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4. Industrial Innovation: Success, Strategy, Trends

Roy Rothwell

Introduction

Whilst for many years technological change was regarded by economists as merely a component of the residual factor in economic growth equations, today few would doubt its importance as a factor in economic progress, industrial change and international competitiveness (G. Dosi et al., 1988). Since the second half of the 1960s when researchers began to look inside the black box of the innovating company (Rosenberg, 1982) a great deal has been learned about the process through which technological change is brought to economic fruition, that is, the industrial innovation process. Below a brief summary is given of the aggregate results of studies of successful innovation and of changing perceptions of, and practice in, the process of innovation.

Success Factors

From the many studies of industrial innovation, including studies of success, studies of failure and comparisons between success and failure, the following success factors can be derived (Rothwell, 1992a):

1. The establishment of good internal and external communication; effective linkages with external sources of scientific and technological knowhow; a willingness to take on external ideas.
2. Treating innovation as a corporate-wide task: effective functional integration; involving all departments in the project from its earliest stages; ability to design for 'makeability'.
3. Implementing careful planning and project control procedures: committing resources to up-front screening of new projects; regular appraisal of projects.
4. Efficiency in development work and high quality production: implementing effective quality control procedures; taking advantage of up-to-date production equipment.

5. Strong market orientation: emphasis on satisfying user-needs; efficient customer linkages; where possible, involving potential users in the development process.
6. Providing a good technical service to customers, including customer training where appropriate; efficient spares supply.
7. The presence of certain key individuals: effective product champions and technological gatekeepers.
8. High quality of management: dynamic, open-minded managers; ability to attract and retain talented managers and researchers; a commitment to the development of human capital.

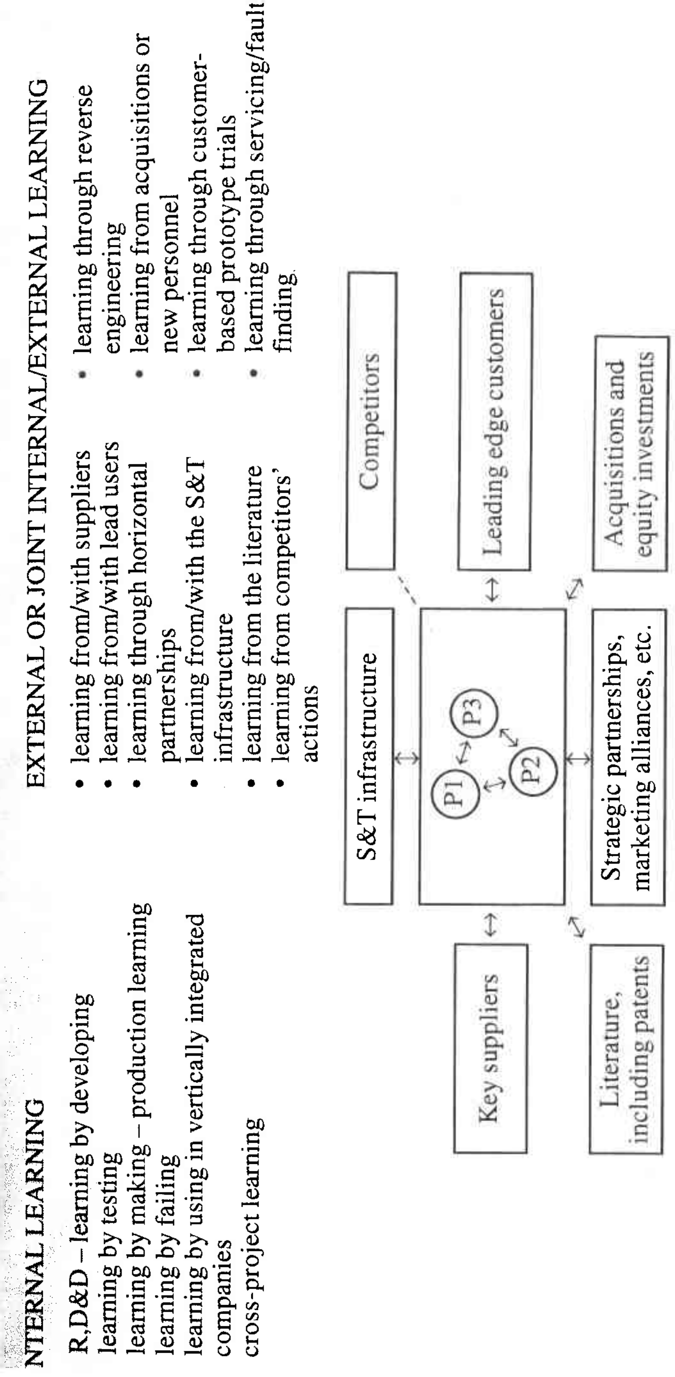
In addition to these project execution-type success factors Cooper (1980) has highlighted, amongst others, three additional kinds of variable important for success. These are:

