A Framework for the Strategic Management of Future Tyre Technology*

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Strategically managing technology faces one major problem: technology planners and managers who mistake 'R & D management' for 'strategic technology management'. In globally competitive markets, survival and growth of tyre companies will increasingly depend upon the ability to manage technological resources strategically. This article proposes a process model which views the strategic management of technology as 'techno-business management', where technology and business strategy, planning and implementation can be facilitated by the use of portfolio frameworks and technology forecasting techniques in analysing and addressing the key strategic management areas of techno-business strategy development and strategy implementation.

Introduction

Driven by a rapidly changing technological environment, achieving, sustaining and exploiting competitive advantage have become increasingly more complex and difficult objectives for global firms. Technology has not only created a host of new industries during the past decade, but has also radically altered the way U.S. corporations must do business. In globally competitive markets, managers have come to realize that technology and survival are inseparable. Technological issues must be integrated with strategic business planning and decision-making in order to both achieve business synergy and leverage technology. Throughout the remainder of this decade, and well into the 1990s, technology-related issues will be the basis for almost every major strategic business decision that managers will face.

Leveraging technology can best be accomplished by viewing technology in strategic terms. That is, it should be treated as an allocatable corporate resource that must be managed as an integrated component of corporate strategic planning and management. Business strategy has historically been developed without a technology content because of the long-held view that technology was not an allocatable resource or asset which could be effectively managed. Given the plethora of strategic planning models developed since the early 1970s by consulting companies, it would seem that the basic principles underlying the strategic management of technology (SMT) were well established. Likewise, it would be reasonable to believe that SMT frameworks were in abundance. Unfortunately, scholars and consultants have only recently begun to develop principles and practical frameworks which address the critical issues involved in strategically managing technology.¹

Purpose

Between 1978 and 1984, sales growth in the tyre industry was less than 1 per cent.² Complicating the problem faced by U.S. tyre producers is the rapid growth of foreign-manufactured tyres which currently accounts for 23 per cent of the U.S. replacement market,³ and significant industry over-capacity. In such a hostile environment where the ‘success formulas’ for strategic planning popularized in the 1970s are being replaced with more focused strategic options,⁴ the need for strategically managing tyre technology has become even more critical because of rapidly changing market forces and the potential for emerging technologies which could threaten core tyre technologies. This paper presents a framework for the SMT, as much for the purpose of creating new business opportunities, as for leveraging the technological capability of a company. Such a framework does not represent a blueprint for strategic management, but rather a way of ‘thinking strategically’ in analysing the

¹ A condensed version of this article was presented at the 130th meeting of the Rubber Division, American Chemical Society, in October 1986.

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which must be addressed in the strategic management of future tyre technology.

Context
Over the past 20 years, the generally accepted approach to technology management has been what can be termed 'tactical' in nature. This suggests that the management of tyre technology has focused on the traditional research and development (R & D) function within the company vis-à-vis the perspective of techno-business management of the total firm. As used here, techno-business management is the coordinated integration of technology planning and management with corporate business strategy and planning. This, then, is the essence of strategic technology management. It explicitly recognizes that all technological decisions, when made in a corporate context, are also business decisions. This being the case, a well-defined, coherent technology posture in which attendant issues are integrated with business strategy and planning is critical to effective decision-making. Thus, frameworks for strategically managing tyre technology will serve to facilitate techno-business management and can become a source of competitive advantage.

SMT frameworks, however, unlike those matrix portfolio approaches of the 1970s which emphasized strategic analysis and planning, must focus on strategic management: the difference being that the latter has as much emphasis on strategy implementation as it does on analysis, strategy development and planning. A second key characteristic which differentiates the SMT approach over traditional approaches to strategic planning is that in addition to leveraging existing technologies, it should serve as a basis for generating and assessing new technology-driven business opportunities. Finally, the SMT process should facilitate the successful exploitation of tyre technologies as a competitive weapon by addressing many aspects of structural and behavioural systems within an organization. These systems range from traditional R & D management functions, like projection selection, to organizational rewards and culture within technical areas.

Background
The traditional approach to managing R & D within the corporation has been 'product management'-oriented. Tyre R & D has tended to focus exclusively on product development and product improvement. Tyre technology has been viewed as an object which could be bought or sold. The problem with these kinds of perspectives, however, is that the essence of managing technology is developing and exploiting the total technological capabilities of the firm. Of course, treating technological capabilities as a product is difficult without experience and know-how. Further, companies within the tyre industry are finding that successful exploitation of technology as a competitive advantage involves a broad spectrum of technical issues ranging from technology assessment to technology cation and management, all of which must be in coordination and integrated with corporate business strategy and plans.

Global competition is forcing the tyre industry not only to develop more effective R & D strategies which go well beyond the centralize–decentralize issue, but to develop mechanisms for linking technology and business strategies.

Less than 10 years ago, the concept of technology management had little prominence, given the hoopla surrounding portfolio/matrix strategic planning models. However, the accelerated rate of change in technology, its global diffusion and management's growing concern (particularly in mature industries, such as the tyre industry, which are vulnerable to the threat posed by emerging technologies) over better linkages between technology and business strategies have forced managers to rethink R & D management. Today, managers must think of R & D in strategic terms. This means integrating technology strategy, planning and management with corporate strategy and planning.

