Strategic management of technological innovations in the small to medium enterprise

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Keywords

Small to medium-sized enterprises, Technological innovation, Competitiveness, Product innovation, Scenario planning, Innovation

Abstract

This paper addresses the problems inherent in identifying technological innovations that can improve company competitiveness with the ultimate aim of increasing the value of a specific enterprise. A model is proposed that, starting with the competitive weight of a technological innovation to processes or products, yields a strategic weight that enables decision makers to evaluate the increase in business value consequent on application of such innovation. The proposed model is composed of four sub-models: the first is an analysis of process/product competitiveness aimed at identifying competitive priorities and therefore appropriate technologies; the second sub-model identifies the priorities of technological intervention from amongst the competitive technologies selected; the third sub-model correlates the two previous sub-models and thereby expresses a "strategic weight" of the technological projects with respect to the competitive priorities of the processes or products; the fourth and last sub-model applies scenario simulation and sustainable growth verification to estimate the impact of strategic project innovations in terms of increased business value.

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The problem of managing technological innovations

An innovation strategy arises from the need to establish a linkage between customer needs and the needs satisfied by a company product (whether new or modified). This linkage must be not only better and stronger than competitors', but also sustainable over time (so that it may translate into a true competitive advantage), something that only the application of advanced technologies or proprietary know-how can achieve.

Establishing and maintaining such linkage in order to best satisfy customers' needs (current and potential) through offerings that incorporate new technologies is what defines technological innovation. Implementing a strategy for such innovation involves pursuing two basic goals:

(1) improving product/service quality with respect to two fundamental market dimensions: customers and competitors (translating in the short term into increased product competitiveness);
(2) improving the company's technological level, once again relative to two dimensions: the current state of technological development; and competitors' positioning with regard to such technologies (translating in the medium to long term into increased competitiveness of company technologies).

Achieving these two strategic goals requires an essential correspondence between the strategic decision-making process with regard to technological innovations and the dynamics of market and technological evolution. Strategic choices therefore involve evaluating the appropriateness of technological investments in order to improve existing products with the ultimate aim of furnishing the firm with an achievable, yet substantial ability to compete[1]. In fact, factors such as product quality, service level, lead-time, and so on, may have a fundamental impact on the company's possibilities for development and very survival, in that they represent prerequisites for achieving long-term success[2].

Interrelations between technology and product competitiveness

Abell (1986) asserts that a product is the physical manifestation of application of a

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

particular technology. Companies must therefore seek to improve (or acquire *ex novo*) those technologies able to offer the greatest competitive advantage in terms of meeting customers' expectations. Of the various physical product properties (such as shape, colour, etc. but also, and especially, the ability to provide a series of functionalities), consumers deem some more relevant than others; these priority factors are represented by "performance features", or simply "quality", and in these terms the product itself simply represents the means to achieve such functionality.

Through this interpretation, it is possible to identify a series of performance features whose effectiveness is linked to the technologies adopted to produce either the components themselves or the interrelations among such components that provide function. The introduction of technological innovations must therefore reap advantages in terms of product quality, intended as the set of performance features, which must translate into a "capacity gap" with respect to competitors that comes from applying better technologies. Therefore, it is necessary to consider the complex relations thus established between a company product, its performance features, the physical components making it up and the relative production processes, while using as reference points, on the one hand, customer requirements and, on the other, the competitors' offerings (Buzzell and Gale, 1988). Analysing these relations enables one to define the strong and weak points of various products in relation to market demands and what the competition offers.

As mentioned, each performance feature must be analysed in relation to a product's constituent components and/or their interrelations, both of which can be achieved through various technological processes. Such analysis, conducted for each and every feature, allows one to identify a "range" of possible innovative solutions achievable through improvements to already existing technologies and/or through the acquisition of new ones. The innovations thus engendered will enable the company to substantially improve its competitive position through greater correspondence between market demands for a certain feature and the company's ability to offer it.

Technology as a dynamic factor

The duration of the competitive "capacity gap" gained through the adoption of a given technological innovation, in terms of the time competitors need to imitate new features and improve their own production, has enormous consequences on the effectiveness of the company's strategies in the medium to long term: the longer this period is, the greater the advantages accruable by the company first introducing the innovation, thereby guaranteeing a less ephemeral success to the strategy adopted[3]. Hence, there is a clear need to formulate strategies able to combine technological with market opportunities, the aim being to achieve the aforementioned dynamic correspondence between innovative change and environment/market forces. It is only through such dynamic strategies that the goal of effective and lasting competitiveness can be achieved through innovation. The timeframe of technological advances is thus a fundamental consideration in adopting innovation strategies and calls for careful consideration of the dynamics of a given technology in analysing its potential effects on product quality.

Therefore, due account must be taken of the technology's maturity, that is to say, its current stage of development with respect to its foreseeable life cycle. In fact, the set of technologies adopted by a company goes to make up its "technological pool" (comprising both "hard" and "soft" elements), which in time inevitably becomes obsolete (with respect to the performance evolution of various technologies) and must therefore be constantly renewed. In other words, the decision to implement or to acquire a given technology must also be assessed on the basis of its place within the company's technological pool. From this perspective, the various technologies will have to be evaluated, not only with regard to their possible future evolution (their maturity), but also with respect to the relationship between the company's technological positioning and that of its competitors.

The results obtained through these two comparisons provide an assessment of the potential impact on the company's technological capacities of the technological innovation chosen to improve production quality. Furthermore, the more the company's technological capacities are based on the accrued technologies providing

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

performance advantages over competitors (at comparable levels of investment), the greater the competitive advantage they will afford.

To sum up then, managing technological innovation involves the two simultaneous, interrelated fundamental objectives of competitiveness:

(1) improving product quality (a prerequisite to success);
(2) improving the company's overall technological quality (a prerequisite to *lasting* success).