- The nature of the product: specifically its uniqueness/superiority and the economic benefit it confers upon the customer.
- The nature of the market: intensity of market need, market growth rate and market size.
- The achievement of technical and production synergies between the new product and existing products.

The latter point emphasizes the importance to success of cumulative knowhow. In other words innovation is best seen in the context of the firm's unique techno/market trajectory and as a process of accumulation of associated specific capabilities and distinctive competences. (Maidique and Zirger, 1985; Dodgson, 1991; Prahalad and Hamel, 1990). Figure 4.1 shows innovation as a process of knowhow accumulation and illustrates the importance of both internal and external learning (Rothwell, 1992a).

The eight success factors listed above define success in terms of what firms do during innovation. To these we can add a set of higher level (strategic) factors that, essentially, are pre-conditions for sustained innovation to take place. These are (Rothwell, 1992a):

1. Top management commitment to, and visible support for, innovation. This is especially important in the case of radical innovations that might encounter internal and external opposition.
2. Long-term strategy in which innovation plays a key role (technology strategy). This enables firms to plan for inter-project technical, production and marketing synergies (planned learning).
3. Long-term commitment to major projects, based not on the sole criterion of short-term return on investment, but on considerations of future market penetration and growth (importance of 'patient money').



gure 4.1 Innovation as a process of know-how accumulation

4. Corporate flexibility and responsiveness to change. This is essential especially in enabling the firm to adapt to the requirements of radical innovation. 'Organic' organizations are more amenable to these requirements than are their 'mechanistic' counterparts (Burns and Stalker, 1961).
5. Top management acceptance of risk and an associated need for sensible termination criteria.
6. Creation of an innovation-accepting, entrepreneurship-accommodating culture. Without this the firm will dampen the activities, or lose altogether, its most valuable asset – dynamic, entrepreneurial individuals.

In general, the project execution and corporate level success factors (summarized in Table 4.1) are common to all sectors, although their rank order of importance can vary between sectors (Rothwell et al., 1974).

In addition, successful innovators generally outperform failures across the board. Success is a matter of competence in all functions and of balance and coordination between them (Cooper and Kleinschmidt, 1988). Finally,

Table 4.1 Success factors

PROJECT EXECUTION FACTORS

- Good internal and external communication: accessing external knowhow
- Treating innovation as a corporate-wide task: effective inter-functional coordination: good balance of functions
- Implementing careful planning and project control procedures: high quality up-front analysis
- Efficiency in development work and high quality production
- Strong marketing orientation: emphasis on satisfying user needs: development emphasis on creating user value
- Providing a good technical service to customers: effective user education
- Effective product champions and technological gatekeepers
- High quality, open-minded management: commitment to the development of human capital
- Attaining cross-project synergies and inter-project learning

CORPORATE LEVEL FACTORS

- Top management commitment and visible support for innovation
- Long-term corporate strategy with associated technology strategy
- Long-term commitment to major projects (patient money)
- Corporate flexibility and responsiveness to change
- Top management acceptance of risk
- Innovation-accepting, entrepreneurship-accommodating culture.

success is 'people centred' and, while formal techniques can enhance the performance of dynamic, gifted and entrepreneurial managers, they can do little to raise the performance of innovatory management lacking these qualities.