Global business operations are forcing managers to find viable alternatives and solutions to the crucial business needs of centralizing for overall system effectiveness, while simultaneously decentralizing in order to permit maximum strategic flexibility in meeting geographic market demands. The strategic management of technology is one such alternative.

Technology Management
Corporate R & D Management
Traditional R & D strategy has been closely tied to the four major marketing strategies of first-to-market, follow-the-leader, late-to-market and segment focus. Because of this, strong commitment to applied engineering, development engineering and product/process engineering by most firms was the norm. Basic, exploratory and applied research essentially were left to university and government research centres, with some exceptions like AT & T's Bell Labs. In many mature industries, such as agricultural and off-the-road machinery and tyre and rubber, R & D activity concentrated on product design and development engineering. As a result, R & D strategy development was subordinated within systems for corporate business strategy development based principally on such factors as sales, marketing and finance. While useful for assessing the competitive environment and as inputs to strategy development, these systems do not adequately address or incorporate technological issues into the process of building a totally integrated business strategy. Examples of the results of failure to integrate technological and business goals, such as those in the consumer goods and video electronic industries, are plentiful.
Given the process of R & D strategy development, it is understandable why R & D management has long been based on the product life cycle and technology life cycle models. During the late 1960s and through the early 1980s, the application of these models in conjunction with the concepts of the experience curve, the strategic business unit (SBU) and portfolio planning directed R & D management toward a separate, supporting role. Technology was to be managed as a function of the attendant product or process it served. Product-process design integration (the process of developing new products and manufacturing processes simultaneously) and technology cross-fertilization (the process of leveraging technologies across SBUs) were beyond the domain of R & D.
management because of their lack of fit with corporate strategic planning. Further, these kinds of issues were not even considered in strategic business planning.

In the tyre industry, for example, the result has been a slow, evolutionary commercialization pattern for auto tyres from the bias ply design, through the bias/belted design, to the radial ply design, despite the fact that the radial tyre innovation was first introduced in 1948 while the bias/belted tyre followed by nearly 20 years. Technology has traditionally been managed as a function of either the product or the process it served. Empirical analysis of the tyre industry has provided indications of the existence of this kind of perspective.

**Corporate Technology Management**

'Old visions of what the industry is, how it works, who the participants are, and which strategic avenues are open, are becoming unglued.' Technology is driving productivity, profitability, decreasing new product life cycles and providing firms with new sources of competitive advantage. Traditional business strategies are being abandoned in the face of shifting global market shares, rapidly emerging technologies and intense global competition. Strategic planning has given way to strategic management, where implementation, evaluation and control as well as problem analysis, strategy development and policy formulation are all linked in the process.

The 'well-defined, coherent technology posture' concept mentioned previously implies that tyre R & D technology must be coordinated not only with engineering and manufacturing technologies, but also with a variety of other technologies, such as information, communications, marketing and human resources. Therefore, to leverage tyre technology, the planning and management of technological resources must be integrated with the overall corporate business strategy and plan. This techno-business management approach appropriately characterizes the strategic nature of technology management.

In viewing technology strategically, the few approaches suggested in the literature share common threads of continuity and a lack of empirical verification. Regarding the latter, this is always a problem when new approaches emerge: there is no basis for a priori testing of their validity. The common threads of continuity appear to be:

- **Assess critical technology areas, both within your firm and among your core competitors.**
- **Develop strategic technological options available to you and your core competitors.**
- **Analyze these options in light of the corporate and business goals and objectives for your firm.**
- **Do the same for your core competitors.**
- **Determine investment priorities for resource allocation among your portfolio of technologies.**
- **Align corporate resources to support techno-business management.**

Analysis of these factors indicates the primacy of technology strategy development in the strategic management process. The SMT process is, after all, a decision-making process where a choice is made among strategic technological alternatives which then forms the basis for the goals, objectives and means a firm uses in order to align itself in a cohesive and coordinated manner with its environment. This techno-business approach to strategy development can probably be explored in a number of different ways. This paper explores the use of matrix portfolio analytic frameworks in developing an integrated strategy.

**Matrix Portfolio Techniques**

Strategists frequently overcome the problems of deciding what information is worth considering in their analyses by using frameworks. Further, novel frameworks can stimulate interesting and unique ways of viewing the environment which could in turn lead to unique strategic initiatives. For these kinds of reasons, frameworks are useful tools in structuring complex decision situations. They have the additional attributes of being easily understood and communicable.

In the framework proposed in this paper, a key analytical tool employed is matrix portfolio analysis. This technique, pioneered by the Boston Consulting Group in the early 1970s, was the strategic planning rage of that decade. In the early 1980s, a second generation of planning matrices has been developed. Because of the flexibility of the technique and its ability to communicate visually complex thought processes, it is likely that this tool will remain popular in business settings. In contrast to previous generations of planning approaches, it represents 'an important improvement in management practice'.

