New concepts and trends in international R & D organization

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Abstract

The globalization of markets, the regionalization of technical and scientific expertise, and the rapid change in technologies are forcing technology-based companies to continuously adjust their R&D organization. Our study of 33 companies reveals five different types of R&D organization in multinational companies (MNC). We classified R&D organizations according to the dispersion of R&D activities and the degree of cooperation between individual R&D units and identified the ethnocentric centralized, the geocentric centralized, the polycentric decentralized, the R&D hub, and the integrated R&D network organization. Five trends of organizational change among these forms of international R&D organization were identified: (1) Stronger orientation of R&D activities towards international markets and knowledge centers, (2) Establishment of tightly coordinated listening posts, (3) Strengthening and reinforcement of foreign R&D sites, (4) Increased integration of decentralized R&D units, and (5) Tighter coordination and recentralization of R&D activities at fewer know-how centers. The search for the optimal balance between coordination and control is reflected by hybrid structures and intermediary configurations detected in some of the investigated companies. Since effective changes in behavioral orientation require considerable time, successful quantum leaps in multinational R&D organization are next to impossible. © 1999 Elsevier Science B.V. All rights reserved.

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1. Internationalization of industrial R & D

Knowledge creation processes of technology-based companies have become increasingly global, yet remain limited to a relatively small number of countries in the world. Technology-based companies strive to locate their R&D activities at centers of technological excellence, i.e., regions characterized by a high rate of new technology output. This trend

is further intensified by a scarcity of resources at home.

Although many smaller multinationals that previously relied on centralized R&D now engage in sourcing technology from around the world, R&D internationalization of 1980s and 1990s is largely restricted to multinational companies. The pioneers of R&D internationalization are high-tech companies operating in small markets and with little R&D resources in their home country, as it is the case for ABB, Novartis and Hoffmann-La Roche (Switzerland), Philips (Netherlands) or Ericsson (Sweden). Swiss, Dutch and Belgian companies carried out more than 50% of their R&D outside their home

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Table 1

Importance of large company R&D activity in triad nations (time period 1994–1997). Data is based on the 50 largest R&D spenders worldwide

Nation	R&D share as of total R&D in that country	Total R&D expenditures in 1993 (US\$ billion)
USA	33%	55
Western Europe	42%	50
Japan	57%	43

Source: Company Reporting (1994) and OECD (1993).

country by the end of 1980s.² These companies increasingly conduct R&D in foreign research laboratories. Companies such as General Electric and General Motors in the USA, Toyota and Fujitsu in Japan, and Daimler–Benz in Germany having large home markets and a substantial domestic R&D base had less pressure to internationalize their R&D activities. Only in recent years have the increased competition from within and outside their industries forced these companies to source technological knowledge on a global scale.

Although the trend towards R&D internationalization had become apparent in the 1970s, it became a widespread phenomenon only as recently as in the late 1980s (Cantwell, 1995) (p. 161). In the mid-1990s, the 50 largest R&D spenders worldwide account for a considerable share of total R&D input in each of the triad nations, thus indicating the importance of (international) R&D activities carried out by multinational companies (illustrated in Table 1). The significance of international R&D activities is even larger when indirect influence of these companies on small- and medium-sized enterprises is taken into account.

As early as 1986, Dutch and Swiss companies had more laboratories outside their home countries than within (Pearce and Singh, 1991). Between 1985 and 1993, overseas investment in R&D by US firms increased three times as fast as domestic R&D. In the US, overseas R&D expenses reached 10% of overall R&D investment, up from 6% in 1985 (National Science Board, 1996) (pp. 4–44). In the same

period, the share of majority-owned foreign affiliates' R&D in the US rose from 9% to over 15% (National Science Board, 1996) (pp. 4–46). In 1991, Japanese multinational companies conducted less than 5% of their R&D abroad (Buderl et al., 1991) (p. 85), but the recent establishment of Japanese laboratories in Europe and the US increases the significance of Japanese-based global R&D (see, e.g., Dalton and Serapio, 1995). According to Buderl et al. (1991), European companies performed about one third of their R&D outside of their home countries.

