Chapter 7 - Multi-Technology Management

– the Economics and Management of Technology Diversification[*]

Ove Granstrand

Center for Intellectual Property Studies, Dept. of Industrial Management and Economics,

Chalmers University of Technology, SE-412 96 Göteborg, Sweden

List of contents

---

[*] Parts of the material in this chapter are also published in Cantwell et al. (2003).

List of Abbreviations

CEO	Corporate (or chief) executive officer
CTO	Corporate (or chief) technology officer
IPR	Intellectual property right
ITT	International Telephone & Telegraph (company)
M&A	Merger and acquisition
MNC	Multinational company
MPC	Multi-product company
MTC	Multi-technology company
NIH	Not-invented-here
P/L	Profit and loss
R&D	Research and development
S&T	Science and technology

Abstract

Recent research in large corporations in the world has shown that technology diversification has important economic and managerial implications with a major potential for growth. While there are many contributions in the literature on business or product diversification of firms, only very recently have there been some attempts to understand the patterns of technology diversification and their implications on various strategic dimensions of corporate development, such as internationalisation, business diversification, strategic alliances, external technology acquisition, organizational structure and economic performance. This chapter provides an account of some of the recent research with analysis of data and case studies of the phenomenon of diversification into multi-product/multi-technology firms and its theoretical underpinnings in terms of economies of scale, scope, speed and space. The chapter also addresses the managerial capabilities needed to develop a multi-technology management approach for reaping the dynamic economies of diversification arising from converging technologies. This type of economies at the same time challenges the conventional wisdom of the economies of specialization, emphasizing focus on core business and core technologies, “back to basics”, “stick to your knitting” etc.

Key words: Diversification, multi-technology, R&D, innovation, corporate strategy, corporate innovation system, technology convergence, technology assembly.

1 Introduction

1.1 How proper is the diversification fashion?

Fashions and fads plague management thinking, and to some lesser extent – hopefully – management practice. It is in fact a significant challenge to members of corporate boards and top management to avoid being overly fascinated by fashions and fads. These may very well build on some sound ideas but are then typically oversold by a host of preachers among fame-driven scholars, money-driven consultants and stock-traders, and novelty-driven managers (often at higher level!) and media, all jockeying for advantages. Diversification, and its converse specialization, is one particular example of a strategic issue being heavily subjected to fashionable thinking. An average corporation's list of product offerings has been lengthened and shortened like a woman's skirt over the years, at least in the Western industrialized world. In the 1960s and 70s, US-style conglomerate diversification came into vogue, based on ideas of attaining attractive growth and risk dispersion through applying various management skills across a portfolio of businesses, acquired or home-grown, related or unrelated, financed externally or internally via a corporate capital market. For this strategy, it was perfectly proper to use the by now fairly well-known divisionalized organization structure, pioneered by General Motors and Du Pont already in the 1920s, as well as recent advantages in management accounting. As it gradually became clear that the promises held out were not materializing and conglomerate profits soured under over-taxed management, "survival of the fattest" became an issue and the fashion pendulum started to swing to the other extreme. In the 1980s and 90s, specialization became fashionable (in the West), dressed in words like "back to basics", "stick to the knitting", "focus on core business", "be lean and mean", "slim the organization", downsizing, outsourcing, demerging etc. Stock prices came increasingly to reinforce this management fashion (and discounting conglomerates) as the financial markets and ownership concerns developed and occupied an increasingly large share of minds of corporate boards and top management.

However, as is well known, stock prices at times do not reflect the real economy very well, so how have the conglomerates and the specialized companies fared economically over the years? In other words, what has been the relation between degree of diversification (or specialization) and economic performance over the years? As a rule, the US-inspired type of conglomerates of the 1960s and 70s did not perform very well (ITT, Philips, Siemens etc.), with General Electric as a still (as of 2002) outstanding exception confirming the rule. On the other hand, many Japanese companies diversified successfully in the 1980s (Canon, Hitachi, Toshiba etc.).

Specialization in the 1980s and 90s improved economic performance in many cases of Western companies, which under influence by fashionable management thinking had become overdiversified in one way or another (too many unrelated products and/or markets). In other cases, specialization or too little diversification jeopardized the company's long-run economic performance, making it too vulnerable to downturns in business cycles or special markets or patent positions, possibly leading to an M&A restructuring (as for Astra-Zeneca in pharmaceuticals). Also many Japanese companies had become overdiversified, mostly as a result of previous diversification successes, and were pressured to dediversify in the Japanese economic crisis of the 1990s (Gemba and Kodama 2001).

Thus, business histories offer many lessons but do not show a clear, overall picture. In fact, economic research has not found any significant connection between diversification (or specialization) and economic performance in terms of profitability (see especially Montgomery 1994 and Ravenscraft and Scherer 1987).

However, diversification is a mixed bag of various strategies, including conglomerate diversification into more or less unrelated businesses as well as diversification into businesses that are highly related product- or market-wise in terms of shared resources or other synergies. Moreover, the benefits (economies) associated with shared resources and synergies do not end up automatically on the P/L account but have to be reaped through active management. But what kind of guidelines are there for company boards and management to judge what is the proper type and amount of diversification?

1.2 Purpose and outline

The purpose of this chapter is to answer this question by penetrating a particular type of diversification related to technology and presenting some guidelines for how to manage this type of diversification successfully. In so doing we need to distinguish between product diversification, commonly understood as extending the range of products (outputs) of a company, and technology diversification, i.e. extending the range of technologies (inputs) a company uses together with other resources for its output products. As will be seen below, recent research has shown that technology diversification has a strong, positive impact on growth of sales, but likely also on growth of expenditures on R&D and technology acquisition, in turn giving management an incentive to utilize the company's technologies for diversifying into new product businesses, i.e. to undertake a technology-related product diversification. The chapter will first briefly illustrate the processes of product diversification as well as technology diversification, then present and explain some results from studies of company diversification strategies and their economic performance. Finally, the chapter will focus on a number of management skills or capabilities needed to successfully manage technology-related diversification processes.

1.3 Literature

A quick account of literature on diversification in general, mostly then focusing on product and market diversification, mostly in a US context, would include classic studies of large corporations such as Ansoff (1957), Penrose (1959), Gort (1962), Chandler (1962, 1990) and Rumelt (1974).

More recent studies, still in a US context, are Ravenscraft and Scherer (1987), Scott (1993) and Markides (1995). Literature surveys are given by Ramanujam and Varadarajan (1989), Montgomery (1994) and also in management handbooks such as Hitt et al. (2001). Essentially, the literature so far gives a mixed verdict regarding the virtues of product diversification in terms of economic performance, apart from pointing out the average underperformance of unrelated conglomerate diversification.

Literature on technology diversification is of more recent origin and in fact has more of a non-US orientation. Kodama (1986) studied technology diversification at industry level in Japan, Pavitt et al. (1989) at company level in the UK, Granstrand (1982) and Granstrand and Sjölander (1990) at company level in Sweden, followed up by Oskarsson (1993), Patel and Pavitt (1994) and Granstrand et al. (1992, 1994, 1997) for samples of large corporations in Europe, Japan and the US. Essentially, this literature has pointed out the prevalence and nature of technology diversification and its association with economic growth and diversification in general. The literature on this topic has thus grown considerably and is surveyed and elaborated in Cantwell et al. (2003).

2 *Empirical findings*

2.1 *Cases of corporate and technology diversification*

Diversification occurs at various levels in industry. A number of not very well defined levels can be discerned, e.g. levels corresponding to different sector levels (e.g. manufacturing, vehicles, cars), product area (e.g. passenger car), product line (e.g. station wagon) and product variant or model (e.g. blue, 2003, turbo).[1] At corporate level, Figure 1 illustrates some types of diversification in the evolution of a particular firm. The company Alfa-Laval has a long, diversified history of which Figure 1 can give only a very incomplete picture. For example, the

[1] The resulting diversity of firms and products is actually bewildering; see e.g. Petroski (1994) and Sanderson and Uzumeri (1997) for good illustrations at product, line and variant level. In a large MNC with general-purpose products such as bearings or separators, having a variety of user situations in various industries and countries, thousands and thousands of product variants occur in perhaps hundreds of product and component areas.

company was acquired by the packaging group Tetra Pak in 1991 (for 16 BSEK, media said), then divested in 1998, although without its liquid food processing business area, which had become integrated into Tetra Pak after the acquisition, while other areas had not. The technologies, originating around centrifugal separation of milk, involving mechanical engineering related to metal forming, material science and precision engineering, then evolved (diversified) over the years, revolving largely around processing of mostly liquid (rather than air or material) flows, i.e. flow processing, for which a portfolio of fairly general-purpose products was developed (separators, heat exchangers, pumps, valves etc.).