Innovation and Strategy

Corporate strategy has many targets to address (Figure 4.2) and its formulation and implementation is a complex and interactive process. All the strategy targets are influenced by or have implications for industrial innovation. Until the work of Cooper (1984), however, surprisingly little attention was paid to the relationship between corporate strategy and innovation success. Cooper showed that strategies associated with high innovatory performance were characterized by the following 'dimensions':

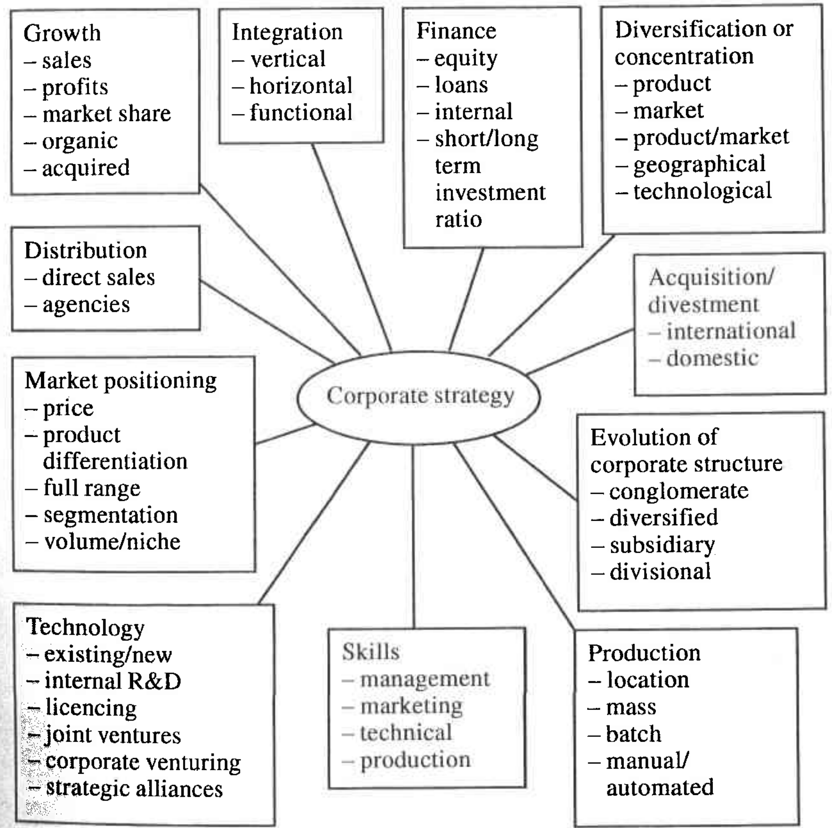


Figure 4.2 Targets for corporate strategy
Source: Rothwell, R. (1992a).

- An aggressive technological orientation: having a strong R&D orientation and being proactive in acquiring new technologies.
- A venturesome, offensive innovation programme that is viewed as a leading edge of corporate strategy.
- A market-oriented programme, featuring strong user linkages and a significant effort directed towards identifying user needs coupled to a proactive search for new product ideas.
- The development of products with marked differential advantages which meet customer requirements better than competitive products and had a marked impact on customers.
- The employment of sophisticated technologies that have a high degree of synergy with the firm's technological and production resource base.
- A relatively diverse new product programme yielding products and end uses not necessarily closely related to each other, but in potentially large, high need, growth markets.

The author concluded: 'What we witness is not a single strategy, but a packet of strategies that differentiated these high performers from the rest of the firms. A marriage of technological prowess, a strong marketing orientation, the search for a differentiated advantage, and a willingness to accept risk appears to be the key to a high performance programme' (Cooper, 1984).

Despite there being no single corporate strategy element uniquely associated with successful innovation, nevertheless at different times during the post-World War II era specific elements have been at the strategic forefront in Western companies. This evolution in 'dominant' strategy elements is outlined in Table 4.2, along with a brief description of the associated major impacting features of the external environment. Taken together this suggests that the dominant elements in corporate strategies at a given time are to a significant extent contingent on exogenous factors although, as Ansoff (1984) points out, firms are also important actors in influencing the environment in which they operate.