Evaluating technological innovation strategies

Innovation strategies must therefore stem from decisions of a strategic financial nature. If the main goals are short-term results, the strategy is to be oriented towards market defence (consolidating one's position) by pursuing costs reduction and resources optimisation. If, on the other hand, the financial strategy is oriented to medium- to long-term objectives, then priorities shift to the creation and/or development of new markets through new, more advanced products and technologies. The specific choices are determined by a number of factors, including the company's current position, financial market conditions, interest rates, self-financing ability, and market receptivity to innovative developments[4]. Moreover, attention to quality, service, product diversification, and so on, can transform traditional costs-oriented results into strategic results in terms of company performance. Therefore, the decision-making process with regard to strategic choices must ultimately be linked to overall company performance.

From such considerations, it follows that the measurement criteria must be able to:

- link strategies to objectives;
- integrate accounting and non-accounting measures.

Thus, the primary (medium- to long-term) objective of increasing company value can be divided schematically into two sub-goals:

(1) market aims: increasing market share, expanding into various markets, and so on;
(2) financial aims: increasing profitability, cash flow and, therefore, the medium- to long-term financial equilibrium.

The medium- to long-term results, which reflect company performance and can be linked to the strategic initiatives undertaken, are measurable through increases in company value (financial performance), according to the perspectives of survival, success and growth. Such perspectives involve various strategic-financial indices, of which the most fundamental is the cash flow engendered by improvements in the company's competitive abilities (increases in sales, market-share, profitability and self-financing ability).

However, apart from the a posteriori stock-taking needed to assess the true effectiveness of the strategies followed, the investments called for in order to implement such decisions must be evaluated a priori with respect to the various alternative courses of action and their estimated chances of success. Only thus can the costs and the risks inherent in each be appraised before decisions are made.

Managing technological innovation in small and medium-sized enterprises (SMEs)

Medium- to small-sized firms are generally unprepared to tackle complex problems, for which the decision-making process requires, more than technical skills, experience or sound business sense, the ability to conduct far-reaching, systematic analysis of data and events for the most part extraneous to the company. Traditionally, the major difficulties facing SMEs with regard to strategic management of technological innovation involve their lack of managerial skills, the inadequate attention generally paid to technologies as a strategic variable, the reduced scope and varying stability of their field of operations (or niche), and the lack of qualified competitors.

Recently, a new generation of executives has brought with them a greater awareness of and preparedness to address the new issues facing modern management: more and more, the potentialities inherent in technological innovations have given new impetus to creative drives and success-minded insight; the potential field of operations has been broadened considerably through the progressive elimination of borders and the opening-up of global markets; and the constant, rapid changes in customer needs are continuously eliminating old markets, while at the same time creating new ones.

Therefore, the foregoing considerations are more applicable than ever, and for all the more reason, to SMEs, simply because they find themselves less equipped to deal with such change.

Often, the difficulty in obtaining the information necessary to assessing one's own competitive situation and conducting scenario analyses is invoked as the main factor keeping SMEs from performing strategic planning. We believe this to be, at least in many cases, more of an apparent difficulty than a real constraint on management; or, at least, we do not see it as sufficient to prevent SMEs' management from undertaking the formulation of well-founded strategies. However, given the highly interdisciplinary nature of approaches to managing technological innovations, it cannot be denied that some difficulties do indeed exist. But, if properly tackled, such management can be facilitated by the realisation that much of the needed information can be deduced through experience and by analysing other data and information that are either already in the company's possession or easily accessible. Another related difficulty that is also more apparent than real involves the fact that information is not collected systematically, thereby rendering burdensome and incomplete any understanding of market evolution and the connected potential technological opportunities.

Instead, a concrete limiting factor for the SME (and not only) on the implementation of innovative strategies is represented by the highly complex nature of the phenomena to be managed. Moreover, there is the related problem of defining clear, unequivocal objectives, and therefore evaluating the impact of the possible strategic alternatives on enterprise performance (which becomes perceptible in the medium to long term). Even the best-prepared manager, when faced with the multifarious complexity of innovation phenomena, may lose sight of the true goals of the decision-making process. Moreover, no manager can be expected to systematically follow the complex task of information processing, which opens up a myriad new alternatives, corresponding to as many as possible scenarios, and thereby further amplifies the already exacting number of interrelations and their consequent effects on overall objectives.

Thus, we undertook to contribute what we believe is a useful "how to" method for managing technological innovations. This contribution, precisely because it is aimed at SMEs in particular, could not but be oriented to management activities and, therefore, to the formulation of a working model for the decision-making process.

The methodology adopted

Generally, decision-making problems of any complexity are addressed through application of quantitative DSS (Decision Support System) methodologies. Such methods, however, are aimed at "problem solving" in rather narrow, well-defined domains and provide the best results in stable contexts. They moreover call for specialised information-science expertise. Therefore, given the uncertainties inherent in potential future scenarios and the evolutionary dynamics of the financial, market and technological settings, tools such as Executive Information Systems (EIS) and Executive Support Systems (ESS) appeared more suitable. However, because of the need for a method oriented towards the development of information-science technologies, we resolved to adopt a so-called Intelligent Decision Support System (IDSS) (Pratali, 1986).

IDSS systems integrate semi-structured processing models for evaluating alternatives. They yield prospectuses and reports that are able to evidence the rationale underlying the choices being made on the basis of the values of only a few factors, considered to be crucial. Such methodologies currently appear to be the most efficient and effective for the information processing underpinning strategic decisions. They leave decision makers the freedom to decide at what level of detail to handle the available information, thereby facilitating and fostering in-depth analysis and systematic diagnosis of the issues, an important prerequisite for coming to well-considered, foresighted decisions. The skills and creativity of individual decision makers are therefore not stifled; their insights can instead be examined and compared, one with the other, as well as with respect to the overall set of elements and factors (deriving from the synergistic

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

relationships among the variables considered), which are then represented in a simple, yet thorough fashion.