**Strategic Management of Technology (SMT) Process**

**Background**

The traditional approach to strategic planning and management in general has been an 'ends—ways—means' model: establish corporate objectives (ends); develop a strategy (ways) for attaining these objectives; and marshal the resources (means) necessary to implement the strategy. The SMT model developed uses this approach, but also uses a 'means—ways—ends' approach simultaneously. This is because mature (and maturing) industries frequently possess core or base technological capabilities (means) with which they seek maximum near-term profitability; key technological capabilities
which are based on those technologies which are being developed to either reinforce, or more likely replace those core or base technologies; and emerging technological capabilities which represent potential capabilities which could revolutionize current industry technologies or lead to new products or industries. With a strategic analysis of such 'means' using the SMT process, firms could develop the strategies (ways) to exploit technological capabilities. These factors considered, realistic and viable objectives (ends) can finally be established. The 'means—ways—ends' model is particularly appropriate to the SMT process because of strategic considerations which must be given to both current and potential technologies and technological capabilities. Here, the difference is one of scope: technology considerations frequently and traditionally are based on business factors, e.g. capital investment requirements, efficiency improvements, production output, etc., while technological capabilities involve additional, more contemporary factors such as productivity improvements, quality of work life, human resources development and globalization issues in addition to the traditional business factors. It is a total organizational embodiment of those technologies which are the heart of the firm.

In the initial work years for many managers, production equipment and machinery were probably viewed with a great deal of respect. Many believed that the best equipment would naturally produce the best products. In much later years—and with more experience and insight—these same managers probably noticed that employee morale and motivation, education and training, teamwork and discipline, and the commitment of management at all levels often made a bigger difference than simply the industrial hardware. The SMT process recognizes and reflects this perspective because it views technology as 'hardware, software and mindware' embodied by the firm. Figure 3 shows a framework for the Strategic Management of Technology process.

Advantages and Limitations
The process is a dynamic, iterative one whose two key elements are (1) the development of a techno-business strategy through the use of matrix portfolio techniques, and (2) strategy integration through the use of technology forecasting and matrix portfolio techniques. Essentially, the first five elements (under 'strategy') plan and develop the techno-business strategy, while the remaining elements address the implementation issue. As with any theoretical model, there are potential advantages and limitations in application.

In general, corporate-level SMT has the following advantages:

- Permits firms to leverage current technologies and technological capabilities by producing a structured mechanism which explicitly integrates technology into business decisions.
- Assists in the development of a coherent and integrated techno-business policy which can become a competitive advantage.
- Allows managers to have greater insight and understanding of technological issues which have near- and long-term implications for the firm.

Figure 3. Strategic Management of Technology process
Some critics suggest that managing technology is not possible because of the following:

☆ Technology's rapid rate of change and its uncertainty in timing and direction cannot be accurately forecast or managed.

☆ Technology is incapable of being managed as an asset or allocatable resource, such as people or capital.

☆ Technology management is just another new buzz word which permits managers to believe that they can scientifically manage and control all R & D activities throughout the product and technology life cycles.

Despite these criticisms, the fact that technology is such a crucial element of a firm's potential competitive advantages is reason enough to consider approaches for strategically managing technology.

**Techno-business Situation Assessment**

The ultimate goal of this assessment is to develop an accurate picture of the competitive environment in which a firm operates. An explicit requirement, then, is the need for determining one's own internal situation, as well as those of core competitors. The literature is full of frameworks for assessing the internal–external business environment: growth/share, multi-factor portfolio, directional policy, Hofer, and Patel and Younger matrices. These frameworks essentially structure competitive business analysis. Unfortunately, the literature is not so rich in frameworks for techno-business assessment. Little has been written about approaches for integrating technology and business planning, much less techno-business assessment.26

In analysing, first, the technology input to techno-business assessment, and second, the business input, there appear to be five factors around which the assessment must focus:

**Cost.** What is the nature of your competitive costs in comparison to your core competitors? What are the key linkages between technology and costs? What investment cost considerations must be made?

**Criticality.** How critical is the technology associated with current products or processes? How critical is it to evolutionary and revolutionary new products or processes? What is the nature of timing with regard to market evolution?

**Compatibility.** How compatible are current technologies with business needs? With other core technologies? With key technologies? With emerging technologies?

**Continuity.** What is the nature of the continuity of the technology to the technology portfolio? How does it fit or how will it fit corporate culture and organizational systems?

**Constraints.** What constraints exist which can impact key or emerging technologies? What strategic fit exists with technological capabilities? With corporate policies? With business definition? With missions, goals and objectives?

These five factors can be analysed most efficiently through the use of a series of matrices linked by one thread of continuity. In this case, the link is the factor called 'competitive technology position'. The vertical axis can range along a continuum from, for example, weak competitive technology position to strong (Figure 4). The horizontal axes of this quadrangle are represented by (A) competitive business position; (B) market potential; (C) stage of technology life cycle; and (D) relative technology importance.

