phase are input for an allocation model, the last phase in the planning process. Again such a model does not fix the ultimate decision but is only to present the consequences of certain decisions in a structured and comprehensive way.

In the literature there exists an almost inexhaustible number of allocation models, all designed as very specific modifications for always the same problem, namely: determine which research projects have to be carried out, at what time and on what level of resources. Such a statement is easily written down but to take a decision in practice about such a problem is something else.

In most cases it is impossible to indicate already at the beginning of an R & D project what benefits and what costs will be involved. This also means that it is inefficient and even wrong to evaluate 'soft' projects with 'hard' allocation models. Allocation models should therefore differ depending on the phase of research. In previous studies we discerned the following aspects:

- ✧ the possibility of a quantitative analysis. Applied research is inherent to a broad scope and consequently to a lot of degrees of freedom. Further on, applied research projects are mostly long-run projects. These are the main reasons that an evaluation of such projects on a quantitative basis, taking into account all criteria, seems to be impossible;
- ✧ the operational business goals and the belonging set of decision criteria. Most of the time applied research goals have a broader scope. A translation to specific operational goals has still to be done after gathering some information about possible results of this research.

Also from this point of view it is unwise to evaluate applied research with 'hard' decision models.

From the previous part it will be clear that the decision-making procedure for research differs from stage to stage. We believe that scoring models are most adequate in the phase of applied research while advanced projects selection models, based on existing evaluations, are suitable for the development phase. We will describe both kinds of models in some more detail.

Scoring Models

Starting point of all scoring models is the belief that a project can be evaluated with the help of a check-list of evaluation criteria. An example of an extensive check-list is described in the Appendix. The way of working is

as follows: specialists attach a score for each criterium to a certain project. Next the value of the whole project is the sum or multiplication of all scores attached per project. In literature these methods are known as additive or multiplicative scoring models. An oversimplified example of possible scores can be found in Table 3.

Table 3. Scoring classes of Mottley and Newton

Evaluation aspect	Possible answer	Score
Probability of success	Unforeseeable	1
	Fair	2
	High	3
Time to completion	Greater than 3 years	1
	1-3 years	2
	Less than 1 year	3
Total research costs	Greater than \$1m	1
	\$100.000-\$1m	2
	Less than \$100.000	3
Strategic need	No apparent market application; must be developed	1
	Desirable to maintain, reinforce, or expand position within market applications currently served	2
	Essential in relation to current or projected markets within market applications not currently served	3
Net revenues	Less than \$1m/year	1
	\$1m-\$10m/year	2
	Greater than \$10m/year	3

In practice one will naturally use more refined and more shaded models than the given example.

Scoring models have the advantage of opening the possibility to take into consideration quantitative as well as qualitative aspects of the project at the same time. Next, the number of aspects can be enlarged or limited depending on the sort of project, the phase in which it is and the availability of relevant information. The simplicity of scoring models makes a successful implementation much easier. The latter advantage is a very important one in our opinion. There is no sense in using models, perfectly describing complex research situations but at the same time being so complex that an application would hardly be possible. The last interesting advantage of scoring models is that these models are forcing everybody to make an inventory of all relevant aspects, which aspects will then be re-grouped into main or sub-sets of criteria.

Disadvantages of scoring models are that scores are suggesting a precision that is only appearance. Very often there is the tendency of taking hard decisions based on soft scoring totals, without realizing that these scores are subjective items and that the sensibility of the score total is very high. Small changes in individual scores would quickly lead to a complete re-arrangement of the score totals of the several projects. Taking into account such a sensibility of score totals, it is wise only to decide which projects are bound to be definite losers, and to re-evaluate at regular times the remaining projects, certainly if new information has become available.

Another disadvantage of scoring methods often mentioned is that contention projects cannot be evaluated in a

detailed and refined way. Our objection against such a statement is that it is impossible to gather hard and detailed information about projects that are just in the beginning phase. Here the choice is not a choice between hard and soft information but between soft information and no information at all.