Amongst the dominant corporate strategy themes that have come to the fore during the late 1980s – early 1990s are:

- inter-firm collaboration (networking strategy);
- technological accumulation (technology strategy);
- integrated product and manufacturing strategies (design for manufacturability);
- flexibility (organizational, managerial, product, manufacturing);
- product quality/performance (differentiation strategy);
- the environment (environmental strategy); and
- speed-to-market (time-based strategy).

Table 4.2 Corporate strategy evolution

PERIOD 1: 1950s–MID 1960s

Period characterized by postwar recovery, the growth of new technology-based sectors and the technology-led regeneration of existing sectors. Introduction and rapid diffusion of major new product ranges. Demand exceeds production capacity. Corporate strategic emphasis on R&D and on manufacturing build-up.

PERIOD 2: MID 1960s–EARLY 1970s

Period of general prosperity; emphasis on corporate growth, both organic and acquired. Growing level of corporate diversification. Conglomerates formed through acquisition and merger. Capacity and demand more or less in balance. During the latter part of the period, intensifying competition. Growing strategic emphasis on marketing.

PERIOD 3: MID 1970s–EARLY 1980s

Period of high inflation and demand saturation (crisis of 'stagnation'). Supply capacity exceeds demand. Strategies of consolidation and rationalization with emphasis on scale and experience curve benefits. Some de-diversification. Growing strategic concern with accountancy and financing issues (cost focus).

PERIOD 4: EARLY 1980s–1990

Initial period of economic recovery followed by recession. Finance-led merger and acquisition boom giving way to concentration on core businesses and core technologies. Growing awareness of the strategic importance of emerging generic technologies with increased strategic emphasis on technological accumulation (technology strategy). Growing emphasis on manufacturing (manufacturing strategy). Growth in strategic alliances, strategic acquisitions and internationalization in ownership and production. Global strategies. Technology fusion.

Major impact of new technologies. High rates of technological change. Intense competition. Rapid product cycles with growing strategic emphasis on time-based strategies. Increased intra-firm and inter-firm integration (networking). Integrated technology and manufacturing strategies. Emphasis on flexibility and product diversity and quality. Continued emphasis on technological accumulation. Environmental issues of growing strategic concern.

The above suggests that today strategy is highly complex with a broad combination of central strategic themes. This is a response to the complex and turbulent nature of the external competitive, technological and economic environment facing companies. To some extent technological innovation is seen as a means by which firms can attempt to adapt to the requirements of this difficult and uncertain environment: on the other hand rapid rates of technological change, associated shorter product cycles and the increased blurring of long-established industrial boundaries (technology fusion) (Kodama, 1992) are themselves a part of the difficulty.

Towards the Fifth Generation Innovation Process

Not only have dominant corporate strategy elements changed during the past forty or so years, but the dominant perceived model of innovation, and to a great extent the practice of innovation, have changed also. These changes are mapped below in the form of five generations of innovation process.

First generation: technology-push
From about 1950 to the second half of the 1960s the dominant model of innovation was the so-called technology-push model shown in Figure 4.3. This was a simple linear model that assumed a stepwise progression from scientific discovery through applied research to technological development and production activities in firms, leading to a stream of new products into the marketplace. The marketplace was seen simply as a sink for receiving the fruits of R&D. A fundamental assumption of this model was that 'more R&D in' equalled 'more innovation out'.

Second generation: need-pull
During the latter part of the 1960s, a period of intensifying competition, studies of actual innovation processes began to place considerably more emphasis on the role of the marketplace in innovation. This led to the emergence of the linear need-pull (or market-pull) model of innovation shown in Figure 4.4, in which innovations were deemed to arise as the result of perceived and sometimes clearly articulated customer needs. In this case the marketplace was seen as the source of ideas for directing R&D, and the R&D department had a largely reactive role to play.

Third generation: coupling model
During the 1970s a spate of detailed and systematic empirical studies showed the linear technology-push and need-pull models of innovation to be oversimplified, extreme and atypical examples of a more general process of *coupling* between science, technology and the marketplace (Myers and Marquis, 1969; Rothwell, 1976; Cooper, 1980). Evidence in favour of this view was summarized by Mowery and Rosenberg (1978) and few today would argue with their case for a more balanced approach between technology supply and market needs.