Market pull development of new technologies and then technology leveraging (technology push) into new applications, often involving initiatives and ideas from users, then leading into new but related product areas, has been a general driving force. Most of the successful product diversifications have been technology-related in this way rather than market-related. (Cases of the latter have occurred when customers have asked to be supplied with other complementary products in their flow process. In order to ensure sufficient economies of scale and scope, diversification policies have been implemented saying that at least X% of the value of an order should relate to core products as defined in technology terms.) However, diversifications have often had many relations and it is difficult to classify them as being related only in a single dimension. The diversification tree in Figure 1 is rather a complex diversification network. The four main types of diversification that can be discerned are the two traditionally recognized ones – product diversification into different product areas (P-div), leading to a multi-product company (MPC), and market diversification (M-div), including internationalization as a special case, leading to a multinational company (MNC) – and then two newly recognized ones: technology diversification (T-div), leading to a multi-technology company (MTC), and application diversification (A-div), leading to a range of applications for technologies within a product area. More types could of course be identified and labeled, e.g. business diversification (including services as well as products) and resource diversification (including knowledge in general and technology in particular).

<< INSERT FIG. 1 >>

Application diversification is not generally recognized in the literature as a diversification type, but is generally recognized as an important phenomenon. Business histories provide ample cases of companies with new technologies and products finding and developing a range of applications over time, often in unexpected ways with unexpected successes, sometimes even overshadowing the original application. Examples are mobile phones migrating from car phones to pocket phones – or an old drug finding new medical indications as with betablockers, originally developed and used for heart rhythm disorders, then migrating also into treatment of hypertension.

Interaction between these types of diversification processes over time provides a significant impetus to the dynamics in corporate evolution. For example, new technologies are developed or acquired (T-div) for a new product (P-div) in a specific application, as a kind of market-pull process. Then technologies thus acquired can be adapted to new applications (A-div) and/or further developed for new products (P-div), possibly requiring still more new technologies (T-div). At the same time new markets (in terms of new market segments and market regions rather than applications) are entered (M-div), bringing the company into contact with new customer groups with new requirements and ideas, leading to new products, technologies and applications and so forth. However, in cases of resource constraints, different types of diversification may become adversary when competing for the same resources. For example, it has proven to be very risky to perform product diversification concurrently with market diversification (internationalization in particular), critical resources then being managerial competence and attention.

In a study of diversification processes in eight large, European MNCs[2] (Granstrand 1982) it was found that:

1. Raw-material-based companies were historically early product diversifiers, incentivized thereto mainly by physical by-products in raw material processing, while late internationalizers. Product-innovation-based companies were early and fast internationalizers while being product-specialized, with product diversification growing (sometimes accidental rather than strategic, often with external impulses) in the postwar boom of the 1950s and 1960s, mainly through acquisitions, producing some failures (due to lack of competence, management and market demand), leading to dediversification on average in the 1970s.The two world wars had on average spurred both growth and diversification (e.g. through import substitution).

2. The continuity and path-dependence were high in the evolution of the companies, and more so at higher levels of diversification (sector, product area) where corresponding product life cycles are then longer. Shifts in core business or dominant business had occurred, but all companies (with century-long histories on average) had stayed in their original sector and most of them in their original product area. Diversification had thus been rooted in most cases, and in general related in some way to existing resources and technologies, spurred by combinatorial opportunities in generic technologies and generic products (as with materials, chemicals, and universal machine elements such as electric motors, lamps, bearings and separators), spurred also by systems orientation in industrial marketing – hampered, however, by top management's unwillingness to integrate forward and thereby start competing with powerful industrial customers. For companies with generic (general-purpose) products, typically universal machine elements, the degree of diversification into various product areas was low while product differentiation within a product area was high, sometimes clearly uneconomically high (as when SKF's different foreign subsidiaries had developed extensive ranges of bearing variants to serve

---

[2] The companies were Alfa-Laval (engineering), Astra (pharmaceuticals), Boliden (mining), Iggesund (pulp and paper), KemaNobel (chemicals), Philips (electronics), SKF (engineering) and Volvo (engineering).

all types of their domestic customers). Leading, invention-based engineering companies such as Alfa-Laval, Philips and SKF thus ran the risk of overspecializing in a product area and overdiversifying within that area.

3. Product diversification strategies had been mixed, changing and controversial, while internationalization strategies had been steadily embraced by top management.

4. Diversification through acquisitions was a preferred mode, except in R&D-intensive companies. Using R&D for product diversification had indeed occurred before the Second World War but gained momentum in the postwar era, during which corporate R&D also grew, internationalized and diversified. In general there was a close, although lagged, connection between growth, diversification and internationalization at company and R&D level – i.e. R&D grew, diversified (technologically) and internationalized eventually as the company did in terms of sales in various product areas and foreign markets.

5. Additions to, as well as shifts in, the dominant core technology of almost all corporations were found, e.g. generation shifts from carbide engineers to polymer technologists at KemaNobel (later merging into Akzo-Nobel); a series of generation shifts in electrical engineering from vacuum tubes to transistors to integrated circuits to microcomputers at Philips; chemistry, biology, electronics and systems engineering being integrated in mechanical engineering at Alfa-Laval; material scientists being promoted at SKF; metallurgists and chemists being added to the 'the mining people' at Boliden; biologists and mechanical engineers being promoted at Iggesund (pulp and paper); a transition from chemistry to biology taking place at Astra; and mechanical engineers being supplemented by various other types of engineers (electrical, chemical, engineering physics etc.) at Volvo. These changes in the portfolio of technological competencies depended on external technological developments and internal conditions, such as the rise of advocates or resistance among management and technologists. Both companies and products thereby became technologically diversified, although not necessarily technologically advanced, i.e. companies and products became multi-technological ("mul-tech") rather than "hi-tech ". In connection with technology diversification

the need for new technologies grew, leading to growth of both in-house R&D and external technology acquisition through various means, in turn making in-house R&D a means also for accessing and absorbing external R&D.

6. Four different types of technology diversification were discerned. First, there was a diversification of competencies pertaining to the core technologies of a corporation, for instance, the differentiation of polymer technology or tribology. This was a kind of 'ordinary' specialization within a technology of decisive importance to the corporation. Second, there was a diversification pertaining to adjacent technologies. These adjacent technologies could concern supporting technologies such as automation technology in production, surface chemistry for lubrication in a part of a product, or materials technology. Corporate R&D often diversified into adjacent technologies through an initial stage of perception of product problems followed by attempts to solve them by extending internal knowledge, often amateurishly, or acquiring external R&D services. Third, there was substitution among different technologies, such as the transition from chemistry to biology in pharmaceutical research. Fourth, a new technology was "picked up" for exploration because of its potential benefit to the corporation, e.g. because it could create entirely new businesses (e.g., KemaNobel acquired polymer technology and Astra went into antibiotics). Often these new technologies were science-related, emerging, and possibly generic, technologies, for which the implementation in products and/or processes was not yet clear. Entry into these could proceed through internal exploratory work (e.g. Ericsson experimenting with computers in the 1950s and 60s) and/or external acquisition of personnel, licenses, projects or companies. Of these four types – (1) differentiation of and specialization within a core technology, (2) expansion into adjacent technologies, (3) substitution of technologies and (4) involvement in new and so far unrelated technologies – the first three are product-related, while the fourth is not (for the time being, at least). Thus, most but not all types of technology diversification could be said to be related to products (and their production processes) already existing in the companies.

7. The diversification into a new technology for new kinds of businesses was quite often evolutionary, with a progression over adjacent or substituting technologies. For example, the

need to preserve milk led Alfa-Laval into heating and cooling, in turn leading to heat exchangers, microwaves, the preservation of other types of food, and finally to a new packaging technology. Alfa-Laval then decided not to go into packaging (see Figure 1). The concept of evolutionary chains is too simplified, though; rather, technologies advance along some lines, may rest until combined with some other technologies, and may then advance a bit further.

Finally, any typology of diversification of technology and R&D is vague, since conceptions of a technology are diffuse and changing. Confluences and combinations occur. Strictly speaking, technology diversification should be considered to decrease if a combination of two technologies gains coherence and recognition. For example, many corporations started to encounter different environmental problems in the 1970s and developed countermeasures in the form of corrective technologies. New competences had to be acquired, and perceptions of which technologies were adjacent and relevant changed rapidly. Thus the kind of technology diversification triggered by environmentalism is hard to classify. It may not even be considered a diversification at all after environmental technology became recognized as a specific technology. Thus, when assessing type and degree of diversification, changes in the underlying typology create classification and measurement problems.

2.2 Survey of diversification strategies for growth

Oskarsson (1993) explored whether there were certain corporate diversification sequences that were associated with high sales growth. Observations of 57 large multinationals worldwide were classified according to sequences of diversification and specialization of technologies, products and markets. Four main patterns of strategic behavior were identified:

A Fourteen companies[3] followed a diversification sequence of, first, increased technology diversification (T-div), followed by product diversification (P-div) and market

[3] 3M, Astra, ABB, Canon, Digital Equipment, Honda, Kyocera, Matsushita, Motorola, Nec, Sandoz, Sony, Toshiba, and Toyota.

diversification (M-div) in this or reverse order. These companies were called “aggressive diversifiers”.