A serious deficiency of scoring models is the lack of a model structure between all the evaluation aspects. By here, one is inclined to underestimate possible interlinks between several criteria and projects. The interdependence of research costs and research time in the model of Mottley and Newton shows that such a danger is not a hypothetical one. The duration of the research phase will probably be a function of the resources involved. Next, expenses in the course of time must be discounted with a discount factor. Also in this respect costs and time are influencing each other. This relationship is not an additive one but a multiplicative one. The same remark could be made regarding the probability of research success. The forementioned model structure is in so far a crucial item that the several models, overlapping each other in the several research phases, must be tuned to each other. If not, one would be using several criteria in the several phases with a great risk of decision-inconsistency. A project that promises to be a 'winner' in the one model, may appear to be a definite loser in the other model, simply because one has been changing the yard-sticks, the evaluation criteria, or the structure between them.

Problems with scoring models that must be investigated further are:

- ☆ what method is the best for attaching scores. Sometimes a group of specialists attaches scores to projects for all criteria. Another methodology is to appoint specialists per subgroup of criteria, so that the total project-score is the 'sum' of the opinion of several specialists.

Another technique is based on individual judgment. Each specialist is asked to evaluate the projects after which a sort of weighted average of all opinions is calculated. As weight factors one may use certain coefficients that are to indicate the relative importance of the several specialists involved. Numerous variations of attaching scores are described in the literature but a critical evaluation of the preferable methods, is still lacking;

- ☆ what is the maximum of evaluation criteria. Some people do not limit the maximum, others assert that five to seven main criteria are the maximum that management can handle. We believe that this opinion is the correct one;
- ☆ what scoring interval has to be chosen and what is the optimal divisioning of this interval into scoring classes?

Looking at all alternative projects, we think that the scoring interval for cardinal scores is fully determined by the maximum and minimum possible outcome. If

for example turnover is an evaluation criterion and the possible outcome of the projects ranges between 1 and 100 mio \$, then the scoring interval has to correspond with that range. The divisioning of this interval into classes is in our opinion not an optimizing problem but depends fully on the hardness of available information. It is useless to make a very refined class system if the information is not hard enough to classify each project with a high accuracy into the correct class;

- ☆ what method is optimal for determining the total project-score (additive vs multiplicative method)? In practice the additive technique is generally just used because this seems to work best. We have already stated that, also looking at the more advanced model which will be used in a later phase, a combination of additive and multiplicative criteria is the soundest situation.

Models for the Development Phase

In the literature some ratios are often proposed as ideal yard-sticks for the value of research projects. Well-known ratios are the indices of Olsen and Pacifico. The index of Olsen is defined as follows:

$$I_o = \frac{\text{Estimated revenues of successful research} * \text{probability of success}}{\text{Research costs}}$$

For determining the revenues of research Olsen proposes the following rules of thumb:

- ☆ estimated cost reductions during 1 year, if the research is aiming at improvements of existent production techniques;
- ☆ 2 per cent of expected turnover over 2 years if the research is aiming at a qualitative upgrading of existing products;
- ☆ 3 per cent of expected turnover over 5 years if research is aiming at a complete new product.

Research activities mentioned under the first two items must be considered as defensive research whereas the research mentioned under item three is regarded as offensive research.

Olsen accepts a project if the index equals or is greater than three.

The Pacifico index is defined as follows:

$$I_p = \frac{\text{Probability of success} * \text{cashflow per year} * \text{estimated life time}}{\text{Total project costs}}$$

Total project costs include costs of research and all investments needed for a successful market introduction of the new product development. The probability of success is the multiplication of, successively, the probability of success of applied research, probability of development and that of a successful market introduction. Pacifico's opinion is that the index should not be smaller than two for a project to be classified as appropriate.

Objections Against Indices

The fundamental difference between the index of Olsen and Pacifico is the definition of what belongs to the area of research and thus what costs and revenues have to be allocated to the research phase. Pacifico considers the development of new products in an integral way; so he has no separate research and market phase. Olsen creates a problem in defining two hypothetical projects, because the result is an unsolvable allocation problem which can only be handled by introducing arbitrary rules of thumb. Olsen's methodology has also another disadvantage, namely the risk of taking wrong decisions. Since only a very small part of the whole project is considered in the research decision (namely costs or revenues during a limited number of years) a go-decision for research may be completely wrong looking at the rest of the life-cycle of the new product. Our opinion, therefore, is that any separation of research and market phase is not allowable. Both phases have to be taken into account simultaneously. A disadvantage valid for both indices is the lacking time element. Both methods do not specify a cash flow per period, neither do they use any discount method. New and adapted indices are developed in the literature to eliminate these disadvantages, for example the index of Disman. Another disadvantage of indices lies in the fact that the critical value of the index (the value three for Olsen or two for Pacifico) is falling more or less from heaven. A motivation of such a critical value is not presented or is motivated by vague arguments from experience and practice. For the rest one could interpret the Pacifico index as a sort of a simple pay-back period because his requirement for a value two could be regarded in case of equal cash flows per year, as the requirement that the pay-back time should be smaller than half the market phase time of the product. We conclude that indices are afflicted with so many disadvantages that these kinds of yard-sticks could give some additional information indeed but they are never suitable as an ultimate decisions criterion.

