Linking Business Strategy to Technology Strategies: A Prerequisite to the R&D Priorities Determination

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Abstract: Choice of priorities in technology development is an important prerequisite to any R&D program (including R&D collaboration). The strategic management of technology is described as an approach which helps to link business strategy to technology strategy, and allows then to rank R&D subjects priorities in coherence with firm overall strategy. Some strategy analysis models are assessed to show how this problem is incorporated and dealt with in the management literature. Then, the need of an integrated approach is pointed out, and an analytical method is developed to help firms in selecting their priorities in technology development and the way of investment on them. Finally, the usefulness of the proposed method is illustrated through its application to a French company.

Keywords: Strategic Management of Technology, Business & Technology Strategies, Technology Portfolio Analysis, R&D Projects Priority.

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1 Introduction

Typically, R&D project can be viewed as a black box into which firms place their resources and wish to harvest benefits from increased technological performance. However, a few authors have attempted to 'open up' this black box by developing R&D project evaluation and selection methodologies and associated techniques [1,2,3]. The relationship between expenditures on R&D projects and firm performance, and especially their effect on the firm competitiveness is still an area of interest both for industries and academic researchers [4].

In this area, two main questions should be answered [5] :

1) Does the R&D program focus on developing capability in technologies that will or may support the firm competitive advantage ?
2) Are decisions about developing a given technology (in house development, licensing, joint or capital venture, academic collaboration, etc.) being examined in relation to the company overall strategy ?

These questions cannot be answered hastily. The path from overall strategy to technology strategy and R&D program is not obvious.

Managers have to take some care to ensure the coherence between R&D program and firm overall strategy. The evaluation of R&D priorities, and selection of some subjects as well as the way of investment on them are among the most important parts of technology strategy [1]. So, positive answer to the above questions requires that technology strategy is settled regarding to the firm business strategy.

It would be worthy to distinguish two level of decision for investment prioritizing in technology issues. At the first level, using the strategic objectives as criteria, some technological fields are settled on which investing is necessary. At the second level, for each field highlighted before, different projects are identified. They are the investment alternatives. Then, using project evaluation and selection methods, alternatives are investigated according to their costs, benefits, risk, life cycle, etc., in order to select one (or more) to execute.

In the management literature, a lot of quantitative and qualitative methods have been presented for selecting R&D projects within an organization (i.e. the second level). Danila [1] has reviewed several groups of these models and classified them.

In comparison to the great number of methods dealing with the R&D projects evaluation and selection, the models for selecting strategic field of technological development (i.e. the first level), have poorly been presented and discussed in the literature.

The aim of this paper is to present an analytical method which allows bridging business strategy to technology strategy in a firm. We are interested only by the first level of decision explained above. So, proposed method helps to clarify some technological field of investment with respect to the firm overall strategy.

First of all, two aspects of linkage between technology strategy and business strategy are distinguished (this paper addresses only one of them), and some strategy analysis models are assessed to show how the problem of linkage has been dealt with in the strategic planning/management literature. Then, a new approach is developed, and its principles and stages are explained. Finally, application results in a French company are discussed.

2 From ‘Business Strategy’ to ‘Technology Strategy’ and R&D Program

Each firm incorporates a set of distinct and identifiable technologies and sub-technologies [6]. From a strategic point of view, all technologies are not equally important, and have a different influence on firm competitive advantage [7]. Even if there was a clear need to improve all technologies, organizations would lack sufficient resources -people, funds, and time- to do so. Beyond resources, most organizations could not involve in all technologies simultaneously. Regarding to technologies interconnection, simultaneous changes in multiple technologies may be difficult to handle and coordinate. Thus, some important technologies should be selected as the firm priorities of investment.

Investment priorities should be settled in coherence with the firm overall strategy [3,5], because technological change is not important for its own sake, but for its effects on the performance of activities and processes, and consequently on the firm competitive position of firm [7]. So, it is necessary to evaluate technologies according to their influence on the firm competitive advantage. Then, it will be possible to select and invest on those that have more significant influence. This is one of the two directions of linkage between competitive strategy and technology strategy we will point out later. But prior to this discussion, it is necessary to indicate which definition of technology and technology strategy we refer to.