B. Nineteen companies[4] followed a sequence of, first, increased technology diversification, then either product specialization or market diversification, or its reverse with market diversification followed by product specialization. These companies were called “stick to the knitting” companies.

C. Five companies[5] followed a strategy sequence of increased technology diversification followed by product diversification concurrent with market specialization. These companies were called “market specializers”.

D. Eight companies[6] specialized both product-wise and market-wise and sometimes even technology-wise. These were called “defenders”.

Eleven companies had selected four other strategic sequences, all of them either growing slowly or declining. They underwent neither rapid increase nor decrease in diversification.

The “aggressive diversifiers” had significantly higher sales growth (in 1980-1990) and expanded their technology base, product base and market base significantly more.

Canon was the company with the fastest growth of all the 57 companies between 1980 and 1990. Canon also followed an “aggressive diversifier” strategy; see Figure 2. The Canon case also illustrates three different types of diversification: first concurrent (and indeed risky as it was) diversification (into copiers); second, technology-related business (product, market) diversification into laser beam printers, exploiting the competence in electro-photography; and third, business-related technology diversification into bubble jet printers, exploiting the competence and position in the printer industry.

---

[4] BASF, Bayer, Electrolux, ESAB, DuPont, Ford, Glaxo, General Motors, Hitachi, IBM, KODAK, Thone Poulenc, Pharmacia, L'oréal, Nobel, Ericsson, Unilever, Volvo and Xerox.

[5] Sumitomo, Sanyo, Merck, Nippon Steel and Siemens.

[6] General Electric, Aerospatiale, ICI, FAG, Thomson CSF, Olivetti, Texas Instruments and Philips.

<< INSERT FIG. 2 >>

A qualitative model of diversification in general is given in Figure 3. Oskarsson (1993) tested a simplified and modified (due to lack of data on feedbacks) version of this model for 1980-1990 with results shown in Figure 4.

<< INSERT FIG. 3 >>

<< INSERT FIG. 4 >>

Technology diversification at firm level was thus an increasing and prevailing phenomenon in all three major industrialized regions, Europe, Japan and US. This finding has also been corroborated by Patel and Pavitt (1994).

Moreover, technology diversification was a fundamental causal variable behind corporate growth. This was also true when controlled for product diversification and acquisitions.[7] Technology diversification was also leading to growth of R&D expenditures, in turn leading to both increased demand for and increased supply of technology for external sourcing.

These findings were not readily explainable in terms of received theories of the firm. Without going into detail about the pros and cons in using received theories to describe, explain and predict the behavior of technology-based firms, taking idiosyncrasies of technology as a special type of knowledge into account, one can note that technology diversification does not feature at all in received theories. Moreover, most theories do not explicate the dynamics and

[7] This finding has later been confirmed also by Gambardella and Torrisi (1997) for 32 of the largest European and US electronics firms.

heterogeneity of technology, and many restrict their focus to process technology. (For an elaboration on these theoretical issues, see Granstrand 1998.)

3 Economics of diversification dynamics

Technology diversification as an empirical phenomenon with its causes and consequences has only recently gained attention among researchers[8] The key role apparently played by this variable in corporate evolution, as described above, is a new finding for which any explanation at this stage must be tentative. Tentative modeling, as presented above, emphasizes progress in S&T together with differentiation of both S&T fields and market needs. In fact, it may be argued that technological opportunities are generated in a fundamentally important and inexhaustible way through the combination and recombination of various technologies, new as well as old. Such a process of combinations and recombinations could be considered to lie at the heart of the invention and innovation processes, in which technologists, managers, and markets filter out technically and economically infeasible combinations.

In the process of taking advantage of technological opportunities, technology diversification at the corporate level may lead to four different but complementary types of economies of diversification: economies of scale, scope, speed and space (the four S's behind diversification). First, there are static as well as dynamic economies of scale. Static economies of scale accrue to the extent that the same, or close to the same, technologies can be used in several different products with minor adaptation costs. Since exploiting knowledge in various applications is typically characterized by small and decreasing marginal cost for each additional application, while the fixed cost of acquiring the knowledge is substantial, static economies of

[8] Incidentally no reference is made to technology diversification in the surveys of diversification literature by Ramanujam and Varadarajan (1989) and Montgomery (1994), nor in general surveys of strategy literature, e.g. Hitt et al. (2001).

scale are significant when a technology has a wide applicability to many different product areas in a corporation (which is the case for generic technologies by definition). Moreover, as is well known, knowledge is not consumed or worn out when applied. On the contrary, knowledge is typically improved through learning processes when applied several times, which also allows for dynamic economies of scale in technology-related product diversification or technology-related application diversification.

Second, different technologies have a potential to cross-fertilize other technologies, yielding new inventions, new functionalities and increased product and/or process performances when combined. This cross-fertilization yields economies of scope, but not primarily the kind of cost-related economies of scope in production that arise from shared inputs, and thus are special cases of economies of scale. This second type of economies of scope of technology diversification depends on the specific technologies which can be combined or integrated. Such economies of scope also vary over time, depending upon the different intra-technology advancements over time. Third, combining technologies usually requires some technology transfer, and (under certain conditions) intra-firm technology transfer is faster and more effective than inter-firm, giving rise to early mover advantages in a multi-technology corporation (MTC). These advantages, related to speed and timing, can be labeled economies of speed. Fourth, many regions in the world are multi-technological, i.e. they are technologically diversified, e.g. the Silicon Valley area or the Tokyo area – regions that also mostly have diversified eminent universities. These regions generate a stream of technological and business opportunities, which are localized and poorly codified, at least initially. An MTC is then better positioned to take advantage of these opportunities through building close external linkages in different areas. These economies, related to location, agglomeration and geographical coverage in general, can be labeled economies of space.

According to the empirical findings above, technology diversification leads not only to sales growth but also, however, to growth of R&D expenditures. Tentatively, the reason is that a larger number of technologies is involved, which means that a larger amount of coordination and integration work is needed, apart from the cost of acquiring each new technology, as difficulties arise in connection with conducting multidisciplinary R&D. These difficulties are widely reported and typically involve conflicts between professional subcultures in science and technology, NIH-effects and other innovation barriers (see below and, for more detailed accounts, Granstrand 1982). Thus, in order to reap net benefits from technology diversification leading to growth of both sales and R&D expenditures, the integrative skills of both technologists and managers become decisive.

There are two contrary but complementary types of diversification having a strong economic potential – diversification into new technologies, mostly related to existing products, and diversification into new technology-related products. The first type, P-related T-diversification, corresponds to a shift in the technology base or portfolio of the company, while the latter, T-related P-diversification, corresponds to a shift in the product (business) portfolio. These two shifts could in principle take place independent of each other, still being economical; but when they combine over time as shown in Figure 5, economic benefits can be strongly enhanced. In fact, it could be argued that a crucial dynamic factor in corporate evolution is the interdependence or interaction over time between *business-related resource diversification* and *resource-related business diversification.*

<< INSERT FIG. 5 >>

The economies of scale, scope, speed and space associated with resource-related product diversification change over time and must be continually assessed and monitored, also relative to other companies. For example, diversification into a new product P_2 (e.g. light trucks) might initially share a lot of resources, including technologies, with an existing product P_1 (e.g. passenger cars), but over time the resource sharing may very well decrease as the new product gradually needs more specialized resources, for example in production. Such resource divergence (with diverging technologies as a special case) may perhaps lead to the point where divestment of some technology or product has to be considered, due to losses of scale and scope advantages relative to other suppliers. Not seldom, a reaction against resource divergence comes too late, leading to overdiversification.

The opposite may also occur. Two initially fairly unrelated products, e.g. computers and telecom equipment in the 1950s, may over time "come closer" in their resource requirements, e.g. through sharing new technologies (e.g. integrated circuits) or serving similar new customer segments.[9] Another example would be heavy trucks becoming more similar over time in resource requirements to construction machinery, while distancing themselves from passenger cars. Construction machinery then corresponds to P_3 in Figure 5, sharing technologies T_3 and T_4 with P_2 (trucks) while sharing only T_3 with P_1 (passenger cars). This kind of resource convergence (with converging technologies as a special case) may then at some point justify diversification one way or the other, through mergers, acquisitions, alliances or organic growth, depending upon the resource position and resource acquisition costs relative to other companies. The resource positions and acquisition costs for different companies are typically asymmetric and uncertain, which makes the direction of diversification important but difficult to assess, especially in early stages of convergence, prompting for experimental diversifications. Over longer periods of time both resource divergence and convergence may occur, e.g. due to technological changes in general.