From this perspective, the adopted qualitative and quantitative analysis tools become useful in coming to decisions under conditions of uncertainty with regard to problems that cannot be completely structured in rigid mathematical models. However, it seems worthwhile cautioning that, however sophisticated, such analytical tools are all ultimately guided and managed by man. Therefore, the skills and expertise of those defining the input to, and the conditions of, the scenario, as well as the interpretative abilities of the decision makers, all represent determining factors in their correct application and, above all, for the reliability of the results they can yield.

Design elements of the innovation-strategies management model

At this point, having defined our objectives and chosen the type of methodology to adopt, the next step becomes to design a conceptual scheme of the proposed system for the analysis and evaluation of innovative strategies according to the specifications presented in the foregoing. The model's framework is represented by the relations between technology, the market, and the firm's effective capacity to implement innovations. This last factor, in turn, involves, on the one hand, the resources a company is willing and/or able to commit and the consequent acquiring power and, on the other, the benefits that may be gained in the medium to long term (in terms of improved company performance). Therefore, the model serves to help select those technological strategies that prove to be the most promising for the ultimate aim of garnering a competitive advantage for the company.

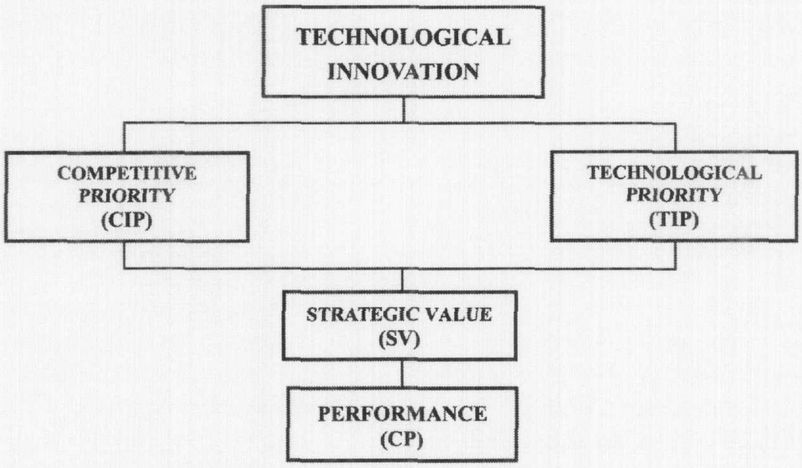
Four stages of the analysis, corresponding to as many distinct sub-models, can be distinguished:

(1) *Stage 1*: selecting the technologies best able to improve the company's market competitiveness (evaluation of competitiveness intervention priorities (CIP), a short-term aspect). This is performed by assessing the position of product performance with respect to the two fundamental market dimensions, customers and competition, with the aim of identifying the features in need of improvement. Then, the processes fulfilling these features are identified, and their influence (weight) measured. The last step in this stage then calls for identifying any technological alternatives able to improve the given features and their weight with respect to the performance benefits they can offer.
(2) *Stage 2*: selecting the technologies able to improve the firm's technological capacity (evaluation of the technological intervention priorities (TIP), a medium- to long-term aspect). This consists of evaluating the company's position in the technologies selected in the previous stage with respect to the competition, as well as the maturity of the technologies themselves (i.e. their stage of development).
(3) *Stage 3*: linking the two indicators (CIP and TIP) in order to evaluate the potential overall strategic benefits of adopting the selected technologies (strategic value of the technologies (SV)).
(4) *Stage 4*: evaluating the increase in company "value" (in the medium to long term) consequent on implementation of the technological innovations with the highest SVs (company performance index (CP)).

In short, the first two sub-models are aimed at analysing the technological factors determining the company's strategic position, and therefore serve to identify the innovative strategies able to enhance the company's competitive and technological position (that is, improve the company's production and overall technological quality). The third sub-model serves to integrate the two previous choices, selected separately for the two distinct dimensions, into a synoptic indicator of the importance of specific technologies for the company's overall competitiveness, termed the "strategic value" of the innovation. Finally, through the fourth sub-model, we seek to measure the effects of the highest-ranking potential strategies (that is, with the highest SVs) on company performance, in terms of the potential increase in "company value" in the medium to long term (Figure 1).

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

Figure 1 The four sub-models



Sub-model 1: the competitive priority of technology

Analysis of competitiveness

Concerning a company's ability to compete, we began with the basic consideration that the more a product's performance features correspond to market demands, as well as to those of competing products, the more competitive will be the company's position in the market. Therefore, company performance must be defined and assessed with respect to market offerings. Defining performance signifies establishing the parameters that target customers equate with "quality". This involves compiling a company ranking with regard to such parameters, a ranking within which the firm must then evaluate its position by determining the correspondence between the quality "demanded" and that which it "supplies" in consideration of both of the aforementioned dimensions of customers and competitors. Therefore, the first step in defining the sub-model's framework consists of identifying those variables capable of "explaining" such a complex phenomenon as the market position of company products.

The first relation to take into account is that between customers and the company. As product features can be assumed to be the parameters measuring quality, this relation can be determined by analysing the correspondence between the quality level sought for by customers and that of company offerings. Such relationship is expressed through the variable termed the index of "called-for improvement" (CI), which represents the qualitative distance, or gap, between market demands and company offerings. Therefore, the wider this gap is, the worse will be the ability of company products to satisfy customers and, consequently, the greater the improvements "called for" by customers.