Galbraith [8] defines *technology* as a practical application of science and technical knowledge. It has been re-used by ADL [6], Dussauge and Ramanantsoa [9], Morin [10] and Jolly and Thérin [11]. We refer, in this paper, to an adapted and integrated definition :

"*Technology is a combination of scientific and technical knowledge and know-how that is embodied in a product, service, process, information system or management method.*"

Technology strategy refers to the firm priority in technology development [11]. It can orient firm future actions in technology issues, such as *technology sourcing* (choice between internal or external source of technology), as well as R&D intensity and focus, joint or capital venture in technology development, technological alliance, as well as staff training and retraining [11,12,13,14].

There are two opposite directions of relationship between 'Technology Strategy' and 'Business Strategy' in a firm (Fig. 1) :

- Using current firm technological competencies to elaborate or implement a competitive strategy ;
- Developing new technological competencies to support the current competitive strategy of firm.

When technology strategy supports business strategy, it must be tailored to the firm overall strategic objectives. Technology strategy, in this case, defines how a company can most effectively improve its technological competencies to accomplish business strategy and to achieve a sustainable competitive advantage. It is called in the literature as *'strategic management of technology'* [15]. The major objective of research in this area, is to increase our understanding of how companies, with respect to their overall strategy, can establish a coherent technology strategy in order to develop or acquire, adopt, adapt and exploit new technologies. The first stage in this process is to highlight some important technologies to invest on. And the linkage between business strategy and technology strategy, in this sense, helps companies to choose some strategic technologies which should be considered as the basic elements of their competitiveness.

On the opposite way, technology strategy initiates business strategy, because technology strategy implementation leads to new technological competencies, and based on these new competencies, company can choose a new corporate or business strategy (e.g. launching a new business activity based on current technological competencies). It is known in the literature as '*competence/technology-based strategic planning'* [11,16]. The major research in this area, concentrates on increasing our understanding of how companies can assess their technological competencies and, more important, how these competencies can be incorporated into a new product or service.

However, the two approaches discussed above are closely connected and this connection can lead to a continuous and iterative improvement of firm technological capabilities. As a matter of fact, when a technological change occurs, it is difficult to see whether it is the consequence of a business strategy or will be the origin of a new strategic orientation.

In this paper, we are interested only by the 'strategic management of technology' (and not 'technology-based strategic planning') approach. It is beyond the scope of this paper to describe how a company should choose its competitive strategy, and we suppose that it has already been elaborated.

Since 1960s, several strategy analysis models have been developed and the concepts of technology and technology planning or management have little by little been incorporated into these models. In this section, some important strategy analysis models are briefly surveyed to underline, as a conclusion, the need of a structural approach in the strategic management of technology.

BCG's model

The '*portfolio analysis matrix*' is one of the most famous strategic planning tools. Boston Consulting Group (BCG)'s model is the first one which introduced the concept of 'activity portfolio'[17]. Based on the experience effect curve, it considers for each SBU, the relative part of market as an indicator that measures firm strengths and weaknesses, and the growth ratio of industry as an indicator that measures the environmental opportunities and threats (Fig. 2). This model supposes a stable environment without any technological evolution -except the fact that technology evolution is behind the experience effect. Thus, the concept of technology is nearly absent from the strategic planning approach

E.B. Roberts [13], indicates that not only experience effect but also technical progress can influence firm competitiveness (Fig. 3). This became a basic idea for the ADL's model.

ADL's model

A. D. Little's model [6] takes into account the influence of technological evolution, on one hand, behind the concept of competitive situation, and on the other, behind the maturity of the industry (Fig. 4). Technology, when it is referred to in this model, is used as an input to position each SBU in the portfolio matrix. Thus, this model tries to integrate implicitly (and not explicitly) the concept of technology in the previous strategic planning approaches. But, these are still the firm business activities (and not technologies) that are clustered and examined through the portfolio matrix. That is why technology strategy cannot be derived easily from this model.

Morin's model

The notion of '*Technology Portfolio Analysis*' is introduced, for the first time, by Stanford Research Institute (SRI) [9]. Using this concept, J. Morin [10] proposes a portfolio analysis matrix enabling organizations to balance their technological patrimony. This matrix, called '*Matrice Attrait-Atout*', uses the firm technological assets as a measure to represent firm strengths and weaknesses in technology issues, and the attractiveness of technology as a measure for evaluating technological opportunities and threats. In this way, technology strategy is elaborated analytically. But this model does not explicitly link the technology strategy to the firm competitive strategy.