The changing resource bases for different product generations or versions may be similarly analyzed. A company operating in a product area may have to offer its customers both an old and an upgraded new product generation for some time, but then eventually have to scrap or divest the old generation. Scrapping obsolete competences is often associated with considerable difficulties, since a number of people, including managers, will be threatened thereby, trying all kinds of defensive behavior, essentially resulting in organizational inertia (or core rigidities in the terms of Leonard-Barton 1995), costs and delays. This is not least the case when old technical competencies (technologies) embedded in engineering subcultures have to

[9] For this type of analysis the concept of technological distance has been developed; see Granstrand (1994).

be phased out (see below). Scrapping resources also involves scrapping some old relations, i.e. scrapping some relational capital, which is difficult. For example, scrapping some customer relations, built up through single-minded corporate campaigning about “listening to our customers,” leading to bias for current ones, is difficult and costly in the short run but even more costly in the long run if not undertaken (see Christensen 1997).

A company wanting to enter the product area is not plagued with these costs, but if it is a new start-up company it must, on the other hand, acquire all necessary resources if it wants to independently launch a new product generation. An existing company, operating in other product areas but attempting to diversify into the product area under consideration with a new product generation, typically based on some new technology, must also acquire new resources but can at the same time draw on some of its old resources insofar as the diversification attempt is resource-related.

Thus, depending upon the resource acquisition cost, the resource scrapping cost, and the synergies between the new product generation and existing resources, either the start-up company (e.g. for mobile handsets or palmtops), or the existing company (e.g. in telecom industry) already operating in the product area, or the existing company (e.g. in computer industry) diversifying from outside into the product area will have a relative cost advantage; see Figure 6.

<< INSERT FIG. 6 >>

4 Critical abilities in management of technology and product diversification

The question is now how the economic benefits can be reaped by proper management of these dynamic shifts in inputs and outputs, or in other words these diversification processes (including divestment). Some general observations on managing technology assembly will first be given. Then some lessons from a few cases may serve as guidelines for further management thinking on the complex and situation-specific issues of diversification. The first case concerns how the Swedish telecom giant Ericsson successfully managed the shift or transition in the technology base for its telecom switching products, i.e. a case of product-related technology diversification. The second case deals with how the Swedish auto and aerospace company Saab attempted to leverage several of its numerous military-related technologies through internal technology transfer to a number of new product areas, collected in a special high-tech group called Saab Combitech. This is a case of mainly technology-related product diversification. (For further details of the cases, see Granstrand and Sjölander 1990). Both cases point at the criticality of managing conflicts, especially conflicts between subcultures associated with different technologies. This issue will therefore be dealt with specifically.

4.1 Managing technology assembly

As seen above, technology-related product diversification typically involves procuring some new resources while drawing on some existing technologies. Procuring new technologies can be done in various ways – by in-house R&D, by alliances or acquisitions on external technology markets, or simply through technology intelligence. Either strategy requires specific management abilities, e.g. in cooperating with lead users, competitors, suppliers or universities. External sourcing requires, in general, technology forecasting (foresighting), identifying, valuing, accessing, transferring and integrating new technologies, the latter often encountering difficulties like NIH-effects. At the same time, internally available technologies have to be internally identified, transferred and adapted to the new product, which may very well encounter difficulties, not least in a large corporation. The saying: “Wenn Siemens wusste was Siemens weiss” is indeed relevant here.[10] Sometimes it may even be simpler (faster, cheaper) to source a

---

[10] The saying is sometimes attributed to the former chairman Karl-Heinz Kaske of Siemens, but its origin is unclear within Siemens (which in itself illustrates the saying).

piece of technology externally, than to go and find it in large, diversified organizations like Siemens, Philips or General Electric and then to overcome internal technology-transfer barriers.

All in all there is a **technology assembly problem,** or more generally *a competence or knowledge assembly problem,* to deal with in technology-related product diversification. This also holds true for product-related technology diversification. In the latter case, however, there is also the problem of managing obsolete resources, and in particular competences and technologies that are embedded in managers and personnel. Their self-interests produce not only inertia, active resistance and political maneuvering but also distortion of information, often even without guile. Top managers and board members are dependent upon internal expertise in judging new product and technology prospects, and all expertise is framed in their own competence. (This is why it is sometimes risky to promote a technologist or scientist, who has successfully specialized in one specific area, to a position as general technology manager.) As diversifying competence for an individual is difficult (costly) and time-consuming, to say the least, an important goal discrepancy or principal-agent problem arises between the board (principal) and the internal expertise (agent). It is then important for top managers and the board to complement internal expertise and judgments with external ones, e.g. in form of external technology audits, technical due diligence, scientific advisory boards, or technical alliance advisors. However, this possibility is limited by secrecy needs (sometimes corporate boards are simply very leaky and top management cannot bring the issue to the board) and by a highly specific and uncertain situation with limited availability of experts.

4.2 Managing product-related technology diversification into digital switching in Ericsson[11]

For over a century Ericsson, as a fairly specialized but highly internationalized company in telecom, has managed a number of transitions into new technologies successfully (with some

[11] This section builds on a series of about 30 interviews in Ericsson during the mid-1980s, reported in Granstrand and Sjölander (1990).

exceptions), pertaining to both switching and transmission of phone calls. The transition into computerized (stored program control) switching in the 1950s to 1980s was particularly successful, leading to the so-called AXE system which provided a strong technological platform for subsequent development of mobile communications (voice and data), in turn very successful as has been widely recognized. The latter development was then a case of technology-related business diversification (with several new products – base stations, handsets etc.) as well as a case of a technological transition from wired (cable) to wireless (radio) transmission in the access part of a telecom network (besides the transition from copper cable to optical fiber in the trunk lines of the network).

In the case of managing a series of technological transitions, several critical managerial abilities could be identified in Ericsson. First is the ability to perform environmental scanning (including technology and competitor scanning, intelligence and forecasting) and to produce technological, industrial and market forecasts. Second, the ability to assess the proper rate, direction and form of strategic competence diversification is critical. There is a long process, perhaps 20-30 years, from the first signals of an emerging technology (e.g. discovery of semiconductivity) to the commercial success of a new product generation based on it. All the time the technology develops, technological options proliferate and the competitors' technological approaches and positions change. When and how to introduce the new technology (if at all), and when and how to exit the old technology, are crucial timing decisions. The experience in Ericsson suggests that the building of competence for these decisions ought to be made at the outset in an experimental manner, without a precise business plan and involving good technologists, young and old. (The latter may be difficult if the product with the old technology is simultaneously successful on the market.)[12]

---

[12] See also Chapters II.1, II.2 and III.3 in this volume for structured approaches to improving these two critical managerial abilities. Methods and tools for managing emerging technologies and the "fuzzy front end" of the innovation process are also presented in Chapter IV.3.

A third critical ability in connection with technological transitions is the ability to handle conflicts. It is almost axiomatic that technological transitions involve conflicts. This should be recognized as natural rather than pathological in the organization. Some conflicts derive from confrontations between different professional subcultures associated with different scientific and technological disciplines involved in a transition. Sometimes, as in the Ericsson case, these conflicts could be mitigated by a strong corporate culture and/or a consensus-seeking problem-solving engineering culture. Some conflicts are associated with power struggles among managers, whose power is based on knowledge in a certain technology. Some conflicts have good effects, e.g. increasing motivation as in some "guerrilla" development work ("skunk work") in a large company, but conflicts may often turn out to be disastrous. Probably the different conflicts in Ericsson's long-standing competitor ITT during the latter half of the 1970s went far enough to delay R&D work on its System 12 competing with the AXE. For several reasons, managers often avoid dealing with conflicts until it is too late, when the conflicts have become overly person-oriented rather than issue-oriented, productive communications break down, tensions and struggles prevail, resources are wasted and speed in decision-making is lost.

Fourth, organizational ability is important in connection with technological transitions. The new always runs a risk of being killed by the old. To organize the work on the new technology, separately from that on the old, in a semi-autonomous organization has often proved to be a viable organizational solution. It is not only a way of separating the new from the old but also gives possibilities of combining the advantages of large and small organizations. In the Ericsson case, the formation of Ellemtel , a joint venture company with the Swedish telecom operator (later named Telia) as a lead user, proved to be highly successful and done at what seems in retrospect the right time.

A fifth managerial ability concerns how to work with parallel approaches in R&D, and when and how to divest or redirect some approaches and concentrate R&D resources on a major design direction for a new product generation. At the same time, increasing R&D costs, increasing possibilities to combine different technological options (due to a general accumulation of S&T advances), and rather constant R&D times (as in the Ericsson case) increase the importance of this ability.

4.3 *Managing internal technology transfer in Saab Combitech*

Saab is a large European civil and military aircraft manufacturer. In a corporate restructuring in the 1980s, Saab Combitech was formed as a large subsidiary, housing a number of technologies and products outside but related to core businesses, for the purpose of diversification, cross-utilization and cross-fertilization (combination) of technologies. This in turn required in-house technology transfer and technology integration or combination.

Combining technologies in R&D work involved the problem of how to manage professional subcultures. It was then of importance that these subcultures rested on some commonalities in communication, values, problem-solving approaches etc., that is to say, that there was some kind of overarching professional culture and corporate culture. The development and sustenance of a corporate culture were facilitated by common historical roots and traditions of various businesses, and by coherence in vision, goals and explicit strategies. This was even more true in a multinational setting in which there were national culture differences as well.