A still highly simplified, but nevertheless more representative model of the innovation process is given in Figure 4.5. This is the so-called interactive or coupling model which, according to Rothwell and Zegveld (1985), can be regarded as:

> . . . a logically sequential, though not necessarily continuous, process that can be divided into a series of functionally distinct but interacting and interdependent stages.

Figure 4.3 Technology push (first generation) (1950s – mid 1960s)

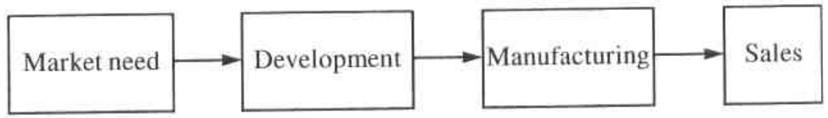


Figure 4.4 Market pull (second generation) (late 1960s – early 1970s)

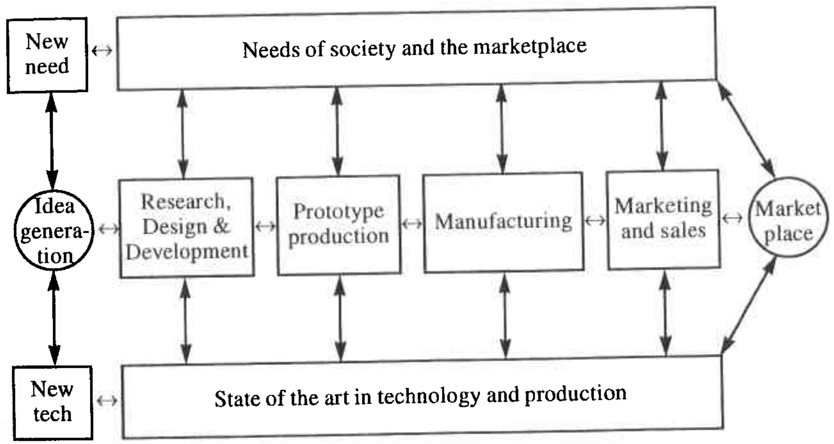


Figure 4.5 'Coupling' model (third generation) (mid 1970s – early 1980s)
Source: Rothwell, R. (1993), 'Systems Integration and Networking: Towards the Fifth Generation Innovation Process', Chaire Hydro-Quebec Conference en Gestion de la Technologie, University of Montreal, Quebec, 28 May (SPRU, University of Sussex, Brighton, UK – mimeo).

> The overall pattern of the innovation process can be thought of as a complex net of communication paths, both intra-organisational and extra-organisational, linking together the various in-house functions and linking the firm to the broader scientific and technological community and to the marketplace. In other words the process of innovation represents the confluence of technological capabilities and market needs within the framework of the innovating firm (Rothwell and Zegveld, 1985, p. 50).

Fourth generation: integrated model

Whilst the third generation innovation process contains feedback loops it essentially remains *sequential*, albeit with some inter-functional interaction and coordination. The first truly *parallel* models of innovation emerged following studies of innovation process in the automobile and electronics sectors in Japan. Here there is total or a very high level of functional overlap during innovation. An example of the 4G innovation process is presented in Figure 4.6, taken from the work of Graves (1987), in the Japanese automobile industry. A core feature of this so-called 'rugby team' approach (Imai, Nonaka and Takeuchi, 1985) is not just its parallelism, but also the high level of functional *integration* during concurrent activity.

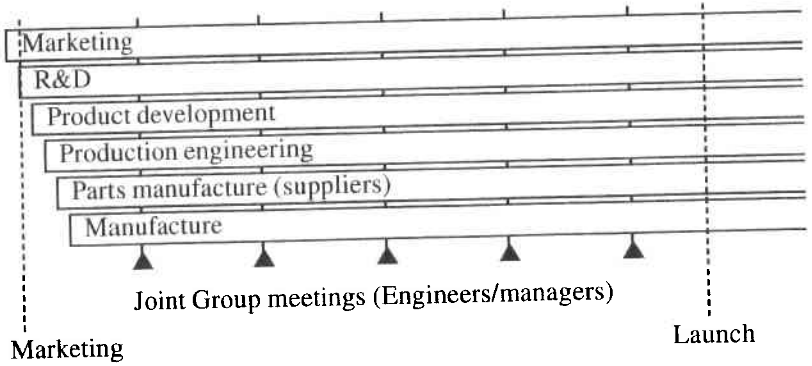


Figure 4.6 Example of the integrated (fourth generation) innovation process (mid-1980s–1990s) – new product development process in Nissan

Source: Graves, 1987.