Porter's model

Simultaneously but on a different way, a systematic approach is proposed by M. Porter [7], who points out that technologies are incorporated into all activities of a company. According to Porter, sustaining a competitive advantage needs to concentrate on technologies that have the most important influence on competitiveness. Using the value chain of technologies, this model tries to link technology strategy and firm overall strategy. It stays at a conceptual level and suggests the six essential steps of technology strategy elaboration.

For example, the 6th step tells that companies have to "select a technology strategy encompassing all important technologies, ... ". At this point, even if we in intuitively understand what to do but, we can feel awkward about how to rank these 'important technologies'. Thus, to implement this conceptual model and the proposed steps, an analytical tool is needed to evaluate the alternative technologies and select some important ones.

More recently, the strategic management of technology has been discussed in many papers and books [3,9,14,15], but it is still missing a framework to link business strategy and technology strategy [2,14]. To bridge this gap, in the next section, an analytical method is developed.

3 An Integrated Approach

The approach we describe hereunder, is an integration of ADL, Morin and Porter's view points, and is based on the five following principles :

1. Each firm includes a group of distinct and identifiable activities ;
2. Each activity involves one or more technologies and sub-technologies ;
3. All technologies do not have the same influence on firm competitiveness.
4. Firm capabilities vis-à-vis each technology are different.
5. The necessary resources for technology development -people, funds, and time- are limited.

To elaborate firm technology strategy in coherence with its overall strategy, the first idea of this method is that a company has first to identify its critical activities :

* **Critical Activities :** internal activities which are the basic elements of competitive advantage (key elements to achieve firm global strategy).

The second idea is that the more strategic technologies are those on which these critical activities rely, called 'strategic technologies' :

* **Strategic Technologies :** technologies which are used or candidate to be used in the Critical Activities.

The third idea is about the priority of investment on the strategic technologies. It depends on two factors : attractiveness of this technology, on one hand, and the firm strength and weakness vis-à-vis this technology, on the other hand.

So, as illustrated in Figure 5, elaborating technology strategy requires the five stages below to be followed :

1. Inventory of firm Critical Activities ;
2. Identification of current or candidate technologies for each Critical Activity (Strategic Technologies) ;
3. Assessment of firm capabilities vis-à-vis each Strategic Technology (internal diagnosis) ;
4. Evaluation of Strategic Technologies attractiveness (external diagnosis) ;
5. Elaboration of technology strategy according to the general outlook of the technology portfolio -in the '*Attractiveness-Competencies matrix*'[1], and according to the position of each Strategic Technology in this matrix.

Technology portfolio will be displayed as a group of points in the matrix. Some *typical* cases of technology portfolio have been shown in Figure 6. Each case deals with a different situation of technological patrimony and implies a special thrust in technology issues. As an example, a company with an 'old portfolio', can choose a technological orientation either towards the acquisition of some more young and emergent technologies by internal R&D, technological alliance, etc., or towards diffusion of its well-mastered technologies in other activities (already existent or new business activities). While, a young company, in technology issues, should rather try to enhance its technological competencies.

Then, the position of individual technologies in one of the 4 zones of the matrix implies a different situation and thus needs an appropriate technology strategy to be elaborated :

Zone-☆ : firm capabilities as well as attractiveness of technologies are suitable. Technologies in this zone are the stars. Company must protect this situation through investment on the technologies in order to go ahead with technological evolution on the market. An other effort may be to transfer these technologies to other products or processes.

Zone-**$** : firm capabilities are suitable but, attractiveness of the technologies is weak. These technologies should be replaced progressively with new and more attractive ones. They may be utilized or sold in order to generate immediate profits.
The firm matured technologies are often forgotten as they do not have any value. While 'selling an *out of date* technology' could be a business-like strategy in technology issue.

Zone-**?** : by contrast with previous zone, firm capabilities are weak in regard to high attractive technologies. As a natural strategy company should improve its competency vis-à-vis these technologies in order to push them to the stars' zone. But, it is often impossible to improve the competency in all candidate

[1] The same matrix used by Morin as '*Matrice Attrait-Atout*'.

technologies. So, selective improvement of technologies is recommended. Then, the causes of weakness for each selected technology should be determined in order to choose a suited way of improvement is chosen (ex. internal R&D, technology transfer, technological alliance, education, and so on).