**Competitive technology position (CTP).** Technological forecasting, a process of using logical, reproducible methods to predict in quantifiable terms the direction, character, rate, implications and impacts of technical advance,27 is a particularly useful tool in selecting the criteria upon which technologies in this dimension are measured. It is of particular importance in the techno-business assessment quadrangle because (1) each CTP has inherent attendant basic strategies, and (2) each factor on the horizontal axis of the quadrangle changes. Each of the five factors upon which the assessment focuses assists in developing, both quantitatively and qualitatively, the criteria to be used in the matrix portfolios. As the factor on the horizontal changes, so too should the criteria for determining what constitutes CTP. Two examples are provided below.

Using the tyre industry as an example, two key market potential criteria could be market growth rate (e.g. for high performance rib tyres or high performance all season tyres) and profit potential (e.g. original equipment market vs replacement market or all season vs high performance). Here, CTP criteria should then be developed primarily in terms of manufacturing and marketing technologies through technology forecasting.

Specific techniques for development and analysis of market potential criteria include nominal group conferencing, impact wheel and Fisher–Pry substitution analysis, while techniques for development and analysis of CTP include cross-impact matrix, expert opinion, technical trend extrapolation, pearl curve and substitution analysis.28

When assessing the CTP–relative technology importance matrix, CTP criteria could be developed primarily in terms of tyre fibre/materials and engineering/design technologies. The projective category of techniques is most useful here, while relative technology importance factors can be developed through use of expert opinion and integrative techniques. In both examples, technology forecasting techniques will permit both
strategic and qualitative treatment of the factor dimensions.

**Competitive business position.** To illustrate the use of this model, the horizontal axis dimension of the competitive business position will be explored. As opposed to the traditional view that market share is the most accurate or appropriate measure of business position, the concept of market leadership is suggested. This is because a quantitative rating (1-4) can be given to a qualitative categorization (leader to not significant), both of which are conducive to use in qualitative and quantitative forecasting techniques. A hypothetical tyre firm can assess its product lines such as industrial, off-road, aircraft, truck and high performance radial as illustrated in Figure 5.

One viable approach to quantifying both the competitive technology and business positions is presented by Patrick McNamee, and is representative of generally used and accepted quantitative techniques. Qualitative techniques like those described by Vanston can supplement the analysis until product line positions, as identified in Figure 5, are established. Factors such as market share, quality, price, cost, efficiency, management and financial resources could be used in developing a quantified business position as a measure of market leadership. Criteria to be used in developing a quantified technology position could be based on factors such as depth of technological skills, patent protection, quality of manufacturing technology, access to raw materials, etc.

The approach described can be used for the remaining horizontal axis factors of the quadrangle (i.e. market potential, stage of technology life cycle and relative technology importance). The matrix portfolio approach, combined with the use of technology forecasting techniques, can be a very useful one, particularly for strategically thinking about, analysing and integrating technology into the business assessment at the front end of the process. A comprehensive assessment of the techno-business environment is key to the strategy development process. The process can be applied at the business unit level across product lines, or at the corporate level across SBUs. Use of this approach provides a multi-factor, multi-dimensional approach to techno-business assessment not only of one’s own organization, but also of major competitors.

As mentioned previously, strategically managing technology must address leveraging the current portfolio of technologies and technological capability, and also must address the issue of creating new business opportunities. The internal and external techno-business scanning and assessment accomplished as a result of the foregoing analysis or assessment will highlight not only the current situation, but serves to help identify strategic gaps which may exist. The use of technology forecasting in this regard is particularly important because it can quantify technological rates of change, timing and directions for key and emerging technologies which can ‘fill’ strategic gaps, when combined with mechanisms to foster innovation. For example, forecasting techniques which can help to identify strategic gaps include pearl curve analysis, exponential trend analysis and morphological analysis. Next, one structural mechanism to foster innovation could
be the implementation of Concept R & D units which would supplement traditional R & D. Here, Concept R & D teams composed of a variety of business skills and backgrounds have the responsibility for gathering, exploring and developing new concepts. This is a much broader issue than developing specific new products or processes, or solving specific technical problems. By defining concept needs, then working to address those needs in part by using technology forecasting techniques (e.g. normative and expert opinion categories), Concept R & D teams could generate new business opportunities. Thus, the integration of matrix portfolios, technology forecasting and Concept R & D can serve as a key source of ideas for creating new business opportunities.

Techno-business Strategy Development
Approaches to tyre R & D strategy development over the past two decades have essentially focused around the product life cycle and experience curve models. Because of this orientation, four basic types of R & D strategies have generally been thought to be appropriate at various stages of the product life cycle: offensive R & D, defensive R & D, licensing and acquisition. More contemporary approaches to R & D strategy have developed around a variety of concepts: technology life cycle; technology portfolio; distinctive technical competencies; strategic technical areas; and competitive advantage.

In developing the basis for techno-business strategy, several issues must be addressed regarding the desirability of technological change.

☆ Will change lead to a sustainable advantage based on lower cost or enhanced product differentiation?

☆ Will this change in cost or uniqueness positioning still favour the firm even if competitors adopt the technology?

☆ Will technology pioneers have first-mover advantages in cost or uniqueness even after the technological lead is gone?

☆ Will change improve the overall industry structure?