The companies in our investigation sample continued to expand their overseas R&D activities during the 1990s, although the R&D-to-sales ratio seems to have leveled off. In general, our data confirms previous predictions of a continuing rise of international R&D.³ Many companies plan to further increase their number of international R&D sites in the next 5 to 10 years despite the notion of De Meyer and Mizushima (1989) (p. 139) that “globalisation of R&D is typically accepted more with resignation than with pleasure”. As Howells (1990) (p. 142) points out, modern information and communication technologies served to connect dispersed R&D activities and thus made distributed R&D organization possible.

While most R&D laboratories are concentrated in the triad countries, new R&D sites are now created in the newly industrialized economies of South-East Asia. Despite this trend, the present international distribution of R&D in many companies is not the

² See Pearce and Singh (1991), Granstrand et al. (1993) (p. 414), and Gassmann (1997a) (p. 53).

³ For example, Roberts (1995), Dalton and Serapio (1995), Odagiri and Yasuda (1996).

result of rational location planning but rather a side effect of decisions not directly related to R&D (e.g., merger and acquisitions, political pressures, tax considerations). The scope of all worldwide M&As has doubled from US\$369 billion in 1992 to an estimated US\$740 billion in 1995. In 1997, the volume of M&As amounted to US\$1630 billion (Securities Data, 1998). About 70% of all acquisitions are based on a market-driven rationale.⁴

Since the acquisition of innovative firms has become a strategy for gaining quick access to new technologies,⁵ the acquirer faces the challenge to rearrange the R&D activities of both firms in order to ensure some form of synergy. Gerpott (1994) suggests that post-acquisition strategy decisions are to be made centrally, as the advantages of a quick and clear provision of R&D strategy and implementation of organizational changes outweigh the motivation costs that might be incurred at the acquired R&D units. He stresses the importance of initiating integration programs in order to additionally improve R&D cooperation between acquired and original sites.

The management of cross-border R&D activities is characterized by a significantly higher degree of complexity than local R&D management. The extra costs of international coordination must be balanced by synergy effects such as decreased time-to-market, improved effectiveness, and enhanced learning capabilities. Corporate top managers are confronted with finding the optimal R&D organization based on the type of R&D activities, the present geographic dispersion of subsequent value-adding activities such as production and marketing, and the coordination between a multitude of contributors to the R&D process.

2. A brief literature review

Literature on R&D internationalization has concentrated on the economic and political perspectives

with a macro-economic or sectoral focus.⁶ Management research has long neglected international R&D.⁷ While an economic analysis of supply and demand factors explains *why* R&D laboratories were established in particular countries, it offers little insight into *how* to manage foreign laboratories (De Meyer, 1993; Gassmann, 1997a). Work by R&D managers and directors is concerned with operative problems of decentralized R&D,⁸ a topic which is only marginally represented in the academic literature.

A principal issue in R&D internationalization is the location decision, which has been studied on various levels.⁹ Although this research has produced invaluable knowledge that has immensely enhanced our understanding of the phenomenon per se, interviews with R&D managers have shown that a practical guiding framework for organizing international R&D is still missing.

Analysis of literature shows a lack of examination of organizational trends in R&D. In the past, researchers of R&D management have developed different taxonomies for international R&D units, but a comprehensive model for organizational change in R&D organization has not been achieved.¹⁰ Recent research in this area includes De Meyer (1993), Granstrand et al. (1993), Pearson et al. (1993), von Boehmer et al. (1992), and Gerybadze et al. (1997), which has been further refined by, e.g., Chiesa (1996), and Kuemmerle (1997a). Chiesa (1996) offers a taxonomy of international R&D organizational structures by distinguishing the type of R&D activities between experimentation and exploitation,

⁶ See Patel (1996), Papanastassiou and Pearce (1994), Beise and Belitz (1996), NIW et al. (1995), Amstad et al. (1996), Håkanson (1981).

⁷ See Cheng and Bolon (1993) (p. 3), Granstrand et al. (1993) (p. 414), Cantwell (1992) (p. 94). Pioneering work has been done by Potter (1971), Terpstra (1977), Granstrand and Fernlund (1978), Fischer and Behrmann (1979), and Håkanson and Zander (1988).