Analogously, the relationship between the company and its competitors, defined as the "level of competitive capacity" (CC), can be analysed and estimated by comparing the level of quality offered by the company with that offered by the competition. Thus, the better the features (sought for by customers) offered by company products in comparison with those of the competition, the greater will be the company's competitive capacity. Figure 2 illustrates the process by which the values of the two variables CI and CC are determined.

Each of the two identified variables (CI and CC) is assigned a qualitative rating (high, medium or low) and positioned on a two-dimensional matrix (such as a classical Ansoff or BCG matrix, or similar approaches), in which the abscissa represents the "level of competitive capacity" (CC) and the ordinate the "called-for improvement" (CI). By means of this matrix, the competitively weak features (i.e. in need of improvement) can be easily identified as those exhibiting the maximum distances between company and market, and company and competitors (Figure 3)[5]. Such features are therefore characterised by a high level of called-for improvement (expressing the discrepancy with regard to market demands) and low competitive capacity (revealing the company's weakness *vis-à-vis* the competition).

However, as not all features will have the same importance for users, each must be assigned a weight in order to account for the degree of market demand for that particular feature, and therefore furnish a basis for

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

Figure 2 Selection of product performance features needing improvement in consideration of market demands and competing products

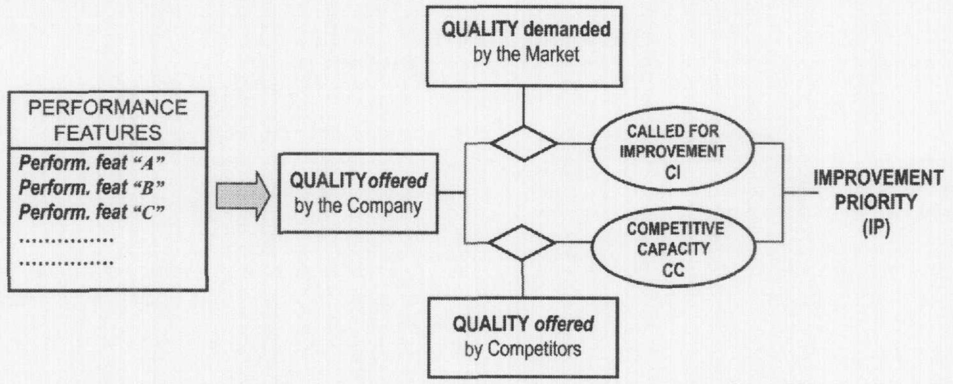
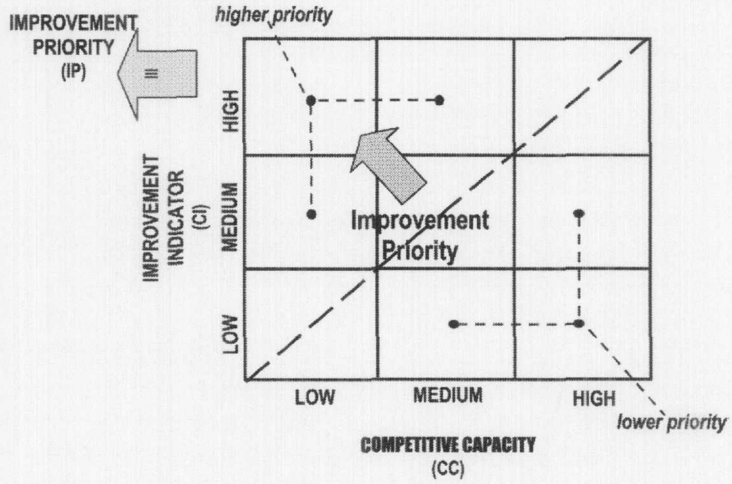


Figure 3 Measure of the improvement priority (IP)



evaluating the need for improvement. Thus, the different quadrants of the matrix will contain features with differing weights, so that, in order to estimate the overall competitive situation, it is necessary to define an idealised, theoretical reference feature characterised by the highest called-for improvement, the lowest competitive capacity and the highest weight. Such feature is thereby assigned a maximum value, termed "absolute priority". Then, by comparing all the other, real features with this hypothetical ideal, it is possible to define a set of those features most in need of improvement, according to the resulting relative values, called the "improvement priorities" (IP), obtained by combining each feature's matrix position with its weight. The use of a weighted element allows improvements in the competitive situation to focus on those features that, on the one hand, represent the company's weakest points and, on the other, have a determining influence on user preferences.

The advantage of this type of analysis lies in the fact that it can be applied to already existing products, as well as to new ones. In the latter case, the evaluation can be performed through two alternative methods. The first one consists of assigning a null value to the quality currently offered, so as to automatically insert the new product's features into the list of those to be improved. The second possibility consists of precisely defining, rather than the quality currently offered, that which could potentially be offered by the company based on its actual capacities. Although this second method clearly involves greater complexity of the analysis, it offers the advantage of delineating a more thorough, realistic picture of the company's competitiveness, one that corresponds to its effective needs and capacities.

Potential innovations can therefore be best identified as market opportunities that

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

present themselves from time in time. Moreover, the analysis enables the company to arrive at an estimate of the competitiveness of a product even before it is made available[6].

Analysis of technological capacity
The second stage (still within the first sub-model) consists of determining what technologies could be acquired or improved in order to achieve concrete competitive advantages. To this end, products must be viewed as combinations of processes, each of which contributes to a varying extent to providing various performance features (Figure 4a). This "contribution" will then represent the "weight" of the process(es) with respect to the feature in question. Thus, the higher this value is, the greater the need to improve the process(es) will be. In practical terms, this means that, by multiplying this weight by the "improvement priority" (IP), we obtain a value that can be thought of as an index representing the perceived power of that process to improve the feature, and consequently the product and, ultimately, the company's competitive capacity.