A firm's competitive position will not be improved if analysis of the foregoing issues is not positive. Analysis of these kinds of issues (assuming there are probably other critical issues which are industry-dependent) help to define the boundaries of techno-business policy. Such policy rightfully should and must integrate a variety of functional policies like R & D, manufacturing, marketing, finance, organizational systems, resource allocation and other corporate-wide or business unit operational policies.

At this point, the group of key managers and planners from the various functional disciplines, as well as strategic planners, must work toward summarizing the techno-business assessment and techno-business strategic issues and policies. This can be done by using matrix portfolio analytic techniques.

New portfolio matrix. The tyre industry, as viewed
through the Boston Consulting Group's new portfolio matrix, could be viewed as being in the stalemated quadrant (Figure 6), based on the previous discussion of the current industry situation. The SMT process can permit competitors to develop viable techno-business strategy options to reposition themselves.

Just as McDonald's repositioned themselves from the fragmented quadrant, through the specialization quadrant, to the volume quadrant, technology and the strategic management of it can permit firms to reposition themselves. General Motors, through technology acquisition of Hughes and EDS, has the potential for strategic repositioning, perhaps toward the specialization quadrant.

Technology can play a very big role in this particular industry assessment framework. It can significantly increase the relative size of the competitive advantage, and when viewed holistically, it can increase the number of ways firms within the industry can attempt to achieve competitive advantage. This being the case, the argument could be made that industries which fail to manage technology strategically will eventually fall back into the stalemated quadrant.

**General strategic thrusts.** From another perspective (Figure 7), the tyre industry can be analysed in order to identify strategic options. World-class competitors are realizing that all general strategic thrusts must focus around cost, quality and product uniqueness or differentiation. Again, technology and the SMT process can permit a greater variety of options.

Competitors must clearly identify how they intend to compete. Getting 'stuck in the middle' will mean less than optimal allocation and use of scarce productive resources.

**Consumer–Product Demand Analysis**

Firms can view themselves from a somewhat different perspective (Figure 8). Demand elasticity in this case can be interpreted in terms of availability, costs involved, materials required, value-added, etc., as opposed to price. Technological advances in fields unrelated to a firm's core technologies can impact upon a firm's products in ways unforeseen or unintended. Tyre products, for example, could be repositioned by using innovations to increase value as well as relative price elasticity to the consumer. Obviously, tyre products could not move into the top right quadrant, but they could be repositioned within their own quadrant, toward either increased price elasticity or increased price inelasticity, depending upon the particular techno-business strategies selected. As an example, a 'commodity' radial tyre would represent a move toward inelasticity, while a 'specialty' radial tyre would reflect a move toward increased elasticity.

The model can be viewed also in terms which will assist techno-business strategy development (Figure 9). As applied to tyre product lines, previously referenced techniques used in development of the techno-business assessment quad can be applied to the tyre product–demand matrix in arriving at, for example, four categories: commodity radial, bias tyre, specialty/high performance and all-season passenger tyres. These categories are illustrated through the use of product lines. By using the dimension of product lines, a tyre firm can more easily integrate product/process and technology/business strategy considerations in its analysis.

Figure 6. New portfolio matrix
Tyre firms with tyre lines in the low relative product value and inelastic demand quadrant could choose to focus their resources on manufacturing strategies and distribution. Firms who seek competitive advantages in the low relative product value and elastic demand quadrant could focus on design styling technology and pricing to differentiate their products. Similarly, competitors who seek to compete in tyre products with a high relative value should choose to focus technology resources on higher technology areas to match product line needs.

Following this approach, the techno-business strategy focus for competitors in quadrants 3 and 4 is likewise different. High value and elastic price
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Figure 9. Tyre product-demand matrix

demand products should focus on design engineering, materials reinforcements and polymer chemistry technologies (a marketing 'product' focus), while high product value, inelastic price demand product competitors should concentrate their technical activities on design styling and rubber compounding (with an attendant marketing 'promotion' focus) in order to achieve or sustain advantage.

The particular technology options for each quadrant will vary from company to company, depending on a number of factors, such as the company's history, its management philosophy, its mission, goals and objectives, particular strengths and competencies and many others. The central thesis, however, remains the same: find appropriate ways to integrate technology into the overall planning process.

In thinking strategically about technology, tyre firms can assess technology options also in terms of customer expectations. As customer demands with respect to product performance become more complex, the tyre product itself can be a more complex system requiring a high level of technological sophistication.

Techno-business strategy development can benefit from another integrative perspective (Figure 10).

A tyre manufacturer may decide that a materials and polymers technology focus is the proper approach if these technologies lie within the firm's strategic technological areas (STA) or distinctive technology competencies (DTC). Use of analysis and planning concepts such as STAs or DTCs are particularly well suited for the SMT process. Analysis of the techno-business environment is facilitated by the use of these concepts. They not only serve to crystallize strategic thinking, but also aid planners and managers in integrating technology into business strategy and planning. The point is that products, markets and technologies must be analysed simultaneously in the techno-business strategy development process in order to both leverage current technologies and capabilities and develop ideas for creating new business opportunities. Matrix portfolio techniques are useful tools for integrating technology and business issues. Further, by using technology forecasting techniques as a coupling mechanism among R & D, manufacturing, marketing and other areas, better coordinated and integrative strategy options for each quadrant (as illustrated in Figure 10) can be developed. By using other analysis and planning concepts such as STAs and DTCs, and a sequence of matrix frameworks, tyre firms can develop holistic estimates which will better define optimum strategic options.