It was moreover important that a well-conceived technology transfer policy was implemented with support by the various business managers. The experience from Saab-Scania Combitech also pointed to the need for incorporating strategic perspectives and responsibilities into the technology transfer function, together with operative and tactical ones. This was facilitated by a CTO or a Vice President Technology with joint staff/line functions, having direct executive responsibilities for group strategic projects, ventures and new technology-based firms together with staff responsibility for supporting the CEO and the various business managers in the strategy development process.[13]

Finally, developing managerial abilities in an MTC such as Saab Combitech took time and needed a great deal of experimentation. This can hardly be done if the overall profitability is low or poor. Therefore, healthy businesses, projects and ventures are needed at the outset.

4.4 Managing conflicts among engineering subcultures

The culture associated with S&T is sometimes presumed to be homogeneous, but is in fact heterogeneous with several subcultures, not seldom in conflict with each other. Scientists and technologists certainly share some basic values and beliefs about the benefits of their work and their methods and what is legitimate in thinking and language. However, at the same time, differences in these respects between disciplines, as well as between generations, are marked. Such differences within an overall S&T culture seem to produce intermittent reorientations rather than smooth, cumulative evolution. Individual scientists and technologists build up conceptions that ossify and obstruct intellectual reorganizations. Science and technology groups are formed on the basis of similarities in educational background and shared conceptions and language. Individuals tend to socialize in at least one group, their social skills improve, they become tied to interests, and they defy fundamentally new conceptions. As a result, disciplines expand and contract, amalgamate (fuse) and split up (diversify), and this is accompanied by generation changes, breakthroughs of new knowledge and, not least, by conflicting interests.

S&T subcultures are typically associated with S&T professions, such as chemists, biologists, mining engineers, mechanical engineers, electrical and electronics engineers, and physicists. These categories correspond to the structure of graduate education and, to some extent, to the structure of industrial branches or sectors (which graduate engineering education

[13] See further Chapter I.2 in this volume on the virtues of having a CTO on the top management team, as is widely practiced in Japan.

is supposed to serve). The formation of subcultures also seems to take place largely during graduate education or in the early years of professional life when much of an individual's professional *'Weltanschauung,'* language and base for socialization is formed. The subcultural features formed during graduate education are often reinforced when the young professional goes into a corporation, due to the structural correspondence between universities and different sectors of industry. The inertia of the educational system in universities then tends to produce a strong and enduring sectoral barrier to change in industry.[14]

There are several determinants behind the formation of cultures and the association of an individual with different cultures pertaining to different segments of his/her life situation. The strength of this association differs between individuals and also changes with time. A high learning capacity makes a professional less dependent upon discipline-oriented knowledge as acquired by formal education, and may therefore permit him/her to be more problem-oriented and less inclined to associate with a certain professional culture. A university researcher may feel associated with S&T in general, but with academic research in particular and even more with academic research in his/her field. Problems in connection with too weak an association of university researchers with the culture of industrial R&D are often witnessed.

The association of a culture with a corporation and its change is of main concern here, especially change associated with professional subcultures. On the one hand, a corporation is associated with different cultures through its personnel. On the other hand, a specific corporate culture is often formed, which may retain its basic characteristics even if turnover of personnel is high. Since a culture reduces variations and uncertainty for its members, it may be instrumental in coordination and communication. A culture may also be instrumental in preserving a power structure. Management has possibilities to influence language, ideology, beliefs and myths in the corporation and thereby influence the corporate culture to the benefit and

---

[14] This circumstance may partially explain the phenomenon of innovation by invasion as described by Schon (1967), that is, how whole sectors of industry are invaded by new technologies outside their traditional fields.

convenience of managers themselves. Thus, there are several motives behind the formation of a corporate culture. However, a culture may also act as a barrier to change.

Changes of professional subcultures in three corporations studied are summarized in Table 1. One can discern a number of factors of primary influence behind such changes, although it is extremely difficult to separate such factors and assess their influence. The most frequently encountered factors are, on the one hand, technological and market changes and, on the other hand, top management behavior, corporate strategy, recruitment and promotion. The latter group of factors directly involves top management. This indicates that top management plays a primary role in cultural change in the corporation and that strategy formation, recruitment and promotion are important instruments in bringing about such change. In this sense a top manager in a large corporation may act in an important manner as a “cultural entrepreneur”. This does not always have to be the case, though. In some cases a corporate managing director has hindered or slowed down a cultural change initiated internally or externally.

<< INSERT TABLE 1 >>

Concerning the instruments for bringing about a cultural change, strategy formation, recruitment and promotion certainly are important. These instruments may, of course, be used in different ways. Thus, for example, Boliden promoted a mining man as head of a new chemical division of the corporation to be able ‘to lift it up’ in the corporate power structure. Astra relied heavily on recruitment of new competence, which was natural considering the total dominance of chemists at the time. (It is a fundamental fact that a specialized professional in one field cannot be converted into a specialized professional in a different field overnight or even over some years.)

A cultural entrepreneur may use other instruments as well. To restructure communications through organization and location is a tangible way of acting. He may also act in a more intangible way on the level of fundamental elements in a culture, such as influencing language and values, creating symbols and rituals, strengthening ideologies and nurturing myths.

However, the dynamics of cultural change as discussed here involves more factors than just a cultural entrepreneur, a concept which is often used in a too simplified explanation. Although there are instruments for management which influence a culture, it would be naive to consider a culture as something that can be created and managed totally at will. Cultural change has, for instance, a prehistory in which external changes and internal conflicts are influential. The whole process of change, which may last over some decades, is characterized by disorder and uncertainty and the outcomes may vary. Starting from the situation of a dominant culture in a corporation, with a new culture emerging, four types of outcome may be discerned:

– amalgamation of cultures;

– transition to new dominance;

– ordered coexistence;

– rejection of emerging culture and regression to old culture.

Of the above, amalgamation (for instance, at Alfa-Laval), transition (for instance, at Astra) and the role of new generations of professionals are important. A new generation may change and amalgamate values and beliefs previously associated with two subcultures or disciplines, and a new generation may be needed to subdue an old subculture. Ordered coexistence of two subcultures (for example, at Boliden) may be accomplished both by hiring new professionals with weaker subcultural association and by structuring organization and management.

5 *Summary and Conclusions*

5.1 Multi-technology management

Diversification into new types of businesses and resources is an old phenomenon and an inherent feature in corporate evolution, subjected to too much controversy as well as to fashion-oriented management. Despite this, diversification has only fairly recently been analyzed in the literature, with inconclusive results as to the impact of product diversification on economic performance. However, more recent research has focused on a new type of diversification into multiple technologies, i.e. technology diversification, which so far has proven to be strongly associated with growth of sales as well as with growth of R&D expenditures and external technology sourcing, especially when combined with product and market diversification. As a result, products become increasingly multi-technology ("mul-tech" rather than "hi-tech"), and corporations develop into MNC/MPC/MTC combines.

In order to reap the economies involved in technology diversification, a number of critical management abilities have been identified, hitherto only through case studies. Thus critical abilities in multi-technology management are to manage technology assembly, technology transitions, technology transfer and conflicts. Conflicts among managers and personnel are deeply involved in innovation and diversification into new technologies, not least conflicts associated with engineering subcultures. In contrast to "hi-tech" management, "mul-tech" management therefore has to focus on sourcing, assembling and exploiting an ever-changing portfolio of various technologies for customer-oriented business development – rather than to focus on in-house R&D of a narrow range of proprietary advanced technologies, which possibly may be over-performing for many market segments and applications.

5.2 Managing diversification dynamics

Some general conclusions regarding successful diversification management can finally be formulated. First, at strategic level, technology-related product diversification as well as its converse, product-related technology diversification, must be clearly recognized as a venue towards growth and profitability, but with strong emphasis on relatedness involving clear economies of scale, scope, speed and space. Often these two types of diversification are best managed in a dialectic fashion, that is, one giving rise to the other in a sequence rather than concurrently, in order to reduce risks. For instance, a product may require new technologies for new features and enhanced performance in order to meet new competition. Once these – probably expensive – technologies have been acquired and integrated, one must ask whether there could be an opportunity for technology-related product diversification. If so, still more technologies may be needed in a next phase and the diversification process continues, often over long periods of time, which requires sustained diversification strategies. Of course, uncertainty and entrepreneurialism may lead to temporary overdiversification and business failures, but the diversification–specialization pendulum must not be allowed to swing to extremes. This is very much a strategic challenge to top management and the corporate board, since commitments and sunk costs create inertia in the organization, at the same time as short-sighted pressures from investors and others, particularly in downturns, create a momentum for divestment decisions, difficult to reverse. The issue is then not so much what is the core business or the core competences, but how distributed competences can be enhanced, leveraged and integrated for developing new valuable businesses (see Granstrand et al. 1997). To formulate a simple but powerful vision for the direction of long-term diversification in the corporation is often helpful. Good examples are the C&C (Computers and Communications) vision of NEC and Toshiba's E&E (Energy and Electronics) vision. However, it must also be kept in mind that despite its long-term nature, the economic lifetime of such a vision is limited.