Considering that every process can be carried out through various alternative technologies (Figure 4b), the technology to be acquired or improved can be identified by assigning a "technological weight" (TW) to each technology with respect to each process, and then calculating the product between this value and the index representing the need for improvement of the process(es). The resulting value represents the given technology's power to improve the product (competitiveness intervention priority (CIP)[7]. Therefore, for each technology, the sum of its priorities of competitive intervention for the various processes represents an index of its power to improve products (and, consequently, the company's competitiveness).

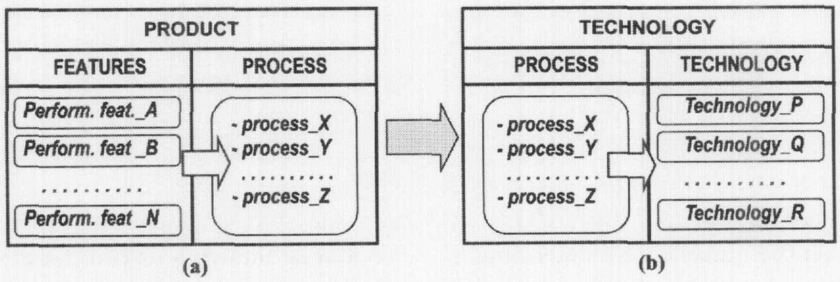
The overall procedures involved in this first sub-model (analysis of the competitive capacities of technology) can therefore be schematised in the following steps (Figure 5):

- identifying the product's most important performance features;
- evaluating the competitive value of each feature and defining its improvement priority (IP);
- identifying the process(es) influencing performance features and assigning a weight to each of these features (FW = feature weight);
- identifying technological alternatives and evaluating their importance in providing for critical processes (TW = technology weight);
- defining the technological intervention priority (CIP) for each technology, which is represented by the sum of the various values obtained by multiplying the improvement priority (IP), the weight of each process on the feature (FW) and the importance of the technology to the process (TW).

Sub-model 2: the competitiveness of technology

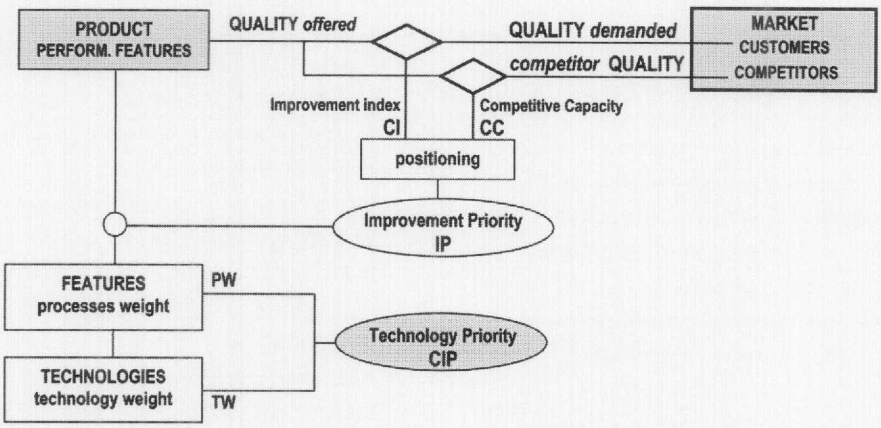
All technologies have limits to their applicability, and such restrictions must clearly be adequately accounted for by companies considering innovations. Such limits do not stem solely from a technology's power to contribute (in various ways and to varying degrees) to product improvement, but rather the given technology's proximity to a stage of discontinuity, that is to say, the moment in which its utility begins to decline due to the advent of new and more effective means to the same end. However, although we cannot speak of a true "technostructure" when dealing with SMEs, we must

Figure 4 Linking technology to performance via process(es)



European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

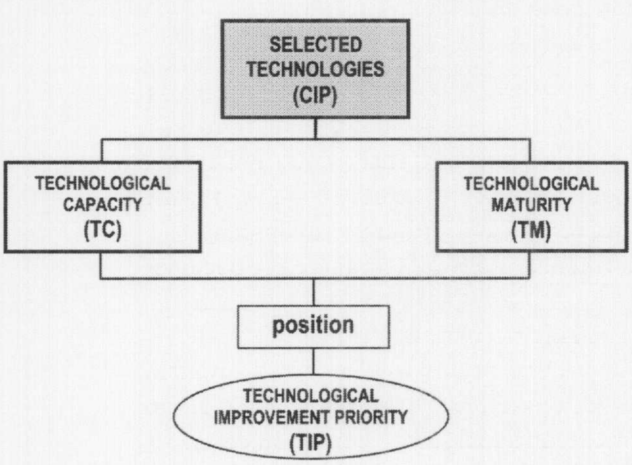
Figure 5 Summary of the first sub-model



nonetheless recognise the existence of "technological quality", represented by the capacity of a company's accrued technical means to yield the best results possible in terms of cost to performance ratio. Such considerations underlie the following procedure for determining a sort of company technological position through the interrelations existing between its technological capacity, that of competitors, and the state of maturity of the technology in question (Figure 6).

To this end, by analogy to the procedure outlined in the foregoing for the relations linking products and features, each selected technology must be evaluated with regard to its possible future evolution ("level of technological maturity" = TM), as well as to the company's ability to compete technologically with other comparable firms (the company's "technological capacity" = TC). The value of the first parameter can be determined by estimating the current stage in which an evolving technology can be placed within its foreseeable life cycle. Such evaluation involves some evident difficulties that can, however, be resolved through recourse to the opinions of experts in the given field. The second parameter, instead, represents the company's ability to leverage the technology in question better than its competitors do. It can therefore be determined by evaluating the company's know-how, patents, human and financial resources and R&D investment, and comparing them with the corresponding values and situations within competing firms.