⁸ For example, Rubenstein (1989), Perrino and Tipping (1989), Asakawa (1996).

⁹ See Brockhoff (1997), Pearson et al. (1993), Gassmann and von Zedtwitz (1996), Håkanson (1992), Gerpott (1991), Wortmann (1990), De Pay (1989), Gassmann and von Zedtwitz (1998), Brockhoff and Schmaul (1996).

¹⁰ For example, Cordell (1973), Ronstadt (1977), Behrmann and Fischer (1980), Pearce (1989).

⁴ Kutschker (1989) (p. 12), Granstrand et al. (1993) (p. 416), Håkanson and Nobel (1993) (p. 402).

⁵ For example, Granstrand et al. (1992), Link (1988).

Fig. 1. Two-phase research process between 1994 and 1998.

and Kuemmerle (1997a) discusses how new R&D laboratories were established and how their primary objective is to be defined as either home-base augmenting or home-base exploiting. An extensive re-

view of international R&D units taxonomy is given by Medcof (1997). Medcof also suggests an eight-category taxonomy which encompasses previous taxonomies.

Fig. 2. R&D internationalization and R&D intensity of technology-based companies (1994–1998).

Table 2
Five typical forms of international R&D organization

Type of R&D organization	Organizational structure	Behavioral orientation
Ethnocentric centralized R&D	Centralized R&D	National inward orientation
Geocentric centralized R&D	Centralized R&D	International cooperation
Polycentric decentralized R&D	Highly dispersed R&D, weak center	Competition among independent R&D units
R&D hub model	Dispersed R&D, strong center	Supportive role of foreign R&D units
Integrated R&D network	Highly dispersed R&D, several competence centers	Synergetic integration of international R&D units

Despite a number of typologies of international R&D a description of the dynamics of international R&D organization is still missing. The development and change of concrete organizational configurations and their basic behavioral orientations deserves more attention. In our analysis we have found that the design of international innovation processes is determined by the dispersion of R&D sites and the potential cooperation between R&D activities. R&D organizations differing in their behavioral orientation and their competitive environment are thus likely to assume different organizational structures. Based on our research sample, we suggest a typology based on the two key parameters of R&D dispersion and degree of R&D cooperation along with a set of trends that characterize the evolution of organization in international R&D.

3. Research methodology

Our results are based on 195 semi-structured research interviews in 33 technology-based companies between 1994 and 1998 (Fig. 1). All companies are highly internationalized in terms of sales and operations in the electrical/electronics, automotive/turbines/heavy machinery, and chemicals/pharmaceuticals industries. Their home bases are in Europe (17), USA (5) and Japan (11).

The data for this research was gathered in personal interviews with principal representatives (R&D directors and managers) of each company, following a semi-structured interview guideline. We focused specifically on the management and organization of international R&D and its evolution over time. Among the issues that were addressed are the autonomy and independence of overseas R&D sites, the

cooperation between central and local R&D units, resource allocation and capital investment flows. This data was complemented by desk research, namely the analysis of corporate annual reports, company journals as well as internal memos, reports and presentations. Moreover, in follow-up sessions with our interview partners, we always confirmed the raw data as well as in-depth cases of the R&D organization and transnational R&D projects at each company.

Our study sample is depicted in Fig. 2. Each company is positioned according to its R&D intensity (R&D expenditures to sales ratio, horizontal axis) and R&D internationalization (ratio of foreign to overall R&D expenditures, vertical axis). The size of the circles indicates the extent of absolute R&D expenditures.¹¹

Based on the work of Bartlett (1986) regarding the structure of MNCs and the work of Perlmutter (1969) on basic behavioral patterns of MNCs, we attempted to classify R&D organization according to the dispersion of R&D activities and the degree of cooperation between individual R&D units.

4. Organizational concepts in international R&D

Besides distributed R&D sites, transnational R&D processes also require a favorable attitude towards

¹¹ Our initial hypothesis of a correlation between R&D intensity and R&D internationalization was not supported. We rejected the hypothesis for standard distribution of R&D intensity at the 90% confidence level, and for standard distribution of R&D internationalization at the 99% confidence level (Kolmogorov–Smirnov One Sample Test). The Pearson Test returned a correlation of only 17.7%. Hence, we conclude that there is no significant interdependence between R&D intensity and R&D internationalization.