Zone-┼ : neither firm capability nor technology attractiveness is suitable. These technologies should be probably dropped out and replaced with some new and attractive technologies.
The previous steps of method ensure that technologies mapped in the Attractiveness-Competencies matrix, are more or less strategic. If the attractiveness of a strategic technology turns to be weak, it is because either the technology is in the maturity phase of its life-cycle, or there is a mistake somewhere in the evaluation process.

4 Application Results

This method was applied in two French companies (one in software production and the other one in electronic sector). The company being analyzed here is a young SME created in 1994, which works in the field of computer software production.

Our purpose here is to show the application results. So, some details on how the work has been conducted will be omitted.

The company has chosen two types of strategic objectives :

- in 'Innovation' field
  - Increasing precision of understanding of the market needs ;
  - Mastering powerful tools for new product development ;
  - Launching a new product per year.
- in 'Marketing' field
  - invading the market very quickly (in France, Europe and USA).

With such objectives, the four following activities are considered as critical activities by the company's managers :

A1 - Customer demand analysis ;
A2 - New product development ;
A3 - Distribution management ;
A4 - Programming tools survey and eventually acquisition.

It is to notice that, although this company operates in a '*Technology Pushed*' environment, a better understanding of customer needs and quickly response to their requirements are its strategic weapons.

The 12 strategic technologies, concerning the critical activities, are then identified (table 1). The company's capability, vis-à-vis each strategic technology, is evaluated through the following criteria. These criteria may be divided into R&D capacity and acquisition capacity :

- R&D capacity
  - Financial resources for developing this technology ;
  - Information about the latest evolution in this area ;
  - Degree of competency in this technology ;
  - Independence of the company, in this technology, from sub-contractors and licensers.
- Acquisition capacity

- Sufficient basic knowledge for acquisition, adoption and adaptation of technology ;
- Organization receptivity ;
- capability in (technology transfer).

and the attractiveness of each strategic technology is evaluated through :

- Impact on competitive advantage ;
- Influence on other technologies of the firm ;
- Potential of further progress ;
- Absence of substitution risk ;
- Competence of actual competitors in this technology ;
- Possibility of protection of the technological development in this area ;
- Government supports or , in the opposite, legal barriers.

Based on these criteria, a questionnaire is designed, and answered by the company's managers. Firm's capabilities as well as technologies' attractiveness are measured and the 'Attractiveness-Competencies matrix' is established (Fig. 7). Most of the strategic technologies situate in the higher part of the matrix. It means that the company's portfolio of technologies seems fairly attractive. The strategic technologies for which the company is less competent (5,6 and 12), concern rather marketing aspect of critical activities. This fact can be explained by the youth of this company.

The technologies 2,10, and 11 seem to be the stars of this young company and should be updated continuously. The technologies 3,4,5,6,8,9, and 12, are the dilemmas. Developing or acquiring all of them is far beyond the human and financial capabilities of this young company. So, they need to be assessed deeply in order to extract and subset to invest on. The causes of weakness should be clearly identified. The technologies attractiveness needs also to be evaluated in detail. These evaluations are possible by using a double weight for some of the criteria. For example, we have chosen here, the firm's internal R&D capabilities and the potential of progress.

Up to now, company's competency in technology issues, has been a mix of internal development capability and acquisition capacity. For a deeper investigation, we can try to visualize whether a group of criteria influences or not the position of a technology in Attractiveness-Competencies matrix, more than the other group. Doubling the weight of internal R&D capabilities[2] as a criterion which identifies the company's strength and weakness in R&D vis-à-vis the technology transfer, shows, for instance, a worse position for the technology 9 (Fig. 8). So, if this technology is finally chosen, it should be developed by acquisition rather than inner R&D.

Even more, a deeper analysis of some technologies in Zone **?**, allows to detect the specific causes of weakness, and to show up the future actions for enhancing firm technology capabilities. It is possible through giving a different weight to the individual criteria of internal R&D and/or acquisition capacity. If the company's weakness is rather because of financial reasons, she must perhaps try to find a partner to joint or capital venture. If the lack of information or knowledge is the cause of weakness, this problem must probably be solved by academic collaboration, technological alliance, licensing, etc. Finally, if the human resources are not enough qualified for the internal development or acquisition of the technology, the company can improve its competence by education (training and retraining) or by recruitment of new employees.