Figure 6 Measuring the priority of technologies (TIP)



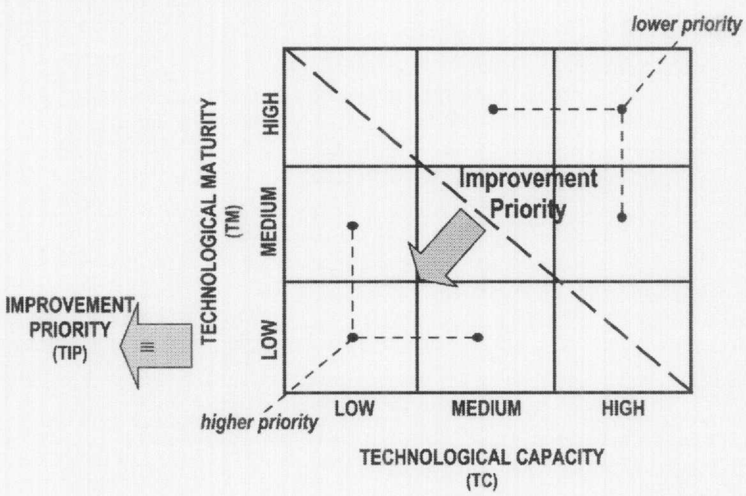
As before, the type of approach allows a two-dimensional matrix to be constructed (Figure 7).

In this case, we plot the variable TM along the abscissa and variable TC on the ordinate. The use of qualitative ratings once again renders the values homogeneous, thereby allowing identification of those technologies to be fostered and those to be eschewed with the aim of improving the technological quality of a given production unit.

Given the difficulties involved in applying such an approach (which go beyond those of garnering the necessary information), the SME may elect to forgo such a technological quality assessment of the company. In this case, however, an indirect assessment of the company's technological quality can nevertheless be included in the relations between technologies and processes by simply increasing the weight of those technologies that will presumably undergo greater future development.

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

Figure 7 The priority of technologies (TIP) matrix

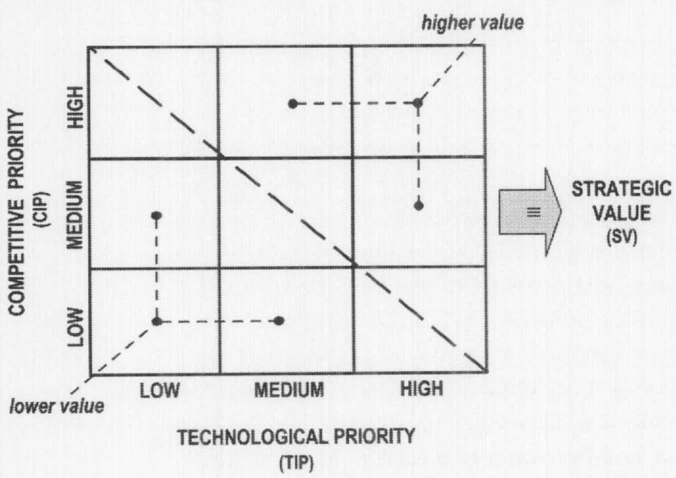


Sub-model 3: the strategic value of technology

At this point, we can proceed to an evaluation of the "strategic value" of the technologies considered, an index of which is obtained by crossing the values of the "competitiveness intervention priority" (CIP) with those of the "technological intervention priority" (TIP). This is clearly possible only because these values are homogeneous, as they both stem from qualitative judgements, and can therefore be linked in a matrix (Figure 8), in a manner similar to that previously described for technologies and processes. Each technology is assigned a strategic value (SV), which represents its ability to confer benefits on the company in terms of improvements to both its products and its overall technological standing. The matrix therefore provides an overall, synoptic view of the "strategic" position that a company can achieve by fostering those technologies with high values of SV.

To provide an overview of the steps covered so far, Figure 9 shows a schematic, integrated outline of the three sub-models described.

Figure 8 Matrix for the "strategic value" of technology (SV)



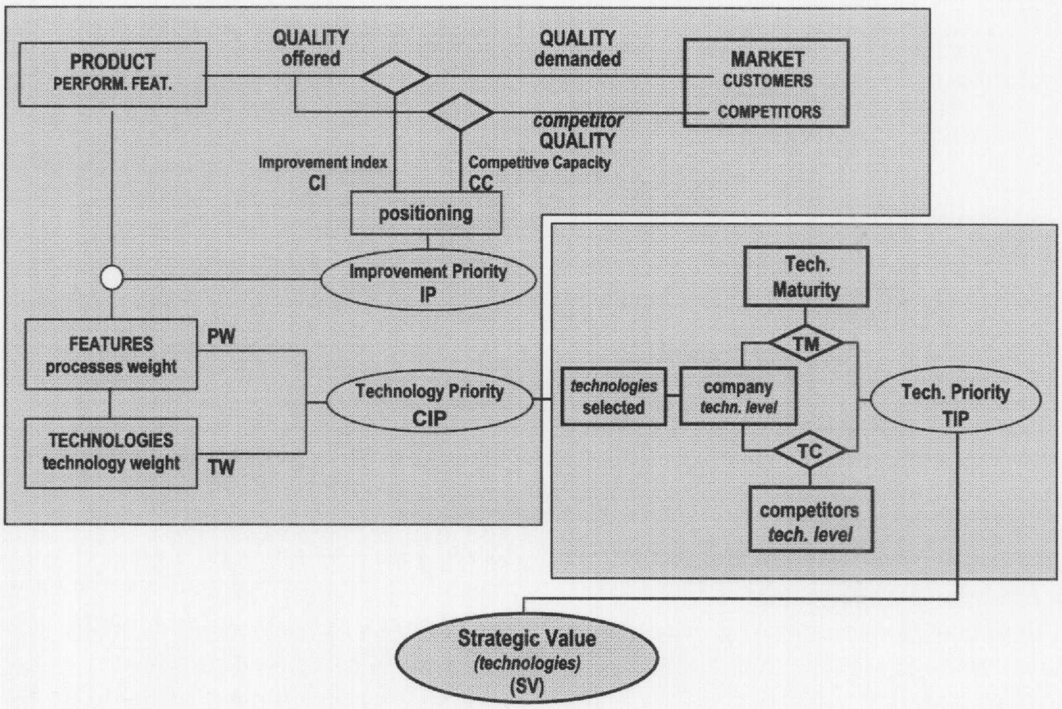
Sub-model 4: company performance assessment