The Net Present Value Method

The method based on the net present value is generally accepted in the investment theory. The NPV equals the sum of discounted cash flows of a certain project. A cash flow is defined as net profit after tax plus depreciations.

Each cash flow should be discounted with a certain discount factor to compensate value decrease of money. A simplified example may elucidate the technique of the NPV method. In Table 4 we have summarized several estimations of the cash flows of a specific project. All amounts are in mio of S. With a 12 per cent discount factor the NPV in 1977 equals:

$$\frac{-5}{(1.12)^3} - \frac{-6.5}{(1.12)^4} - \frac{1.05}{(1.12)^5} - \frac{3.05}{(1.12)^6} - \frac{7.55}{(1.12)^7} - \frac{10.3}{(1.12)^8} + \frac{10.8}{(1.12)^9} = 5.9$$

Since the outcome of this project is greater than zero, the project is bringing a higher profitability than 12 per cent; so a go-decision should be justified unless even better projects are available and resources are limited. A steady increase of the discount factor until the NPV equals exactly zero results in the so-called internal rate of return. In our example this internal rate would be nearly 29 per cent. In actual practice the quantification of cash flows is a tremendous work, certainly for research projects for which one has to go a long time before market introduction is reality. One has to realize that such guessing work will eventuate in conjuring and juggling with mere figures. Besides there is the tendency to work more or less consciously toward a certain outcome. This danger exists especially if somebody is devoted so much to a project that it is hard for him to accept that his project will be a real failure for the firm. Although the estimation of cash flows is a hard job we believe that the NPV method presents the only acceptable method for the evaluation of R & D projects, on the understanding that the information is hard enough to use such a technique. If the latter condition is not fulfilled, scoring methods are preferable as stated before. Naturally one can make numerous refinements of the NPV model, for example by introducing probabilities (stochastic NPV) or by introducing restrictions regarding available resources (money, people, production capacity, etc.). Advanced optimization models are the result of those exercises but in principle the NPV technique remains the same.

Conclusions

In the previous paragraphs we tried to present an outline of the most significant aspects of research planning in relation to strategic planning. An aspect not discussed so

Table 4. Estimated cash flows of a project

	1980	1981	1982	1983	1984	1985	1986
Research expenditures	-10	-5					
Turnovers			5	15	25	20	10
Prod. costs incl. depreciation			1	2	3	2	2
Sales/distribution costs			0.5	1.5	2.5	2	1
Gross margin	-10	-5	3.5	11.5	19.5	16	7
Net margin	-5	-2.5	1.75	5.75	7.75	8	3.5
Investments production		-4					
Depreciation			0.8	0.8	0.8	0.8	0.8
Mutations working capital (debtors, stocks, creditors)			-1.5	-3.5	-3.0	1.5	6.5
Cash flow per year	-5	-6.5	1.05	3.05	7.55	10.3	10.8

far, is how to motivate research people in an optimal way. Often management tries to motivate research people by introducing the concept of parallel research, which means that two or more research teams in or even outside the firm, are working on exactly the same technical problem. The probability of a technical failure would be drastically reduced by such a policy. Also these aspects could be part of an extended NPV model as discussed before. Other motivation aspects can be found in the organizational theory such as the concept of project teams, preferable with an interdisciplinary set-up, the concept of the so-called 'flat' organization structure, etc.

All those aspects cannot be discussed within the scope of this article.