<p><u>Behavioral Orientation</u></p> <p>Ethnocentric inward orientation Think tank as national treasure in home country Protection of core technology against competitors Homogeneous R&D culture</p> <p><u>Configuration</u></p> <p>Central R&D in home country Central and tight coordination and control of R&D program</p>	<p><u>Examples</u></p> <p>Balzers British Gas General Dynamics Microsoft Nippon Steel Sigg Toyota Volvo</p>
<p><u>Strengths</u></p> <p>High efficiency Low R&D costs (scale effects) Short cycle times Protected core technologies</p>	<p><u>Weaknesses</u></p> <p>Lack of sensitivity for local markets Danger of missing external technology NIH syndrome Tendency towards rigid organization</p>	

Fig. 3. Ethnocentric centralized R&D is characterized by a lack of transnational R&D processes as all R&D activities are concentrated at the home base.

cooperation and free flow of information. The differentiation of international, multinational, global and transnational companies by Bartlett (1986) is fundamental to the analysis of internationalization of corporations. For the purpose of our analysis in globally dispersed R&D and the relationship between individual R&D sites, we combined Bartlett's model with the categorization of multinationals according to their behavioral orientation by Perlmutter (1969). Based upon this work and our empirical observations, we discerned five ideal forms of structural and behavioral orientation in international R&D organization (see Gassmann, 1997a,b; p. 49) (Table 2).

Our terminology is derived from previous work concerning the international organization of firms.

4.1. Ethnocentric centralized R&D

In the *ethnocentric centralized* R&D organization, all R&D activities are concentrated in the home country. It is assumed that the home country is technologically superior to subsidiaries and affiliated companies in other countries, a notion which also defines the asymmetrical information and decision structures between home base and peripheral sites. Central R&D is the protected 'think tank' of the

company, creating new products which are subsequently manufactured in other locations and distributed worldwide (e.g., Toyota in Great Britain, Volkswagen in China). The core technologies, which ensure long-term competitiveness of the company, are retained as a 'national treasure' in the home country base (Fig. 3).¹²

Besides providing protection against uncontrolled technology transfer, this concept demonstrates high efficiency due to scale and specialization effects, which results in lower R&D costs and reduced overall development times. An efficient R&D unit therefore requires a certain critical mass of capital and personnel. Physical collocation of R&D employees, standardized management systems and a common understanding of R&D vision and values promote the flow of information between scientists at the R&D center and facilitate the control of R&D activities.

The main drawbacks of ethnocentric centralized R&D are the lack of sensitivity for signals from foreign markets and its insufficient consideration of

¹² This notion is supported by the 'Case of Non-Globalisation' of Patel and Pavitt (1992).

local market demands. Furthermore, the Not-Invented-Here syndrome occurs frequently, and the organizational structure tends to be very rigid (see, e.g., Quinn, 1985).

MNC should maintain this organizational form only if they do not differentiate between regional markets and have all the necessary technology in-house. This organizational form is typical for smaller MNCs because of specialization advantages, scope and scale effects, and limited resources. The organization is rarely questioned before a certain critical mass for R&D internationalization is achieved. The success of Microsoft shows that centralized R&D can be highly competitive and successful both at home and abroad when competencies and resources are abundant at the home country and product adaptation to local needs is minor, although even this dominant market leader recently established an overseas R&D unit in Cambridge, UK. If a company manages to establish a dominant design (Utterback, 1994) on a worldwide basis, then an explicit international orientation of R&D is not necessary. It may then be sufficient to consider certain country specific requirements like languages or different keyboards as in the case of Microsoft.