On the other axis, technology attractiveness is evaluated through a mix of 7 criteria. To the same reason, a second step of analysis is needed to visualize the relative impact of each individual criterion on the position of technology in Attractiveness-Competencies matrix. For example, 'potential of further progress' is a criterion which determines whether the technology will be more attractive, in the future than at present. By doubling the weight of this criterion, it can be seen that the technology 4 is highly more attractive in future (Fig. 8). It should be preferred, for example, to the technology 3 if they turn to be mutually exclusive as resources are limited.

[2] Set of the 4 criteria of internal R&D capacities evaluation : Financial resources for developing this technology, Information about the latest evolution in this area, Degree of competency in this technology, and Independence of the company from sub-contractors and licensers.

5 Conclusion

Prior to R&D projects evaluation and selection, it is necessary to get a rank of priorities in technology development. If the initial step is poorly managed, it can lead to the dissipation of organization energies, resources, and time. We have proposed, in this paper, an analytical method to ensure that this ranking is based on the firm competitive strategy.

This method starts with the firm strategic objectives, already determined. Then, the most influent activities on these objectives are identified -the critical activities. Technologies embodied in the critical activities are listed, evaluated through a multi-criteria evaluation system, and placed in the Attractiveness-Competencies matrix. Technology strategy (i.e. priority and way of investment on strategic technologies), can eventually be elaborated according to the portfolio of technologies and the position of each technology in this matrix. In R&D collaboration issue, for example, the method will help to select the technologies on which collaborate as well as to precise the subject of collaboration, such as academic collaboration, technological alliance, joint or capital venture, etc.

Once the technology strategy has been elaborated, the next step which is not dealt with in this paper, is to examine R&D projects in order to select some feasible and economic ones. The relevance of R&D projects to the firm overall strategy can now advantageously be examined through the evaluation of their relevance to the concerning technology strategy.

The application of method in a small French company has given reasonable results. It has shown that for a young company with an excellent technical information and competencies on computer and software production, master some more competencies concerning management of customer requirement may be a strategic weapon. As, it may be difficult to simply discover, without applying the analytical method.

This research can be completed at least by adding the two following directions which are our further objectives :

- to increase the reliability of the connection between technology and business strategy. We believe that the link of activities to overall strategy is too intuitive. So, we are trying to use a process based approach as an interface. This will lead to find the main processes vis-à-vis firm overall strategy and then, only for these processes, to identify some particularly 'critical activities'. For this purpose, we are looking at some techniques used in the '*Business Process Reengineering (BPR)*' approach.

- to integrate into the approach firm 'product' technologies as like as 'process' technology. The proposed method considers particularly the firm process technologies (in the wide range). It will be worthy to enhance the portfolio with technologies embodied in the firm products or services.

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Table 1. **Critical Activities & Strategic Technologies**

Critical Activities	**Strategic Technologies / Competencies**
Programming tools survey and eventually acquisition	**T1-** Data base management. **T2-** Network management.
New product development	**T3-** Programming. **T4-** Software testing. **T5-** Socio-economic evaluation of new projects. **T6-** Market study. **T7-** Project management.
Distribution management	**T8-** Distributors data base management. **T9-** Logistic management.
Customer demand analysis	**T10-** Resource assignment. **T11-** Customer needs data base management. **T12-** Quality Function Deployment (QFD).

Fig. 1: **Two directions in bridging between technology strategy and business strategy**