As mentioned in the foreword, the effects of adopting technological strategies are manifest through measurable increases in market shares and/or expansion into previously untapped markets. Therefore, any parameter used to measure the consequent improvements in company performance (on which its future success and prosperity depend) must necessarily be expressed in economic-financial terms. However, as also mentioned, traditional financial measures are unsuitable for estimating such phenomena. Return on investment (ROI) and other static indicators are unable to reflect the dynamic nature of technological strategies: they cannot take into account the supplementary investments necessary to maintain competitiveness, nor are they able to express the variability in results in the medium to long term. In times of rapid change, the assessment system must be capable of accounting for the impact of market dynamics on company performance. The problem therefore becomes one of formulating a measure of company "financial performance".

Various approaches to solving this problem have been advanced. Recently, many seem to be oriented to measuring performance in terms of the creation of company "value",

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

Figure 9 Integration of the three sub-models for evaluating technological priorities



that is to say, a system (such as economic value added (EVA)) that enables one to estimate decisions with the potential to increase a company's economic value in the medium to long term. As is clear from the foregoing, such a "value" system has been adopted in formulating the current assessment model[8].

By improving its technology, a company, by virtue of its enhanced competitiveness, can increase not only its sales volume, but also its productivity, thereby reducing costs. On the other hand, the problem of the availability of the financial means necessary to implement innovations may be aggravated by the increase in circulating capital consequent on greater sales revenues. Implementing innovation raises a far-ranging series of economic and financial issues inextricably linked to the size of the investments involved. In fact, a company decision to make a certain investment, rather than another (also in relation to the amounts involved), is not a matter of indifference. Therefore, it is necessary, not only to co-ordinate a set of factors entailing variable degrees of uncertainty (and therefore risk), but to link the various assessment parameters of the decision-making process (costs to sustain vs. anticipated benefits).

The foregoing considerations have led to definition of the specifications for a performance assessment model of the decision-making process for technological innovations. The fundamental objectives are to endow the model with the following abilities:

- to measure variations in company value;
- to verify the "practicability" of development;
- to simulate scenarios (both internal and external);
- to conduct sensitivity analysis in order to estimate the incidence of risk factors, the reliability of the processed information and the varying degrees of uncertainty inherent in the assumed scenarios;
- to express results in the form of synoptic reports that, as previously stated, can evidence the criticality and significance of the different parameters and variables defined.

Measuring variations in company value

In order to achieve this first objective, the model adopts the well-known concept of measuring company "value", formulated for our current purposes in terms of the increase in economic value consequent on implementation of a given strategy. The parameter adopted to reflect such increase is the projected additional net cash flow consequent on adoption of the strategy (over a four- to five-year forecast horizon) (Chiavaccini and Pratali, 2000). The increase in company value is therefore given by the following relation[9]:

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

EVA (ΔValue) = Discounted [NCF (forecast horizon)] + Final value – Initial value
where NCF = Net Operating Profit – Net Added Investments.

The only modification made to the original formulation is the introduction of a "desired" return on venture capital for calculation of the discount rate (the average, weighted with respect to indebtedness, between the return on venture capital and the cost of borrowed capital) [10].

Thus, the model aims to calculate the increase in value achievable through the selected (i.e. high-priority) innovation strategies for three hypothetical levels of sales increases (minimum, medium, or maximum, corresponding to pessimistic, positive, or optimistic expectations) under conditions of fixed capital costs, indebtedness, and so on.

Development practicability
We use the term "development practicability" to refer to the combination of the ability to sustain the sales increase (with a given return on investment (ROE) and dividends distribution policy), on the one hand, with the duration of the value created, on the other. In other words, the ultimate aim is to verify the feasibility of the financial growth that is compatible with the created value, in the light of financing (indebtedness ratios) and dividends-distribution policies. Therefore, the model must calculate the maximum practicable growth rate of sales, as well as that rate which will no longer be able to furnish any increase in value at all (with the given indebtedness and dividends policies).

Simulating scenarios and conducting sensitivity analysis
This consists of endowing the model with the ability to effect "what-if" analysis through the processing of those parameters deemed to be most meaningful to the creation of added value. Clearly, the analysis must account for the risk factors stemming from the varying levels of uncertainty and/or reliability inherent in the chosen parameters. Of the various possible parameters, we shall consider the following:

- indebtedness ratio;
- incidence (on turnover) of working capital;
- percentage of hypothecated earnings;
- variation in the percentage of operating costs (productivity).