Note: This representation of 4G focuses essentially on the two primary *internal* features of the process, i.e. its *parallel* and *integrated* nature. Around this in practice is the web of external interactions represented in the 3G process (Figure 4.3).

Fifth generation: systems integration and networking (SIN) (taken from Rothwell, 1992a)

An important feature of product development as practised in Japan is the apparent speed and cost advantages it provides Japanese innovators over their innovating counterparts in the West. For example several authors have, in seeking Japanese/US comparisons, shown that Japanese companies develop products faster and at lower cost in sectors as diverse as marine transmissions (Stalk and Hout, 1990) automobiles (Clark and Fujimoto, 1989) and machinery and instruments (Mansfield, 1988). In other words, cross-functional (parallel) development and more effective overall integration, with their inherently greater potential for higher real-time

information processing efficiency, can yield a speedier and more efficient product development process. Since one of the dominant corporate strategy elements during the 1980s has been development speed (time-based strategy), this has provided Japanese firms with a strong competitive edge.

Achieving increased development speed might, of course, carry with it additional costs; doubling development resources, for example, would almost certainly reduce development time considerably. According to Graves (1987) compressing development time by 1 per cent can increase costs by 1–2 per cent. Gupta and Wileman (1990) propose a 'U'-shaped time/cost curve and, quoting from the work of Mansfield (1988), suggest that Japanese firms are willing to devote considerably more resources to compressing development cycles if the long-term benefits (e.g. greater customer value) justify the short-term expense. Even when being first is not of overriding importance, the ability to be fast or timely might confer advantage to the firm. The ability to control product development speed can be seen as an important corporate core competence.

One interpretation of the comparative US/Japanese time and cost data is that the Japanese firms were operating near the bottom of the 'U' whilst US firms were too far to the right along their particular industry time/cost curve (there will be strong sectoral specificities). There is, however, little or no indication that Japanese firms are faster but more expensive than their US counterparts at product development. It seems reasonable to suggest – and there is strong evidence from the automobile sector in support of this contention (Graves, 1991) – that the US and Japanese firms were operating along different 'U'-curves; that US firms were operating along a third generation (3G) innovation curve whilst Japanese firms were operating along a fourth generation (4G) curve (Figure 4.5).

There is considerable evidence to show that innovation today has become significantly more of a *networking process*. During the 1980s the number of horizontal strategic alliances and collaborative R&D consortia have increased dramatically (Contractor and Lorange, 1988; Hagedoorn, 1990; Dodgson, 1993; Haklisch, Fusfeld and Levinson, 1986), vertical relationships, especially at the supplier interface, have become more intimate and strategic in nature (Maier, 1988; Lamming, 1992) and innovative SMEs are forging a variety of external relationships with both large and small firms (Rothwell, 1989; 1991). At the same time, pressures to become a *fast innovator* increased and, as we have seen, the Japanese have succeeded in being both fast and efficient innovators. Leading edge innovators today are moving towards a third and even more efficient time/cost curve (Figure 4.7) that is determined by the 5G innovation process – which is one of *systems integration and networking* (SIN) – in which, centrally, the use of a sophisticated electronic toolkit (elements of which are described in the following section) is enhancing the speed and efficiency of product development across the whole system of innovation (in-house functions,