5.3 Managing quasi-integrated corporate innovation systems

Second, at structural level, the suitability of the divisionalized organizational structure is commonly recognized for large, diversified corporations. With technology-related business divisions operating on a short-term P/L account, a rationale arises for centralizing some R&D and technology acquisition operations. In addition, internally competing technologies may have to be organizationally separate to some degree, just as some new business development activities may have to, in order not to be stifled by dominant business divisions and day-to-day operations. The suitability of such an organizational structure with semi-autonomous units for R&D on radical new technologies, new business development and corporate venturing is by now fairly well recognized. However, there is a wide spectrum of quasi-integrated structural solutions and strategies for such units, regarding at what level they should be organized, how economic performance should be evaluated, how they should source ideas, technologies and ventures internally and externally, preferred entry and exit stages and modes, preferred interfaces with the rest of the organization, management reporting and accountability etc. To elaborate beyond this call for awareness, though, would be to exceed the scope of the present chapter.[15]

5.4 Corporate entrepreneurship

Third, at a more operational level, technology management for diversification must have a commercial and entrepreneurial orientation. Technology has to be managed as an asset that can be built up (procured) in various ways, not only through traditional in-house R&D but also through alliances and various forms of external sourcing, requiring commercial skills. The technology asset can also be exploited in various ways, not only through traditional downstream investments in production and marketing but through alliances, spin-offs, divestment and technology marketing. These latter strategies have become increasingly attractive since the strengthening of IPRs and financial markets in the 1980s. Technology exploitation therefore has come closer to corporate venturing, thus calling for commercial skills beyond merely buying technology and interfacing R&D with marketing people in a traditional way. This is probably the most important type of extension of traditional R&D management into modern technology management.

---

[15] See also Chapter III.5 in this volume on quasi-external acquisition of know-how and Chapter III.4 on various forms of external technology marketing.

Literature references

H.I. Ansoff, “Strategies for diversification”, *Harvard Business Review*, 35/5 (1957) 113-124.

J. Cantwell, A. Gambardella and O. Granstrand (eds.), *The Economics and Management of Technological Diversification* (London: Routledge Publ., 2003).

A.D. Chandler, *Strategy and Structure: Chapters in the History of the American Industrial Enterprise* (Cambridge, MA: MIT Press, 1962).

A.D. Chandler, Jr., *Scale and Scope – The Dynamics of Industrial Capitalism* (Cambridge, MA, London, England: Belknap Press of Harvard University Press, 1990).

C.M. Christensen, *The Innovator's Dilemma: When new technologies cause great firms to fail* (Boston, MA: Harvard Univ. Press, 1997).

A. Gambardella and S. Torrisi, “Does Technological Convergence Imply Convergence in Markets? Evidence from the Electronics Industry”, *Research Policy*, 27 (1998) 447-465.

K. Gemba and F. Kodama, “Diversification Dynamics of the Japanese Industry”, *Research Policy,* 30/8 (2001) 1165-1184.

M. Gort, *Diversification and Integration in American Industry* (Princeton, NJ: Princeton University Press, 1962).

O. Granstrand, *Technology, Management and Markets* (London: Frances Pinter Publ., 1982).

O. Granstrand and S. Sjölander, “Managing innovation in multi-technology corporations”, *Research Policy*, 19/1 (1990) 35-60.

O. Granstrand, E. Bohlin, C. Oskarsson and N. Sjöberg, “External Technology Acquisition in Large Multi-Technology Corporations”, *R&D Management*, 22/2 (1992) 111-133.

O. Granstrand (ed.), *Economics of Technology. Seeking Strategies for Research and Teaching in a Developing Field* (Amsterdam: North-Holland 1994).

O. Granstrand, P. Patel and K. Pavitt, “Multi-technology Corporations: Why They Have ‘Distributed’ Rather than ‘Distinctive Core’ Competencies.” *California Management Review*, 39/4 (1997) 8-25.

O. Granstrand and C. Oskarsson, “Technology diversification in MUL-TECH corporations”, *IEEE Transactions on Engineering Management*, 41/4 (1994) 355-64.

O. Granstrand, “Towards a Theory of the Technology-Based Firm”, *Research Policy*, 27/6 (1998) 465-489.

M.A. Hitt, R.E Freeman and J.S. Harrison (eds), *Handbook of Strategic Management* (Oxford: Blackwell Publ. Ltd., 2001).

A.B. Jaffe, “Characterizing the ‘technological position’ of firms, with application to quantifying technological opportunity and research spillovers", *Research Policy*, 18/2 (1989) 87-97.

F. Kodama, "Technological diversification of Japanese industry", *Science*, 18/7 (1986) 233, 291-296.

D. Leonard-Barton, *Wellsprings of Knowledge. Building and Sustaining the Sources of Innovation* (Boston, MA: Harvard Business School Press, 1995).

C. C. Markides, *Diversification, Refocusing, and Economic Performance* (London, England and Cambridge, MA: The MIT Press, 1995).

C.A. Montgomery, "Corporate diversification", *Journal of Economic Perspectives*, 8/3 (1994) 163-78.

R.R. Nelson and S. Winter, *An Evolutionary Theory of Economic Change* (Cambridge, MA: The Belknap Press, 1982).

C. Oskarsson, *Technology Diversification – the Phenomenon, Its Causes and Effects*, Ph.D. Dissertation, Department of Industrial Management and Economics, Chalmers University of Technology, Göteborg, Sweden (1993).

P. Patel and K. Pavitt, "Technological Competencies in the World's Largest Firms: Characteristics, Constraints and Scope for Managerial Choice". *STEEP Discussion Paper No. 13, Science Policy Research Unit*, University of Sussex (1994).

K. Pavitt, M. Robson and J. Townsend, "Technological Accumulation, Diversification and Organisation in UK companies 1945-1983", *Management Science*, January 35/1 (1989).

E. Penrose, *The Theory of the Growth of the Firm* (Oxford: Basil Blackwell, 1959 (citations are drawn from the 2nd ed., 1980)).

H. Petroski, *The evolution of useful things* (New York, NY: Vintage Books, Random House Inc., 1994).

V. Ramanujam and P. Varadarajan, "Research on Corporate Diversification: A Synthesis", *Strategic Management Journal*, 10 (1989) 523-551.

D.J. Ravenscraft and M. Scherer, *Mergers, Sell-Offs, and Economic Efficiency* (Washington, DC: The Brookings Institutions, 1987).

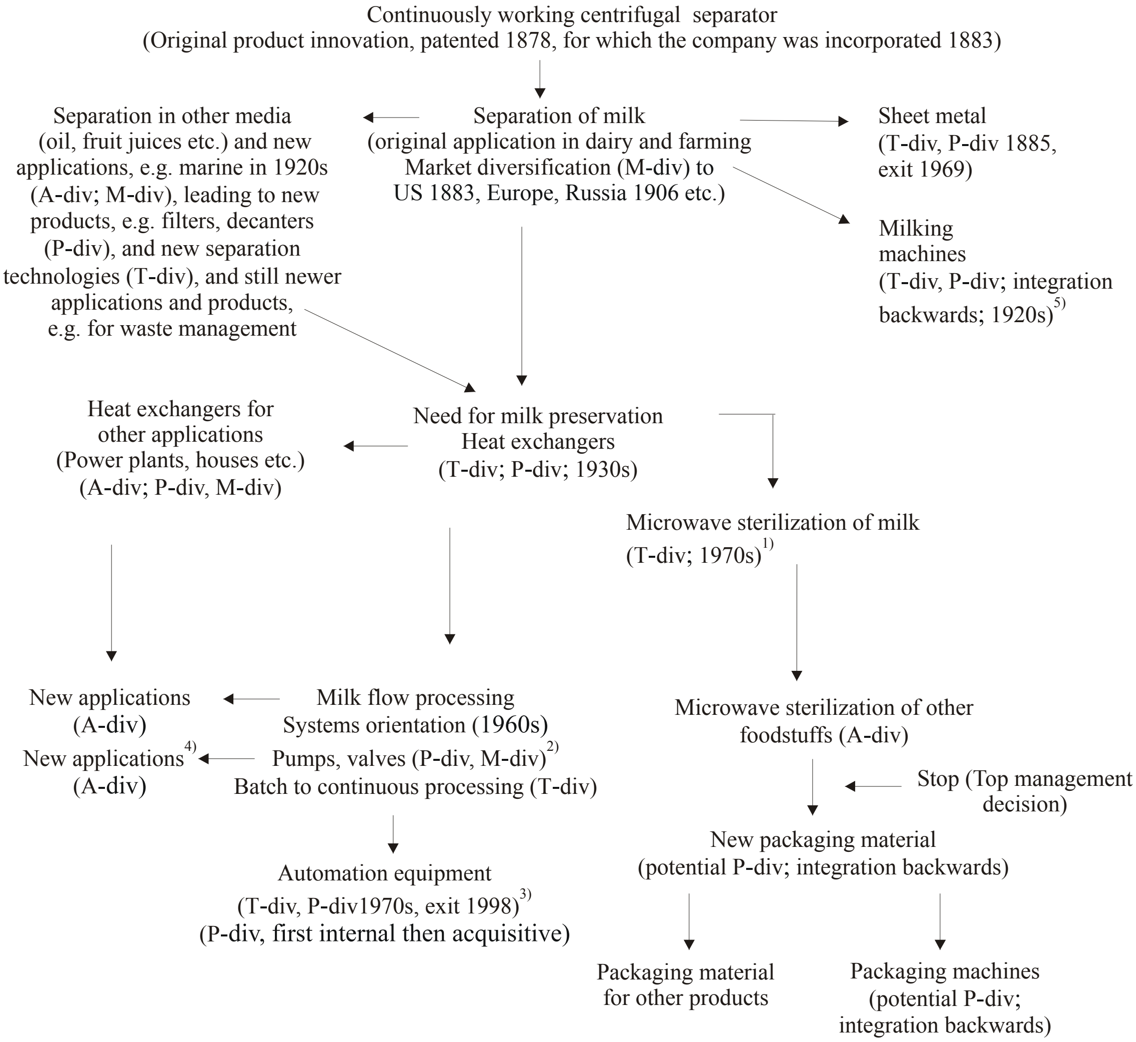
R.P. Rumelt, *Strategy, structure and economic performance* (Cambridge, MA: Harvard Business Press, 1974).