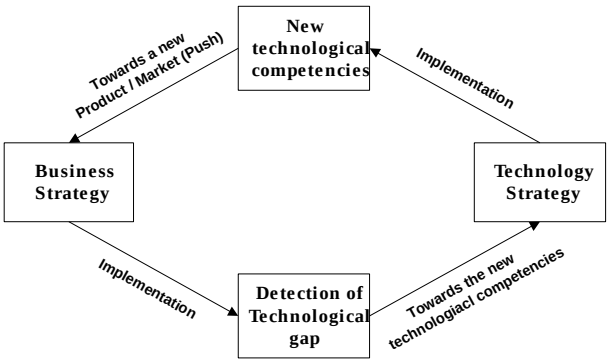


Fig. 2: **BCG's model of strategic analysis**

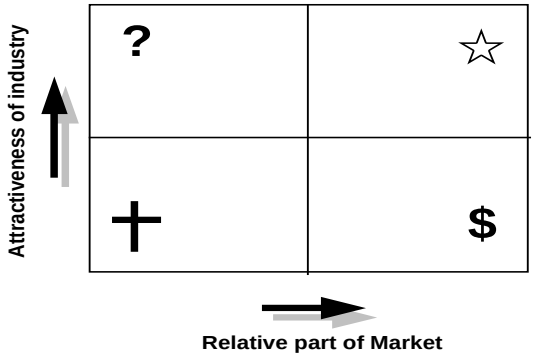


Fig. 3: **Price-performance Analysis (source : J. Morin 85)**

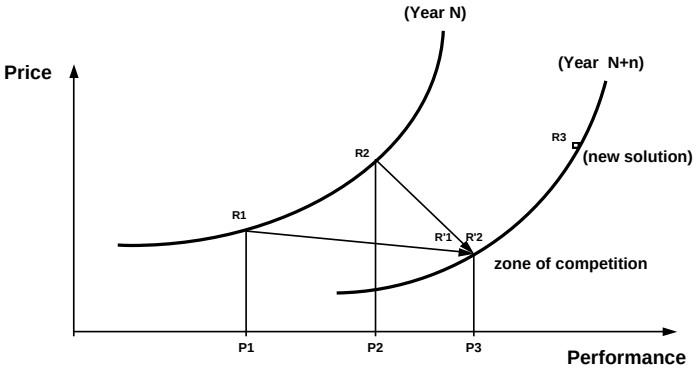


Fig. 4: **ADL's model of strategic analysis**

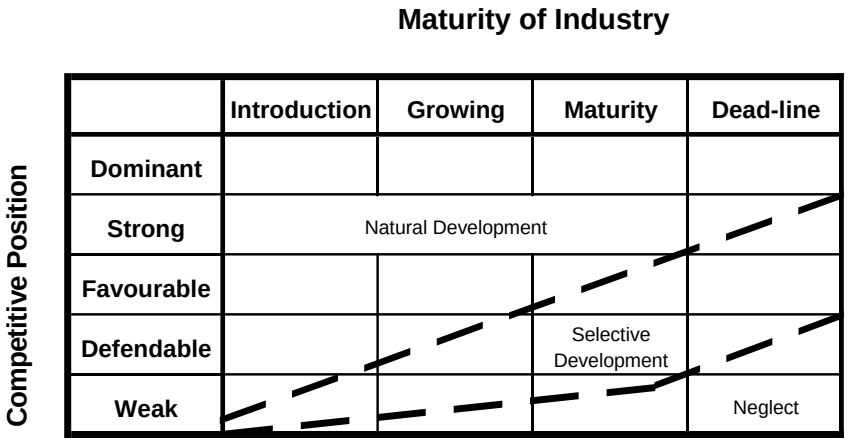


Fig. 5: **Five steps of technology strategy elaboration regarding to the firm overall strategy**