*Techno-business Portfolio Development*

Technology portfolio analysis is a method to identify and systematically analyse corporate core, key and emerging technologies. This analysis can produce a profile of the corporate portfolio of technologies in terms of marketplace importance of the technology and competitive position. The analysis can also be done on major competitors to develop scenarios and analyses of potential options.
available to these major competitors (Figures 11 and 12).

Technology importance is the relative importance that a specific technology plays with respect to a product or process. Criteria to determine importance could include rate of change, value-added, potential impact on the market or industry, etc. Technology forecasting can aid in the criteria selection process and the quantification process. Relative technology position is essentially a measure of a firm’s investment in a given technology. Criteria to indicate relative position include patents issued; technological productivity; product cost history; or human resource capabilities. However, it is apparent that high investment by a firm in R & D will not necessarily mean that it will have a high relative technology position, particularly during the
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Offensive and Long Range R&D Investment

Withhold R&D Investment or Divest

Withhold R&D Investment or Divest

Selective R&D to Defend, Penetrate or Withdraw

Defensive R&D to Keep Market Position

R&D Investment to Penetrate Market, or Withdraw

Defensive R&D only if Needed

Strong

Relatively High

Low

Withhold R&D Investment or Divest

Relative Techno-Business Position

Source: Adapted from Frohman and Bitondo.34

Figure 12. Techno-business portfolio No. 2

The remainder of this century when technology continues to explode and the impact is being felt by firms and industries far removed from the initial development of the innovation. Current and future technology positions for not only one's own firm but also one's major competitors should be analysed so that alternative competitive scenarios are developed. Scenarios, a technology forecasting technique, serve as a valuable aid in thinking strategically. Planners and managers can use technology forecasting in selecting key criteria which will accurately reflect their firm's relative technology position.

Technologies which lie in the 'bet' quadrant place the firm in excellent position for increasing competitive advantage. The firm should commit to leading-edge technologies, innovation and high risk new product ventures in order to increase market share, open new markets, increase profitability, etc. One major tyre competitor may have viewed high performance tyre technology from this perspective when it chose to exit the original equipment tyre market in the early 1980s, in favour of focusing its product line on high performance tyre technology for the replacement tyre market.

Technologies in the 'draw' quadrant must either receive funding in order to attain leadership and/or competitiveness in the attractive and lucrative areas, or have funds withheld. In the 'cash-in' quadrant, a firm's technology position is strong, but in terms of competitive advantage, there is little to be gained by having a strong advantage. Hardnosed management of the technology with little more than investment maintenance could be the approach here. Finally, technologies in the 'fold' quadrant must be considered as sunk costs. Withholding investments or abandonment of the technology are alternatives.

Another way to view technology portfolio development from a techno-business perspective is by using a directional policy matrix (Figure 12). Use of previously described technology forecasting techniques can be used to identify and position technologies A–H in relative positions.

Such an analysis recognizes that the technology portfolio can vary along a number of dimensions, from offensive through divestiture. Depending on what the firm considers as its distinctive technological competencies or strategic technical areas, the portfolio can be strategically balanced with other portfolios, such as the age and financial balance of products. From a business unit perspective, Bitondo and Frohman, in their article on 'Linking Technological and Business Planning', provide innovative approaches in using directional policy matrices which can be applied to techno-business portfolio development.

Technologies A–H are in better perspective because they have been evaluated in an integrative sense with traditional forms of business portfolios. By such evaluation, technology planners can better communicate the nature of the techno-business relationship to other corporate business planners. This is a critical aspect for strategy integration.

Techno-business Strategy Integration

The reality of corporate development is, after all, one where technology strategy is often viewed as synonymous with R & D strategy. Thus, attempt-
The SMT process thus far developed has integrated the familiar business portfolio (Figure 13) with the techno-business portfolio (Figures 9-12).

The business portfolio provides a product-orientation, generally measuring a firm’s product lines in terms of market competitive position and attractiveness or importance. In this example, products A and B are positioned in key markets (whether measured in growth rate, profit potential or any other criteria). However, B’s competitive position is poor. In viewing the firm’s technology portfolio (Figure 14), product B’s competitive position can be improved. Current technology B1 is important, but the firm lacks this technological capability. The firm does, however, have strengths in key and emerging technologies (B2 and B3, respectively), which are options available to reposition B’s competitive business position. The importance and attractiveness of either technology B2 or B3 can be evaluated by the use of technology forecasting technologies.

Frohman suggests several useful checks to insure coordination and consistency between business and technological goals.46 Such checks serve as principally an aid to opening lines of communication between technical and business groups. In addition to these checks, firms can benefit from strategic technology forecasting (i.e. alternate scenarios, expert opinion, morphological analysis, nominal, group conferencing, etc.) techniques to strengthen and extend lines of communications, as well as permit a holistic strategic planning view as described.