S.W. Sanderson and M. Uzumeri, *Managing Product Families* (Chicago: Irwin, 1997).

D. A. Schon, *Technology and Change, The New Heraclitus* (New York, NY: Delacorte Press, 1967).

J.T. Scott, *Purposive Diversification and Economic Performance* (New York, NY: Cambridge University Press, 1993).

K. Yamaji, Market economy and intellectual property oriented management. *Speech at LES International Conference in Beijing*, 7 May 1994.



Legend:

A-div =Application diversification (application = physically similar user situations)

M-div = Market diversification (segments, regions) (market segment =behaviorally similar customers)

P-div = Product diversification (= extension of the range of product areas)

T-div = Technology diversification (= extension of the range of technologies)

Notes

1) Not significant diversification for sales growth. Included as an illustrative example here of top management deciding to stop further diversification.

2) Major related acquisitions 1969, 1971.

3) P-div first through internal development, then through acquisitions (a common feature in other instances of P-div as well). Divested to ABB 1998, due to insufficient A-div to cover rising R&D costs.

4) Two major types - sanitary (incl. food and health) and industrial. Industrial pumps and valves exitted 1980s and 1990s.

5) Further P-div into various areas of farm equipment

Figure 1. Diversification tree – case of Alfa-Laval AB (as of 2000).

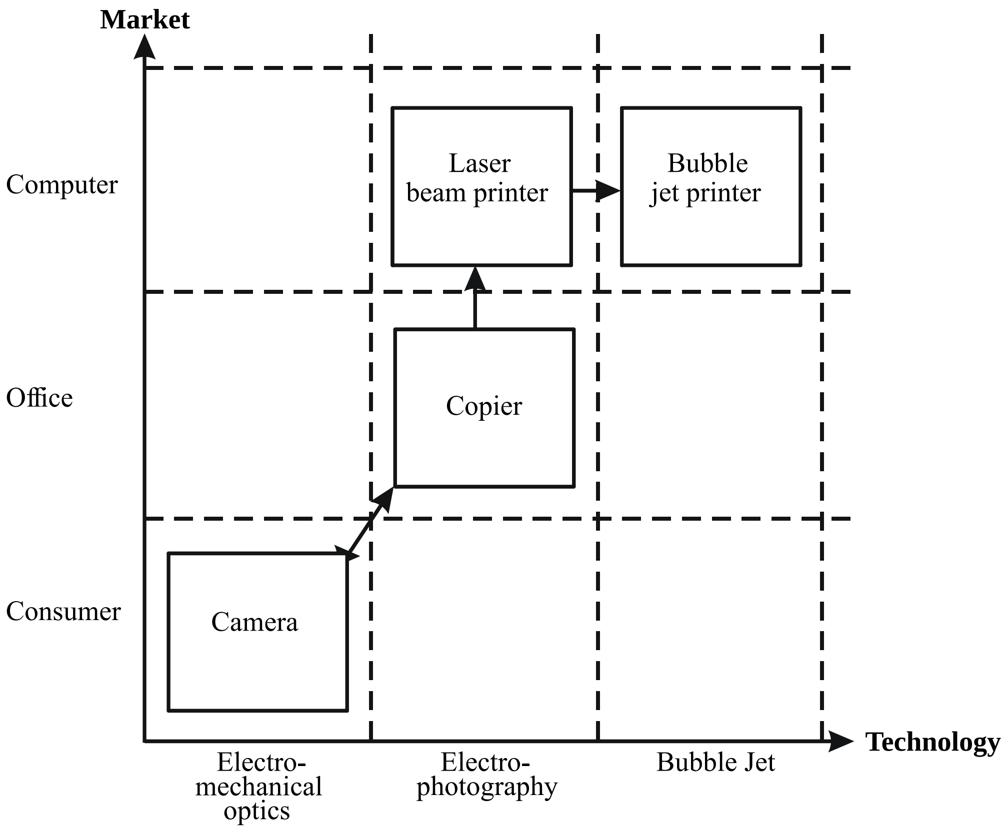


Figure 2. Canon's diversification trajectory.

(Source: Yamaji 1994)

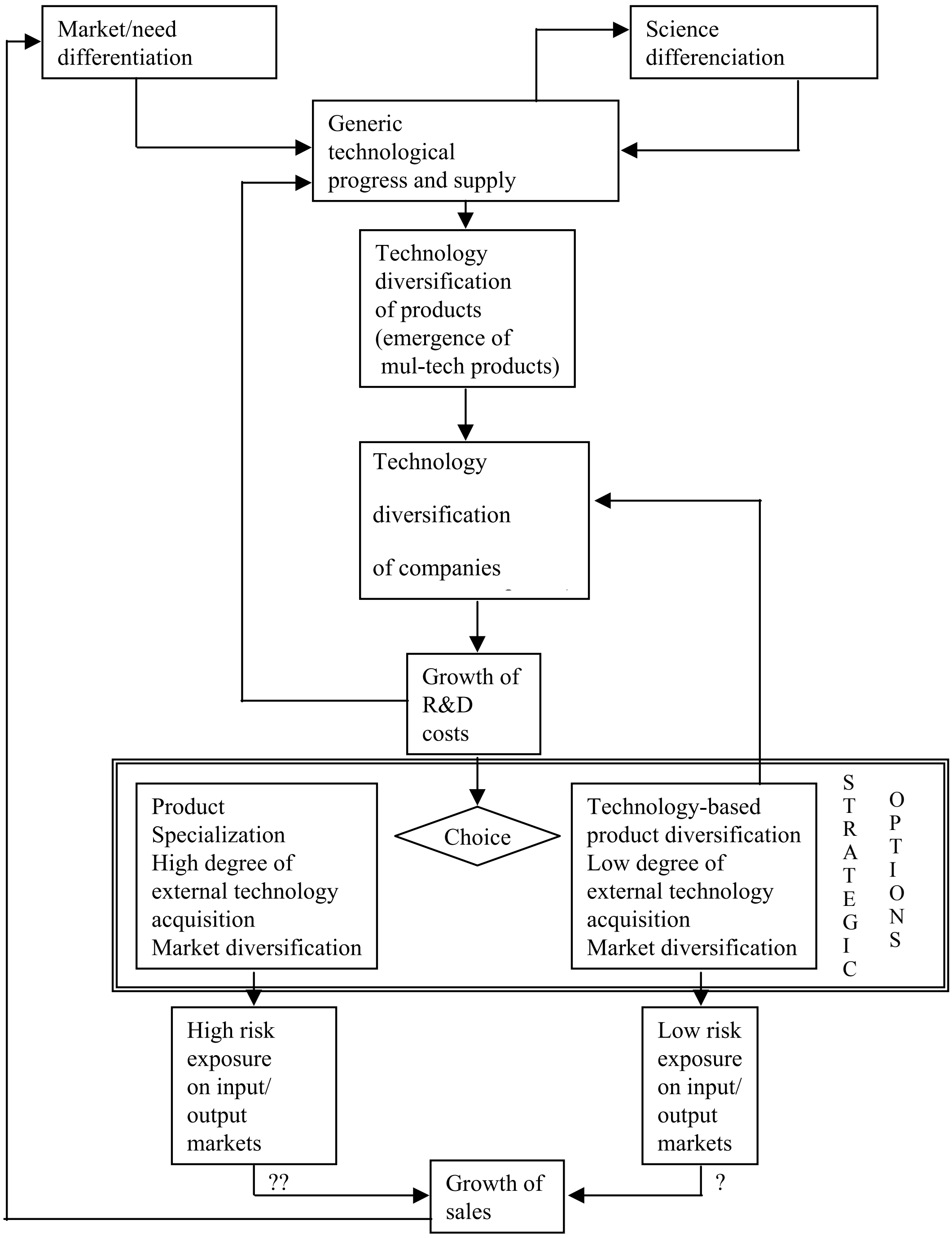


Figure 3. A strategic choice for technology management in "mul-tech" companies.