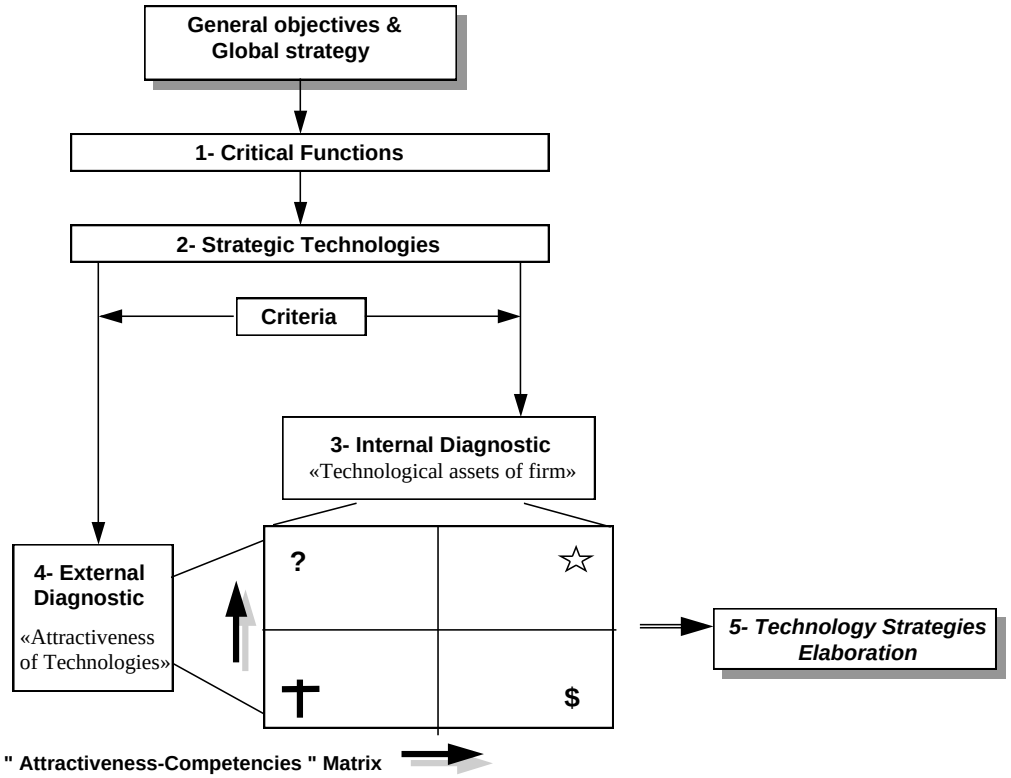
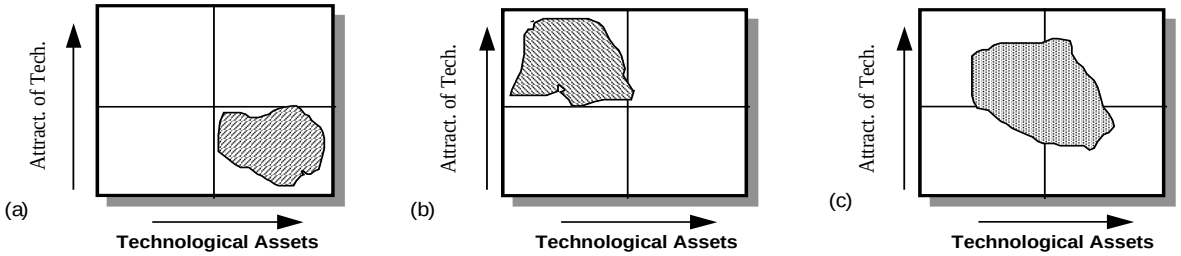


Fig. 6: **Different typical cases of Technology Portfolio**



(a) An old company in technology issues ;
(b) A young company in technology issues ;
(c) A balanced situation in technology issues.

Fig. 7: **'Attractiveness-Competencies' matrix**

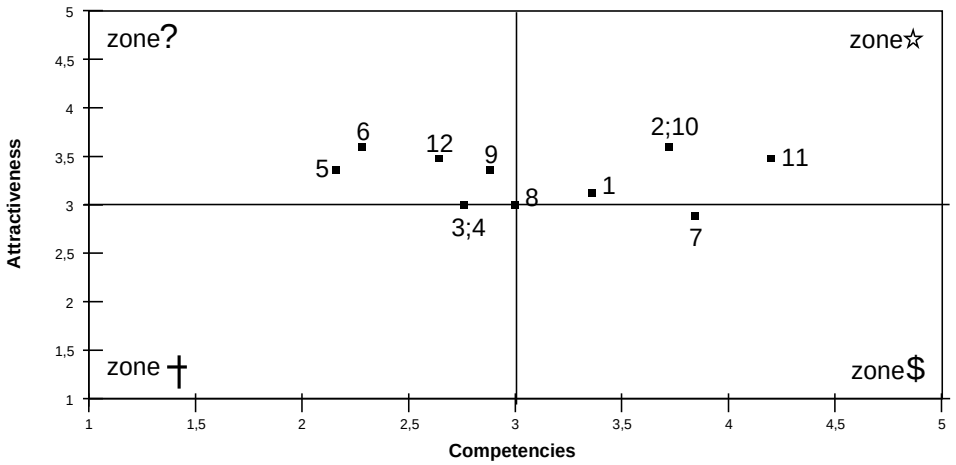


Fig. 8: **'Attractiveness-Competencies matrix' (attract. + potential of progress & Compet. + R&D capabilities)**