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**Figure 13. Example business portfolio. Source: adapted from Petrov,33 p. 73**

![Business Portfolio Diagram](image1)

**Figure 14. Example technology portfolio**

![Technology Portfolio Diagram](image2)
by Sethi, Movesesian and Hickey, and Mason. The strategic use of technology forecasting, then, is not so much for quantifying rate, direction, timing, etc., of technological change as it is a means for linking the various business elements in the strategic planning process.

**Technology Investment Prioritizing**

The final step in the strategy development process is the setting of investment priorities. This step prioritizes all major technology sources of competitive advantage to be leveraged. As the last step, it ensures that technologies which are shared among a corporation’s SBU’s are not dealt with on a fragmented or individual business basis, but instead are understood and managed with an understanding of the strategic implications for the firm. This can be facilitated by matrix portfolio analysis. Using Figures 11, 13 and 14, we can develop a general approach to establishing priorities.

A diagram based on Figure 11 can be established to organize the portfolio approach to prioritizing investments (Fig. 15).

The investment matrix prioritizes strategic options developed from previous portfolio analyses and indicates whether funding should tend to increase, decrease or remain constant. In Figure 15, a hypothetical example is given where technologies B and E are candidates for retaining current funding levels. Technology D is a candidate for funding cut-back, while A and C should receive an infusion of capital to become competitive in a desirable market. For mature industries, the investment strategy of ‘betting’ supports empirical findings which suggest that ‘successful strategies come from purposeful moves toward a leadership position’. Such is the case for technology A. The optimum range criteria could be based on a risk vs return trade-off. The principles used in constructing this investment matrix could also be used with more complex frameworks, such as directional policy matrices. The normative technology forecasting technique of relevance tree analysis is a particularly useful tool in this process. Another portfolio approach to resource allocation is suggested by Kathryn R. Harrigan (Figure 16).

This approach underscores two central issues which strategists like Michael Porter attempt to address: one, the question of industry attractiveness over the long run, and two, competitive position within the industry. The resource allocation issue becomes even more critical to the tyre industry because of the low relative industry attractiveness level.

**Technology Implementation**

Breakthroughs cannot be managed ... yet the evolutionary periods and innovative applications require us to manage technology. Managing technology to turn breakthroughs into useful products is the problem. The difficulty is in managing the processes from concept to the production line and the market beyond, creating an environment to encourage innovation.

Contemporary strategic technology management thinking is increasingly focusing on the issue of implementation. A case can be made that traditional tyre R & D management within the industry has not been directed toward the issue of implement-
tation because R & D strategy has been driven by issues like centralize vs decentralize; buy vs lease; sell vs license; or develop internally vs acquire. R & D management has tended to focus on the technology, vis-à-vis technological capability issue.

In the SMT process, the focus is on technological capability. A techno-business strategic perspective can be implemented at the corporate business level by addressing five strategic planning and management areas (Figure 17) in a coordinated and integrative fashion.

Technology integration and implementation via traditional techniques like acquisition, leasing, licensing and internal development are still important options. However, they must be evaluated from a much broader techno-business perspective, as shown in Figure 17. Selection of example implementation strategies illustrated in Figure 18 must be based on a holistic techno-business planning framework which cuts a wide swath across all business units. Other implementation strategies, such as those proposed by Maidique and Patch, could likewise be considered in light of Figures 17 and 18.

Strategy options as shown in Figure 18 essentially represent an overall or grand strategy, within which previously developed specific technology functional or operational strategies should fit.

Issues management. There are a variety of opinions concerning the definition of issues management. Some are as simple as 'the process of environmental scanning'. Others are more definitive: 'the organizational process of “identifying, monitoring, and analyzing forces and trends which affect the organization, interpreting, implications/options and setting a plan into action”'. Issues management provides an analysis of the implications of social, economic, political, etc., developments in the organization’s external environment on potential performance of the organization. The issues management function is an important aid for permitting strategic thinking about the future of the organization.

Technology assessment. As described previously, this area deals with scanning and analysing the internal and external technological operating environments of the firm. The goal is to develop an accurate estimate of the situation regarding technological capabilities of not only one’s organization, but also those of major competitors. Technology forecasting, competitor intelligence, patent analysis and scenarios are useful tools in this effort. Such an assessment should be at a corporate, strategic level. That is to say, it should focus on more than just industrial technology or hardware. It should be broad and encompassing so that hardware, software and mindware are assessed equally in importance.
Figure 17. Strategic planning and management areas

Figure 18. Example technology implementation strategies. Source: adapted from Nemec, *Outlook*, 5, p. 28 (1981)

Technology management. The activities of R & D and engineering centres, as well as manufacturing or process technologies, are coordinated and facilitated through this functional area. The goal is to aid in smooth and effective intra- and inter-unit exchange of technology. It should, therefore, address a wide variety of subjects: communications, information systems, clearing house mechanisms, technology transfer, innovation, market research, research activities, development activities, equipment engineering and many others.