(Source: Granstrand et al., 1992)

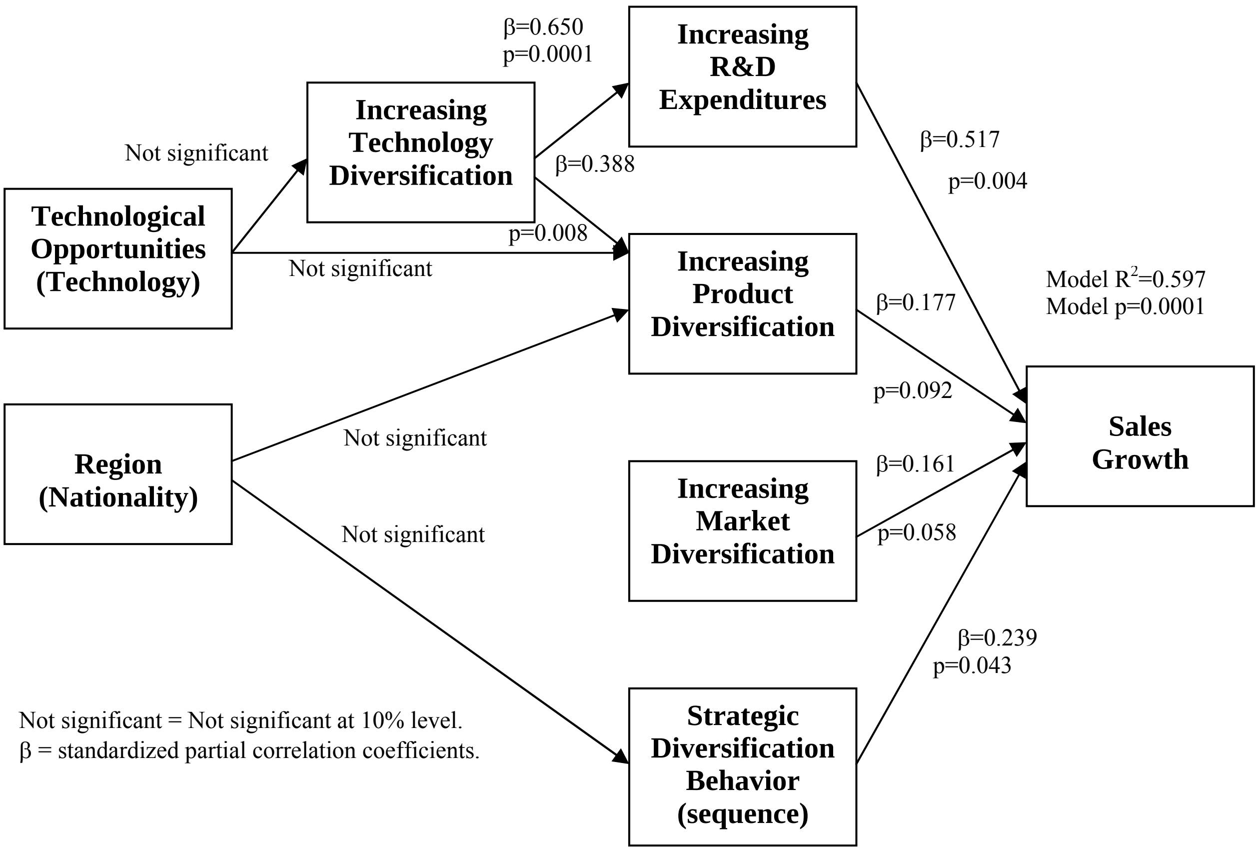
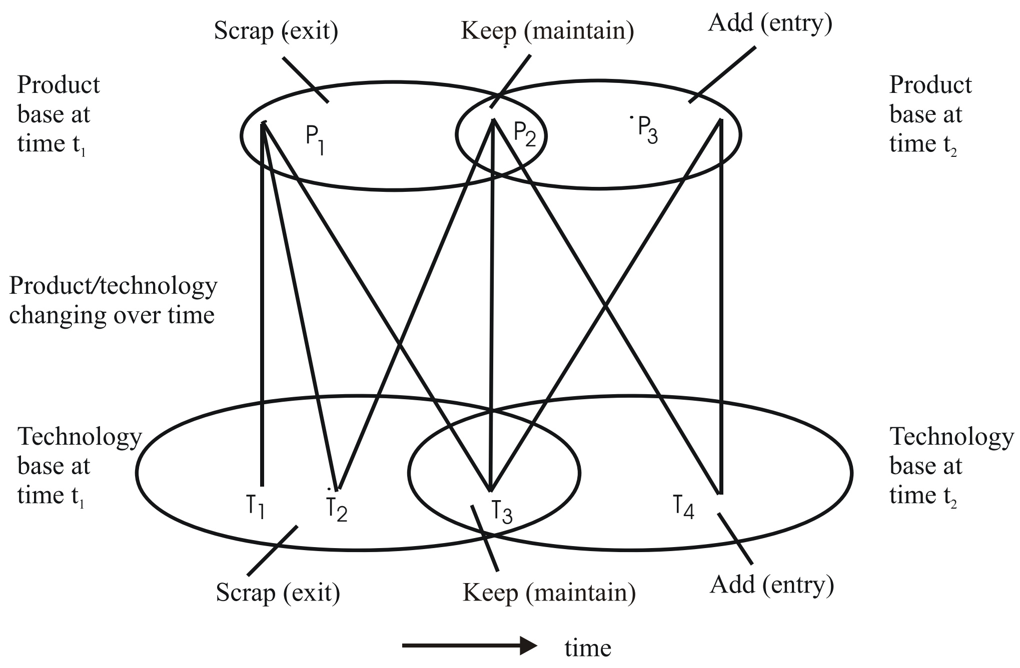


Figure 4. A test of a model for growth and diversification (N=55).

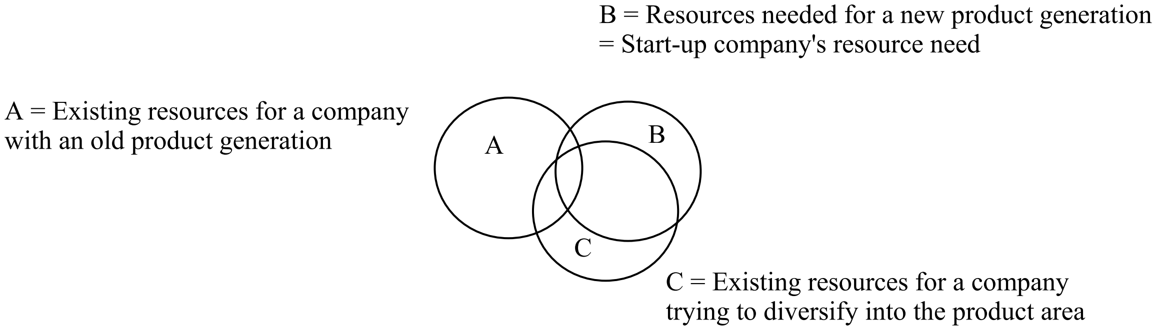
(Source: Oskarsson, 1993)



Legend:

(ellipse)	Base (portfolio) of products and technologies of the company at a specific point in time
P_1, P_2, …	Products
T_1, T_2, …	Technologies /

Figure 5. Evolution of a company in terms of changes in its product and technology bases.



Note:

The comparative advantage of A visavi C corresponds to A's unique part of the resource overlap with B, that is the part of A's resource overlap with B which is not within C's resource overlap with B (i.e. in set theoretic symbols $(A \cap B) \setminus C$). The figure indicates that C has a greater comparative advantage than A (for the time being).

Figure 6. Resource bases (including technology bases) for an incumbent (A), a start-up (B) and a product diversifier (C).

Table 1. Examples of subcultural transformations in business histories in 1960s-1970s

Change involving a subcultural transformation	Factors of primary influence
Astra	
Transition from a chemistry orientation to a biology orientation	Corporate origin Top and R&D management behavior Recruitment Technological change
Boliden	
Integration of chemistry into the mining orientation	Top management behavior Recruitment and promotion Corporate strategy Technological change
Alfa-Laval	
(a) Integration of economics into the engineering orientation (b) Transition from component orientation to systems orientation	Top management behavior Recruitment Corporate strategy Internal conceptualizers Technological and market change Product troubles
(c) Integration of electronics into the mechanics orientation	R&D management behavior Independent subsidiary action Recruitment Technological change

Source: Adapted from Granstrand (1982).