From the foregoing it may be clear that planning of research and decision making in a structured way is not an easy task. This has to be underlined even more when looking at actual practice when only very few models are really used. Baker and Freeland summarize that state of art with respect to models as follows:

The trend in application appears to be away from 'decision models' toward 'decision information systems'. Two legitimate reasons can be suggested for this trend. First, the existing models are incomplete in the sense that they do not include all the important, relevant aspects of the R and D environment. As a result, the manager is forced to adjust the recommended allocations in order to account for the often numerous environmental conditions not included in the model. The second reason is that the decision problem is characterized by multiple criteria, many of which are not easily quantified. The typical approach is to quantify preferences or subjective estimates of benefit with methodologies which are far from satisfactory. As a result, managers are highly sceptical of the validity of the estimates and of the subsequent allocation recommendations. (Ref. 1, page 1173.)

As a consequence managers are often using less rational methods of decision making such as the 'white charger technique' which is described very humourously by Cetron and Johnson:

Here the various departments come dashing into top management with multicolor graphs, hand outs, and well-rehearsed presentations. If they impress the decision maker, they are rewarded with increased resources. Often the best speaker or the last man to brief the boss wins the treasure. (Ref. 3, page 194.)

It will be clear to the reader that we prefer a far more rational method of decision making instead of the manipulation just described.

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Appendix: Check-List for the Evaluation of Research Projects

Check-List for R & D Costs

- (1) Which technical know-how is available or has to be developed for the product asked?
- (2) What kinds of research means are required for the development of the new product and what can be said about the availability of these means?
- (3) Which research manpower is required or available?
- (4) What is the estimated applied research time?
- (5) What is the expected development time?
- (6) What is the earliest possible introduction time of the new product and what is the latest one?
- (7) Which additional manpower and research means are required for speeding up the research time?
- (8) What are the consequences (e.g. financial) of an earlier or better completion of the research phase compared with the most optimal introduction time of the new product?
- (9) What synergy effects are likely to occur taking into account other research projects?
- (10) Which technologies, required for the development of this product, are relevant for the research policy of the company in the long run?
- (11) What technological developments are realized by competition in this area and which amounts are reserved by competition for these kinds of products?
- (12) In how far are the technologies completely new to the firm?
- (13) What is the innovation value of the new product and how long will this innovation value exist?
- (14) Will the new product ask for market introduction for continuous defensive research to keep the product features up-to-date; what resources will probably be required for this?
- (15) What are the estimated design costs and production costs of a prototype/pilot plant?
- (16) Which additional research resources will make it possible to design a product essentially different from competitive products?
- (17) Which alternative technical solutions are possible for the relevant technological bottle-necks?
- (18) What is the probability of technical success?
- (19) How and with which additional resources could this probability of technical success be influenced?

Position Analysis of the Product

- (1) Which requirement functions is the product primarily intended to fulfil?

- (2) Which specific function within these requirement functions does the product fulfil?
- (3) What are the present or future peripheral requirement functions in which the product can compete?
- (4) What alternative applicatory functions are open to the product without modifications to these peripheral requirements?
- (5) Which modifications will have to be made on the product in order to make it suitable for full-scale introduction for peripheral requirements?
- (6) Which of the requirements mentioned are completely new to the company?
- (7) Does the product form a basis on which a potential broadening of the assortment can take place?
- (8) In such a case, which variations on the product can be expected?
- (9) Is the product a supplement to the established company assortment?
- (10) Are there comparable products on the market and do they satisfy a similar kind of need? What are these products and who manufactures them?
- (11) Is the product an improvement on, or a substitute for another product already on the market?
- (12) What technical changes have been made on the product since its very first introduction onto the market?
- (13) At what rate have these changes taken place during this period?
- (14) Based on the changes that have taken place in the past, what changes are expected to take place in the future?
- (15) What are the basic causes for these changes?
- (16) How and by what means can the company exercise influence on these causes?
- (17) What are the conditions or circumstances under which the product is used?
- (18) Which ideal technical characteristics must the product possess?
- (19) Which of these characteristics can be realized at the present moment, and which not, taking into consideration the technological know-how of the company?
- (20) What are the expected factual characteristics of the product?
- (21) Which are the technical characteristics of competitive products within the same range of demand?
- (22) Which characteristics require to be different to those of the competitor, and to what degree?
- (23) What is the desired life time of the products or of the separate parts it comprises and how does this compare with its actual life time?
- (24) Which accessories or services will be required for the product and which of these are completely new to the company?
- (25) What is the expected life-cycle of the product?
- (26) What are the factors that will chiefly determine this life-cycle.
- (27) How and by what means can the company exercise influence on these factors?
- (28) What is the patent situation with respect to the product or the parts it comprises?