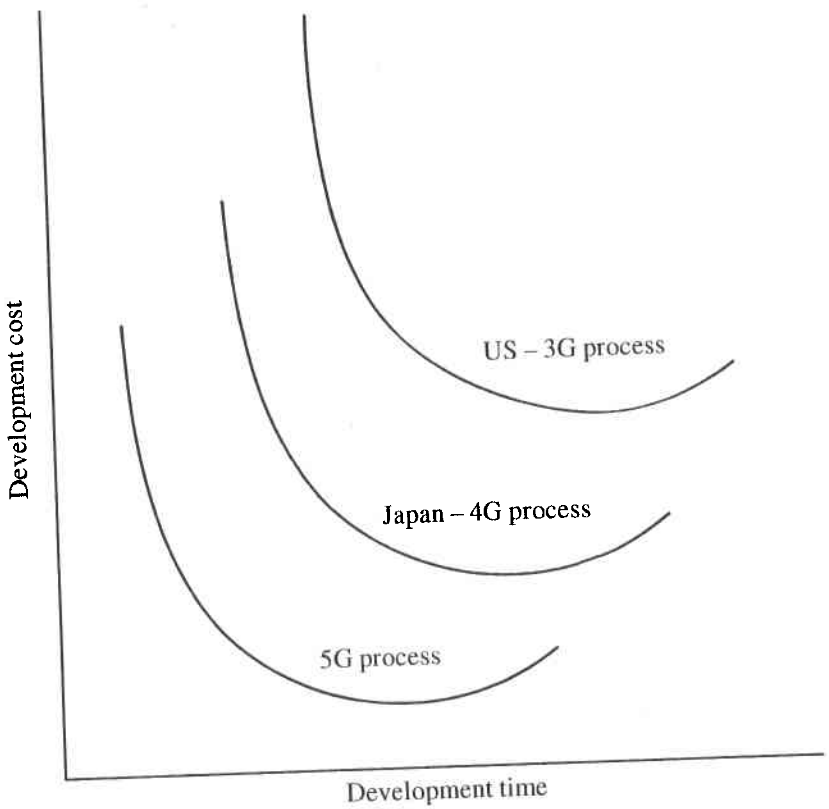


Figure 4.7 Product development time/cost relationships for the 3G, 4G and 5G innovation process

Source: Rothwell, R. (1993), 'Systems Integration and Networking: Towards the Fifth Generation Innovation Process', Chaire Hydro-Quebec Conference en Gestion de la Technologie, University of Montreal, Quebec, 28 May (SPRU, University of Sussex, Brighton, UK – mimeo).

suppliers, customers, collaborators). *5G essentially is a development of 4G in which the technology of technological change is itself changing.*

A wide variety of managerial, organizational and technological factors have been identified which contribute to enhanced speed and/or efficiency of innovation. Many are well established in the innovation literature; a few are more recent in origin. The most significant of these factors are dealt

(i) *Time-based strategy*
Given the scope of activities that needs to be addressed in order appreciably to accelerate product development, it is unlikely that significant gains could be achieved unless the issue was tackled on a broad front. This means that being a fast innovator must be at the forefront of corporate strategy.

(ii) *Top management commitment and support*
Visible top management commitment and support is important in achieving faster product development speed (McDonough and Barczac, 1991). Moreover, top management should be involved in the development process from the very beginning since, where late involvement occurs, this often results in design changes that are highly costly (Sommerlatte, 1992).

(iii) *Adequate preparation: mobilizing commitment and resources*
This comprises what Ansoff (1992) terms building platforms for change. It involves careful project evaluation, analysis and planning and, centrally, gaining commitment, understanding and support from the corporate entity and staff who will be involved in the project.

(iv) *Efficiency at indirect development activities*
Activities such as project control, project administration and coordination can account for up to 50 per cent of total project development time (Sommerlatte, 1992). Clearly, actions that render these activities more efficient have potential for significantly reducing development times and costs.

(v) *Adopting a horizontal management style with increased decision-making at lower levels*
The greater empowerment of managers at lower levels reduces the number of approvals required, and the reduction in hierarchy reduces approval delays (Dumaine, 1989).

(vi) *Committed and empowered product champions and project leaders*
Empowered product champions and project leaders can play an important role in achieving both successful and faster new product development (Graves, 1991).

(vii) *High quality initial product specification*
Not surprisingly, when the initial definition of product requirements is flawed, it results in unplanned changes during product development and can be a major factor in delay (Gupta and Wileman, 1990). It will also add significantly to development costs.

(viii) *Use of integrated (cross-functional) teams during development and prototyping*
Where parallel activities take place outside the framework of the fully integrated team, then continuous inter-functional interaction