New ventures. Not only are traditional mergers and acquisitions studied and evaluated in this area, but so too are technology venture activities whether by licensing, leasing, purchasing or any other approach. Close coordination must exist with the other functional areas described so that critical,
timely and accurate information can be exchanged. Long-range product planning, Concept R & D and future technology infrastructure are some issues and areas which should be addressed.

**Business development.** With so much emphasis having been placed on the future, there must be an area that focuses principally on nearer-term activities. Business development serves not only to coordinate the activities of the current organization, but also to prepare the organization for revolutionary or evolutionary advancement into the future. Therefore, it should also address a wide range of activities: new product planning and development, new applications of existing core technologies to new products and processes, organization development, market planning, technology transfer, personnel training, etc.

It should be apparent that the activities addressed in the five interfunctional areas briefly described are overlapping. Global competition is forcing firms to view themselves as a system of interrelated parts. Technology is increasingly becoming a more influential part. Hence, the need to manage it strategically. Technology implementation facilitates the SMT process by linking techno-business assessment, strategy development, portfolio development, strategy integration and investment priorities.

Most future decisions which top managers will face are likely to have two common characteristics: an underlying technology issue and a systems implication issue. This means that corporations will have to make decisions for the good of the entire organization because it is a system tied together through a variety of technologies. Companies, however, will still have to give geographic division managers a certain amount of autonomy in order to permit them to achieve optimum performance within local markets. Thus, there will be the simultaneous need for ‘centralizing while decentralizing’ for all global companies. The structure suggested in Figure 17, when implemented at the corporate level, will aid the company in viewing itself as a system of interrelated parts. Such a globalized matrix strategic planning and management structure will serve the ‘centralizing’ need of the company. It will essentially function as a clearing house for strategic activities in facilitating information and technology flows, communications, coordinating activities, etc., between and among all business units and the central headquarters. This will permit top decision-makers the ability to make better systems decisions for global companies. It will also permit top geographic business unit managers to see the same ‘big picture’ which top corporate managers see. Thus, local business unit managers will better understand how their local decisions may impact upon the total system by having more and better information.

**Technology Resource Management**

Through the framework described in Figure 17, the critical functions which strategic management must integrate across the entire organization in implementing strategy have been identified. The technology resource management (TRM) function is similar to the implementation process discussed, with a refinement in scale and scope. The Technology Resource Management function is perhaps the most complex issue in the SMT process because the issues list of ‘how do we’—or ‘how should we’—type concerns that implementors face is extensive. The key areas which should be addressed and coordinated in this process focus around structural issues, such as market planning and manufacturing management; policy issues, such as technology transfer, innovation and human resource development; and behavioural issues, such as organizational effectiveness and quality of work life (Figure 19).

In terms of scale, the TRM function addresses divisional or business unit levels and below, whereas technology implementation responsibilities lie at the corporate level. At the lower operating level, TRM focuses on implementation actions. TRM will cover a broad variety of functions such as organizational effectiveness and dynamics, human resources development, market planning and administration, manufacturing management, traditional R & D management, productivity and quality of work life, creativity and innovation, and many others. TRM, however, address these functions in an operational sense, in terms of execution. This is in contrast to the implementation function which addresses many of the same issues, but in a coordinating, integrative sense. Here, then, is the transition to the refinement in scope.

The scope of the TRM function is reduced as compared to the implementation function. For example, the issues management function need not be as broad in perspective. Indeed, the division manager may rely on the corporate level for this input. Similarly, the technology assessment function should be more directed and focused on technology-business needs of the division. This suggests that technologies which could ‘blind-side’ a firm are evaluated at the corporate level, while key and selected emerging technologies are managed at the division level. TRM is part of the planning process which transforms information flows among R & D, manufacturing and marketing activities into a balanced operation of product and process technologies, so that the overall techno-business strategy can be effectively implemented.

**Summary and Conclusions**

Technology issues will underlie almost every major business decision that firms in the tyre industry will make during the remainder of this decade and well
into the 1990s. In making these decisions, managers will have to approach technology management strategically and analytically. The methodology presented in this paper outlines the conceptual process for planning the strategic management of technology using the technique of matrix portfolio analysis. A key tool in the use of this process is technology forecasting. The primary focus of the SMT process is the development of an appropriate, integrated techno-business strategy in order to achieve or sustain competitive advantage. The payoff comes as much in the identification and development of new business opportunities attributable to an integrated analysis of the techno-business situation, as in the leveraging of existing technologies within the corporation in order to strengthen or improve technological capability. Only through the integration of technology and business issues in developing strategy and a sharing of responsibilities in implementation will firms be able to succeed in globally competitive markets.

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(48) Petrov, The advent of the technology portfolio, p. 72.
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(52) Four broad strategies commonly found in high technology industries are: (a) leader strategy, where there is a strong commitment to applied R & D; (b) fast follower strategy, which requires a strong development and engineering capability; (c) cost minimizer strategy, which requires product and process engineering skills; and (d) specialist strategy, which requires a strong applied engineering and flexible manufacturing capability. Such strategies listed here or shown in Figure 18 are not mutually exclusive or collectively exhaustive, nor are they complete definitions. A wide spectrum of other strategies is possible. See Readings in the Management of Innovation, pp. 276-277, for more detailed discussion.

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