If the market (global or national) has traditionally been served from a central location, the company must have exceptional motives to locate R&D outside the immediate range of operations. As a company in the heavy industry, Nippon Steel came under enormous competitive pressure from economies with

low labor costs. The company has four corporate research laboratories near Tokyo (about 1000 researchers) and process development units in seven steelworks (about 150 engineers) supporting the factories and performing customer-related development tasks. The process development units also serve as interfaces between the steelwork sites and the central R&D laboratories. Corporate R&D was centralized in order to improve communication and to share the use of costly facilities. Plant engineers and researchers can easily communicate about plant layouts addressing cost considerations (the plant engineer's interest) as well as new product development (the researcher's interest) (Fig. 4).

Steel making is a highly complex undertaking requiring process and handling know-how. It is very difficult to establish a new plant abroad: Large plant investments are needed, and local competition can be very strong. Furthermore, protectionism is high in developing countries because their first steps into industrialization usually begin with heavy industries. Steel production is less attractive for highly industrialized countries, where technological knowledge is abundant. Thus, Nippon Steel engages in business partnerships through technical and financial cooperation, conducting all R&D centrally (see also Herbert, 1990; Kimura and Tezuka, 1993). The company also branches out into other domains of research, such as information technology, life sciences, and chemicals. In 1994, only 55% of all R&D expenses was invested in the traditional steelmaking research,

Fig. 4. Efficiency and low cycle times at Nippon Steel's centralized Corporate R&D Laboratories near Tokyo.

whereas 45% was assigned to R&D for ‘new businesses’.

4.2. Geocentric centralized R&D

The ethnocentric organization becomes inappropriate when a company becomes more dependent on foreign markets and local competencies. The *geocentric centralized* organization overcomes the ethnocentric home-base orientation while retaining the efficiency advantage of centralization. This requires extra investments in R&D personnel in order to increase their international awareness. At the central R&D site, knowledge of worldwide and external available technologies is accumulated. R&D employees’ sensitivity for international markets increases. This can be achieved by sending R&D employees abroad to collaborate and intensively communicate with local manufacturing, suppliers and lead customers. International awareness can be further improved by recruiting multi-lingual or foreign engineers with working experience abroad (Fig. 5).

In the early 1990s, Nissan had successfully implemented the geocentric organization. During the automobile development of Primera, a car targeted for the European market, Nissan formed a core project team located in Western Europe. This team was supported from Japan by some hundred engineers

who all had European cultural experience from numerous visits and extended stays. Primera was the first major market success for Nissan in Western Europe (Fig. 6).

Kubota established a technology development headquarters to ensure company-wide coherence of all R&D carried out in four central R&D laboratories and five divisions. As R&D activities differ from division to division, formal coordination between all R&D units can be quite complex. Kubota therefore relies on an indirect means of coordinating R&D: The exchange of R&D personnel, also at the manager’s level, is very important for fostering cross-functional collaboration. Kubota has no international R&D locations since the domestic market is still dominant. Strong linkages exist between global production sites and the home-based R&D organization, since the production sites are a main provider for new market needs and customer feedback. A computerized information network connects the entire corporation and rationalizes corporate functions and accelerates the innovation process by giving employees worldwide access to Kubota researchers and their work.

Geocentric centralized R&D offers a quick and inexpensive way to internationalize R&D without giving up the advantage of physically centralized R&D. The implementation requires a fundamental

Fig. 5. Geocentric R&D organizations overcome the lack of market sensitivity.

Fig. 6. Nissan's Primera development.

reorientation of values and behavior of home-based R&D personnel. Change agents with intercultural experience or background are needed to push for international orientation of all employees. If R&D internationalization is not systematically ensured, crucial local market requirements such as taste, trends and standards are ignored.

4.3. Polycentric decentralized R&D

Frequently, companies with a strong orientation towards regional markets (e.g., many European

MNCs in the 1970s and 1980s) adopt a *polycentric decentralized* R&D organization. Local R&D laboratories have been established by local distribution and manufacturing units, mainly in order to respond to customer product adaptation requests. Some firms exhibit a polycentric R&D structure because they have been formed by M&A activities and the synergy potential in R&D reorganization was not exploited. The organizational structure is characterized by a decentralized federation of R&D sites with no supervising corporate R&D center. Information flow

Fig. 7. The major challenge of polycentric decentralized R&D organizations is to overcome the isolation of formerly independent R&D units and to integrate them into a wider R&D network.

between foreign sites and the home base is limited with reports on current R&D activities often being late (Fig. 7).