Position Analysis and Nature of the Consumer

- (1) Which consumer categories come under consideration for the new product?
- (2) Which of the remaining consumer categories can also be considered?
- (3) What are the most important characteristics of these consumer categories with regard to:
 - ☆ investment or buying potential;
 - ☆ degree of education;
 - ☆ job or profession;
 - ☆ knowledge of the new product and similar competitive products respectively;
 - ☆ buying motives?
- (4) Which consumer categories are new to the company and what

consequences can this have for the company's traditional method of approach to the customer?

- (5) What are the demands of the various consumer categories?
- (6) What are the main reasons behind these demands?
- (7) What kind of trend was noticeable in these demands in the past and what are those expected in the future?
- (8) How can the company influence such trends?
- (9) What is the level of education expected of the consumer. In how far must the product be modified to reduce this expected level?
- (10) For how long does the consumer expect to use the product, in the company's estimation?
- (11) What kind of image does the product conjure up in the eyes of the consumer?
- (12) Does this image coincide with that desired by the company?
- (13) In how far must it be possible to fulfil special product requirements of the consumer?
- (14) Which guarantees or servicing conditions will the consumer normally expect?
- (15) Which degrees of quality are desired from the consumer's point of view?
- (16) To what extent are the consumers already acquainted with other products of the company?
- (17) To what degree does the competitor already enjoy a fixed reputation with the consumer, and what is the nature of this reputation?
- (18) What, in the opinion of the consumer, are the strong and weak aspects of the product in relation to other products manufactured by the competitor.

Market Structure and Market Size

- (1) What is the estimated total market demand at the present time?
- (2) Which factors influence this market demand, such as:
 - ☆ level of employment;
 - ☆ national product;
 - ☆ national income;
 - ☆ national savings;
 - ☆ national investments;
 - ☆ national consumption;
 - ☆ rate of interest and credit facilities;
 - ☆ fiscal facilities;
 - ☆ import and export level;
 - ☆ population?
- (3) What are the prognoses for these demand determining factors?
- (4) How can the company influence these factors?
- (5) To what extent is the demand sensitive to seasonal or conjunctural fluctuations and which factors are largely responsible for this?
- (6) Which marketing means can the company use to minimize this sensitivity?
- (7) What is the total saturation level of the market?
- (8) Which substitutional market brings the new product into existence?
- (9) What is the total demand, divided into national and international demand?
- (10) Which section of the national demand is provided for by national products and imports respectively?
- (11) Which are the most important national manufacturers and import firms respectively?
- (12) What are the respective market shares of these companies?
- (13) Which factors can influence in a positive or negative manner, the entry of new competitors onto the market?
- (14) To what extent can the company control these factors?
- (15) What is the total expected market share of the company seen in the course of time?

- (16) In how far does the new product affect the market demand for other products manufactured by the company?
- (17) What is the geographical spread of the market?
- (18) To what extent must cost or returns from licenses be taken into account?

Pricing Policy

- (1) Which price categories and degrees of quality does the company wish to indulge in?
- (2) What was the price development of similar products in the past and which prognoses can be derived from these for the future?
- (3) In how far is the cost price decisive for the price fixation and what is then the expected margin between cost price and sales price?
- (4) To what extent does demand react to price variations (price elasticity)?
- (5) Which price reactions are to be expected from the competitor and within what limits will these lie?
- (6) Which reductions are offered by the competitor, disguised or not?
- (7) Which reductions are envisaged by the company for which consumer categories?
- (8) What is the price strategy with respect to service, maintenance, installation, etc. as compared to that of the company?
- (9) In how far are price agreements permitted by law?