Figure 10 summarises the structure of the sub-model up to this point. The input data relative to each selected technology (output from the first three sub-models) must be derived from:

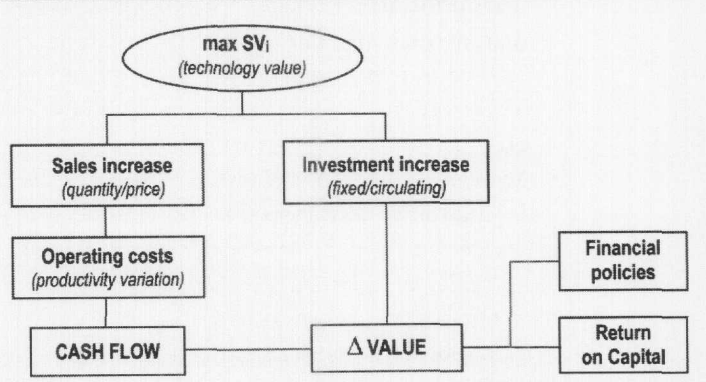
- the estimated growth in sales revenues for three possible scenarios (less favourable, medium, and more favourable) consequent on varying degrees of market responsiveness and/or competitor reactions (new offerings);
- the estimated variation in both variable and fixed operating costs consequent on implementation of the technology, the former being linked to hypothetical increases in productivity, the latter to an enhanced structural capacity;
- the estimated circulating capital requirements; linked to the increase in sales volume;
- definition of financing means, the return on capital and the cost of money.

Reporting results synoptically
As previously stated, the final results of the analysis must be structured in such a way as to provide easily interpreted, synoptic information, which must, however, be thorough in terms of both the details provided relative to each of the various technologies considered and the comparative data furnished. Moreover, the reporting must allow for varying the values of the significant parameters and presenting the results of simulation in an easily readable, summary form for all the technologies, including clear indications of the degrees of uncertainty involved in each parameter (increase in value and development practicability) [11].

Conclusions

Before drawing any final conclusions, it must first be said that we do not purport the

Figure 10 Sub-model for evaluation of company value



European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

proposed model to be exhaustive. It most certainly suffers from limitations in its resolving power with respect to the many and multifarious effects on performance consequent on the decision-making processes involved in adopting innovation strategies. Perhaps the most important of such effects are those due to the synergies activated between old and new technologies, though those stemming from the simultaneous action of the various assessment parameters (flexibility, cycle times, service levels, and so on) should not be underestimated. Moreover, technological innovation, whether it involves products or processes, nearly always leads to a revision of the design criteria underlying the production system (methods, cycles, lay-out, programming and control, and so forth), and will therefore have an impact on the organisational-managerial system as well; in other words, it almost inevitably involves "systems innovation".

Nonetheless, our belief is that this model, despite such limitations, represents a first important step in defining a method enabling the decision maker to quickly, efficiently and interactively obtain important information for the selection of the most promising strategies in terms of increasing company competitive capacity. We, moreover, believe that the model, through its various stages (analysis of competitiveness, technology and strategic value), offers the major advantages of helping management, first, to "understand" the market, its customers, products and competitors and, second, to reveal the close interrelations between the dynamics of technological innovations, product quality and company know-how and, lastly, to adopt a forward-looking perspective, thereby promoting commitment to strategic planning. In closing, its seems worthwhile stressing the novelty of the approach, which resides in its shifting the treatment of the issues at hand from a "problem solving" perspective towards one of "problem setting".

Notes

1 Customers' perceptions of product or service quality is a key factor in market competition, which more and more often depends on the company's ability to properly define performance features in conformity with its customers' wishes and equip its products accordingly through production processes able to guarantee high quality and reliability (De Witt, 1993).

2 Competitive capacity is measured in terms of the future; therefore it is necessary to pursue effectiveness rather than efficiency strategies (Kaplan and Norton, 1992).

3 Quality contributes to company performance in two ways: in the short term, higher quality produces greater profits through price increases; in the long term, higher relative and/or improving quality constitutes the most effective way to expand and maintain business.

4 The fear of failure may attain such levels that the perceived risks impede investment decisions. Alternatively, the investments needed in order to implement the strategic design may be so burdensome as to jeopardise the company's financial equilibrium.

5 In the working model, the qualitative evaluations are converted to scores of 1 to 5 (1 = low, 5 = high).

6 The analysis procedure described requires the company to gather a good deal of information and data: the performance features and their weights, the quality demanded and that offered by both the company and competitors. Such data can be garnered, for example, through specific surveying methods (market trials) or input into the model interactively. The first system is undoubtedly preferable, provided that reliable data are accessible. The second, which should instead be used when the available information is incomplete, consists of proceeding by successive approximations, in which the analyst modifies the underlying assumptions depending on the step-wise processing results of the data input.

7 There are information issues in this case as well: analysis of the technological variables calls for the support of "technologists". Such specialists, apart from general expertise in the field of technology, must also possess specific experience in the company's field of operations, a good knowledge of the product and the ability to formulate objective judgements.

8 However, above and beyond the indicators chosen to measure the effects of the adopted strategies, the effectiveness of the hypothesised model instead resides in its ability to process various hypotheses and scenarios with which, through the selected indicator, to compare the different decision-making alternatives according to different perspectives (profitability, risk, significance, etc.)

9 Assuming that company activities at the start of the forecast horizon (initial value), as well as those at its end (residual value), generate positive cash flows in the precise amounts necessary to cover the investments costs of maintaining a constant company-economic value (i.e. a "perpetual flow" system).

10 The return on capital should be measured in relation to the minimum return (obviously, after accounting for projected inflation) that, on the one hand, would not prompt disinvestment, but, on the other, is sufficient to attract new injections.

11 For example, the uncertainty in and/or reliability of the various parameters' values can be linked to the resulting degree of variability in the solutions in order to determine those factors deserving of the

European Journal of Innovation Management
Volume 6 · Number 1 · 2003 · 18-31

most attention (thereby prompting greater focus on the most reliable values that produce significant variations in the solutions, as opposed to those presenting greater uncertainty and low significance).

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