The R&D director of a subsidiary in a polycentric decentralized R&D organization reports to local management. Although this configuration is optimal for local market sensitivity and the exploitation of local resources, its disadvantages are high autonomy and little incentive to share information with other R&D units (in particular central R&D) in early project stages. Efforts to preserve autonomy and national identity impede cross-border coordination, and therefore lead to inefficiency on a corporate level and redundant R&D activities. Furthermore, the company is in danger to lose the focus on a particular technology and technology convergence is difficult to achieve.

Royal Dutch/Shell spends almost US\$700 million on R&D carried out by 15 research establishments all over the world. The four elements to Shell Research are the research coordination in London and The Hague, Shell Group Laboratories, the Shell Oil Research Organization, and Shell operating company laboratories. The Amsterdam central laboratory and the seven group laboratories are located in the Netherlands, UK, France, Belgium and Germany.

These report directly to the Shell Group research coordinator, whose responsibility is coordination and planning of research activities. At Shell Oil USA, oil and chemical R&D is carried out mainly in Westhollow, whereas R&D relating to exploitation and production is conducted in Bellaire and Woodcreek. Certain other Shell operating companies also run laboratories in Canada, France, Germany, and Japan (Fig. 8).

Both pitfalls and opportunities of Shell's R&D organization can be exemplified in the case of Carilon, a multiple-application polymer developed between 1984 and 1997 in the central laboratory in Amsterdam, the Westhollow Research Center in Houston, and at a Belgium R&D laboratory. Duplicate R&D activity and the Not-Invented-Here syndrome were overcome to reach the decision of moving Carilon R&D to Houston, as the United States was the eventual target market. What was characterized as 'the most poorly managed project' in the company's history, became to be known as the first multinational product development at Shell. The decision to give one R&D center complete responsibility and the focus on market development turned the polymer into a success story. In retrospect, the multi-site configuration is considered more as an

Fig. 8. Shell's R&D organization is characterized by strong market orientation and a focus on customer adaptation work.

asset than as a problem, especially in the commercialization phase. Carilon succeeded because entrepreneurial business spirit eventually overcame technology orientation, secrecy problems and difficulties in process technology development.

The polycentric decentralized R&D configuration is the ‘dying model’ among the five forms of international R&D organization. Although the benefits of extreme market orientation are clear, most MNCs feel the pressure to reduce R&D costs. The emergence of distinct capabilities at each site, corporate-wide technology strategies, and the elimination of redundant development activities requires the proactive coordination of R&D units; hence the polycentric decentralized configuration gives way to hub or network-like structures of organization.

4.4. R&D hub model

The R&D *hub model* with its tight central control reduces the risk of suboptimal resource allocation and R&D duplication. Former Ciba-Geigy’s Head of R&D François L’Eplattenier maintains that “only those who knows how to control R&D from their home base know how to manage an international company strategically.” The R&D center in

the home location is the main laboratory for all research and advanced development activities, retaining a worldwide lead in relevant technological fields. Foreign R&D which usually evolve from technological listening posts sites focus their activities on predefined technological areas. The R&D center tightly coordinates decentral R&D activities by means of long-term R&D programs as well as resource and personnel allocation. This model guarantees an efficient technology transfer and permanent technical assistance. An R&D center may be formed as a legal entity which owns all of the technological knowledge and intellectual property (Fig. 9).

The Research and Technology Department of Daimler-Benz, one of the largest industrial groups for automobiles and transportation, has its corporate research center in Stuttgart, Germany. Five other German R&D sites were integrated into corporate research after their parent companies were acquired or through internal reorganization. Starting in 1995, Daimler-Benz established local R&D presence outside Germany. R&D internationalization was driven by two factors: Search for centers of innovation, and market proximity (Vöhringer, 1997). The Research and Technology Center in Palo Alto was located near major information technology companies and close to Stanford University in Silicon Valley. As

Fig. 9. The R&D hub model is usually a reaction by centralized companies to the internationalization of resources.

early as 1997, Daimler-Benz was able to introduce a prototype car dubbed 'internet multimedia on wheels', integrating latest navigation, communication and internet technologies. The Research Center India was established in Bangalore in order to be present in this region of high software productivity: India's software industry has been growing by 40% annually. Daimler-Benz not only expects substantial input for its multimedia, telematics and manufacturing solutions, but also considers Bangalore as a bridgehead for gaining access to local subsidiaries and the Indian industry (Fig. 10).