Check-List for Marketing Costs

- (1) Which distribution channels are taken into consideration for the new product?
- (2) Which of these channels are completely new for the company?
- (3) Which distribution channels are used by the competitor for similar products?
- (4) Which sales methods are desirable for the new product and what costs do these involve (costs for representatives, dealers, etc.)?
- (5) Which aspects of the product must be accentuated in particular when it is introduced to the consumer and is the present company organization already familiar with this policy?
- (6) In what manner are the consumers approached at the present time by the competitor for similar products?
- (7) Does the competitor have sales advantages due to a better balanced or fully developed product range than that of the company. How can the company eliminate these advantages?
- (8) Which development can be expected in the method of approach to the consumer and what are the consequences regarding costs?
- (9) Which promotion media must be called in and to what degree should they be used:
 - ☆ advertisements in newspapers, periodicals, etc.;
 - ☆ direct mail;
 - ☆ exhibitions;
 - ☆ public relation campaigns;
 - ☆ sales leaflets and brochures?
- (10) To what extent is the established reputation of the company an advantage for the introduction of the new product?
- (11) What service guarantees must be offered to the customer and what financial consequences do these involve?
- (12) How large is the total product population for the period in which service or guarantee must be given?
- (13) Which fault patterns are to be expected and to what degree?
- (14) What is the ability level and number of service technicians then required by the company?
- (15) Does the new product fit in with the present sales and service organizations for the nature of the persons as well as their number?

- (16) Which components and in what quantity will be required for the new product?
- (17) Which distribution costs per unit product are expected, taking into account possible transport losses due to damage, etc.?
- (18) Which aids must be offered to the representatives, service technicians, and what financial consequences will this entail?

Check-List for Production Costs

- (1) Which raw materials, semi-manufactured materials will be required for the new product?
- (2) Which suppliers are taken into consideration for the supply of these raw materials and semi-manufactured materials?
- (3) What are the purchasing conditions for raw materials and accessories in the light of:
 - ☆ quality;
 - ☆ price;
 - ☆ delivery time;
 - ☆ continuity?
 What expectations are there for the future as to these aspects?
- (4) Which production installations are essential for the manufacture of the new product?
- (5) Can the new product help towards improving the capacity utilization of the existing installations?
- (6) What is the processing time required for the product in each individual installation?
- (7) To what degree do the production costs vary with amount produced (economies and diseconomies of scale)?
- (8) What are the capacity limits of the existing or new production means?
- (9) Which alternative production processes can be taken into consideration for this product?
- (10) Which current products or products under development can form a bottle-neck for the production of the new product?
- (11) What kind of internal transport does the new product demand and does this fit in with the existing transport picture?
- (12) To what measure does the product require quality control and in how far does this deviate from existing quality controls?
- (13) How many operators does the new product require?
- (14) To what extent must the existing or newly acquired personnel receive additional training?
- (15) What is the expected gross wage development in the future?
- (16) Which energy costs are summoned by the new product?
- (17) Will the introduction of the new product interfere with the supply of energy?
- (18) How large is the dwindling in production means due to:
 - ☆ failures;
 - ☆ maintenance;
 - ☆ change of production program;
 - ☆ preliminary losses?
- (19) Which drop out percentage must be taken into account and what measures can be taken to influence this percentage?
- (20) Which 'compulsory-investments' are prescribed by the government with respect to safety and/or environmental hygiene?
- (21) What form of packing must be used and what are the costs per unit?
- (22) What additional accommodations are needed for the product?
- (23) What additional services must be recruited during the production of the product (drawing department, automation department, etc.)?
- (24) How large are the estimated direct and indirect manufacturing costs per unit product, excluding the costs of fixed assets?
- (25) What will the developments in these costs per unit be in the future?

Market Entrance Costs and Investments

- (1) Which investments must be carried out in which periods?
- (2) Are there fiscal facilities for these investments?
- (3) Which market entrance costs can be distinguished for the introduction of the new product?
- (4) What is the desired introduction moment for the new product?
- (5) Which additional market-entrance costs will evolve when spreading up or delaying the introduction moment and which costs will be incurred during the realization of the desired introduction moment?
- (6) What is the technical life time of the procured investment goods?
- (7) What is the value of these goods after depreciation bearing in mind the life-cycle of the new product?
- (8) What are the fiscal rebate possibilities of the depreciation over the various periods?
- (9) Which technological developments are expected in the production process and which consequences can these have on the

replacement of invested goods in one's own company and in that of the competitor?

Mutations in Working Capital

- (1) Which 'out of stock' is tolerable for this new product and what effect will this have on the average existing stock of finished products?
- (2) Which interim stocks of raw materials, auxiliaries, and semi-manufactured articles must be retained?
- (3) What are the expected credit terms the company will acquire from their supplier(s)?
- (4) What are the expected credit terms for the consumers of the product?
- (5) What are the credit facilities of the competitor for similar products?
- (6) Based on developments in the past, what developments are to be expected in these credit facilities in the future?