The second factor of internationalization was to locate R&D close to the local market. In Shanghai, a joint research laboratory was established to support the microelectronics subsidiary Temic in electronic packaging. These R&D activities are tightly coordinated with microelectronics research in Germany; scientists are exchanged between China and Germany on a regular basis. Since 1996, the Vehicle Systems Technology Center in Portland supports the US-American Freightliner subsidiary. The aim is to introduce local market specifications early in the product development process, particularly in automotive system technology. Another research focus is on 'human factors engineering'. The Portland center coordinates with automobile research in the German headquarters and other international R&D sites.

The four foreign R&D centers are also responsible for keeping abreast with local technology development. In Russia and Japan, where Daimler-Benz is not present with research centers of its own, this task is assigned to designated listening posts. Their agenda also includes technology monitoring, initiation and coordination of research cooperation, and the establishment and maintenance of scientific networks.

Another example of a company with an R&D hub organization is the United Technologies Corporation, a high technology group in the aerospace, building systems and automotive industries. The corporate research center (UTRC), from where international R&D activities are coordinated, is located only miles away from the headquarters in Hartford, Connecticut. Development is decentralized in competence centers mostly across the US, and some in Japan and Europe. The UTRC operates small outposts in Germany, Spain and Japan to facilitate access to local talent and resources. Another rationale for local presence is proximity to the market as well as to local universities and other research institutes. Since access to technological knowledge external to the company is crucial for sustaining continuous innovation, the UTRC encourages intensive networking, conferencing and bilateral research contacts. International UTRC units serve as bases for

Fig. 10. Daimler-Benz's R&D hub model—listening posts and tightly coordinated research sites.

local researchers to convey technological information back to central research in East Hartford. One of the main tasks of the UTRC is to realize synergy effects from a multitude of technological competences for further exploitation in product development at the UTC's business units.

The advantages of the hub model are the quick recognition of local demands and the sustained integration of global R&D activities. The innovativeness of the company is reinforced by the exploitation of dispersed competencies and the variety of their input. The main drawbacks are found in the rising costs of coordination as well as the danger of suppressing creativity, initiative and flexibility in decentralized R&D sites by central directives.

A critical success factor of the hub model is the size of the foreign R&D units: On the one hand, each unit must be large enough to ensure a critical mass of operation; on the other hand, it must not exceed a level where the risk of redundant activities is too large (see Kuemmerle, 1997b, for an analysis of laboratory size and its determinants). Furthermore, the management systems of all R&D sites must be compatible, as intensive information flow between the center and the decentralized R&D units is to be ensured. The center has to hold sufficient compe-

tency to fulfill its technology leader role and to coordinate all worldwide activities effectively.

4.5. Integrated R&D network

It is next to impossible to exploit globally distributed competencies by means of bilateral treaties between a dominant center and peripheral units. The classical dyadic center-subsidiary relation loses its significance in the *integrated R&D network* model. Domestic R&D is no longer the center of control for all R&D activities. Central R&D evolves into a competency center among many interdependent R&D units which are closely interconnected by means of flexible and diverse coordination mechanisms (Fig. 11).

MNCs that assumed a network organization were often organized along a hub or polycentric configuration. In contrast to the hub model, foreign R&D units in the integrated R&D network assume strategic roles affecting the entire company: A competence center should not only act as a sensor for possible change in its respective area, but should also engage in defining appropriate strategies and new business development. While the major effort in this case is to improve the authority and competency of

Fig. 11. The integrated R&D network is characterized by authority for technology or component development based on individual capabilities of R&D units.

R&D units, the shift from a polycentric to a network configuration is based on exploiting potential synergy between newly connected R&D sites. A prerequisite condition for effective network operations is a sophisticated global information technology infrastructure (Howells, 1995; Boutellier et al., 1998).

Although polycentric decentralized R&D units may also establish excellent local competencies, the integrated R&D network makes sure that their skills and knowledge are best leveraged for the benefit of all R&D units. Various companies, among them Nestlé and Philips, moved from a polycentric decentralized organization towards an integrated R&D network, thus increasing global efficiency of R&D. The pharmaceutical industry is also characterized by a systematic development towards competence-based organization. Pharmaceutical giants such as Bayer, Hoffmann-La Roche, Novartis, Hoechst and Schering are assigning their R&D centers clear long-term objectives.

The integrated R&D network requires a change from simple control structures to a set of complex coordination structures. In particular, the role of the central R&D site changes from a control center to an R&D unit with equal rights and duties. Flexible connections and relations between network partners enable better utilization of available competencies, contribute to the realization of specialization and scale effects, and reduce the risk of duplicate development. Multi-site projects pose an ideal forum for focusing goal and task-oriented resources, while their temporary character assures their flexibility.

Each unit in the network specializes on a particular product, component or technology area. Due to the accumulation of knowledge in a particular field of specialization, this unit assumes a leading role as a competency center. The unit is then responsible for the entire value generation process, not just for product-related R&D. The unit is assigned a “world product mandate” (Pearce, 1989) if it holds exclusive rights to manufacture and market a product, and if it agrees to carry out all the necessary R&D activities. Knowing best about potential markets and application areas for this product, the unit is responsible for the coordination of product generation and world-wide market introduction.

Nestlé's R&D network consists of 15 research centers and 21 R&D units in 10 countries. Most of

the R&D locations were acquired during the market-oriented expansion of the company. Each of the research centers specializes in a particular technology area. The coordination of worldwide activities and the identification and exploitation of synergies is managed by less than 20 people who reside in the legally independent R&D company called Nestec. Besides R&D coordination, Nestec is also responsible for technology and know-how transfer as well as technical services for the globally dispersed production sites. Each of the production sites has entered a license contract with Nestec for above-described services and the usage of the Nestlé trademarks.

Nestec shares its know-how with group companies through a technical assistance agreement. When entering into such an agreement, Nestec's partners have access to R&D results, norms and quality standards, and industrial know-how, including the assistance of qualified specialists and R&D support for market introduction. Nestec also offers professional development and management training. This ensures a common corporate culture encompassing the traditions, mentalities and cultural differences of 3000 employees from 60 countries around the world.

In 1996, Schindler Lifts started to implement a competence-based R&D network. Schindler's rapid expansion—the worldwide leader in escalators and second in elevators—is based mainly on acquisitions. Its R&D is therefore dispersed over several units in Switzerland, France, Spain, Sweden and USA. In order to avoid duplication and to realize synergy, its management has started to identify and analyze core competencies in R&D. These core competencies and the change from a functional organization (e.g., software, mechanics, electronics) to a module-oriented organization (e.g., drive, control, hoistway, car) have been the basis for a major reorganization of R&D in 1998. R&D activities are now conducted in three areas: Corporate R&D, manufacturing R&D and field operations engineering. Each R&D area has its own mission; the efficient integration of these areas in a highly interdependent network is a prerequisite for the low cycle-time development of advanced product systems (Fig. 12).

The role of the R&D sites and the involved individuals should be defined anew for each project. The breadth of perspective and interorganizational

Fig. 12. Schindler's integrated R&D network is based on core competencies.

flexibility is supported by career paths that offer not only vertical but also cross-functional and horizontal assignments. Learning processes are usually initiated by sporadic and ad-hoc exchange of information and experience. Long-term support and institutionalization of such learning processes is facilitated by a coordination function, especially if these processes span several locations. The coordinators promote intensive flow of communication between all nodes of the network.

5. Trends in organizing international R&D

The international R&D organization of a firm is not rigid nor uniformly understood throughout the company but subject to continuous change. Five principal trends of organizational change have been identified in our research sample (Fig. 13).

Trend 1: Many companies with centralized R&D are adapting to their international environment. They have realized that their R&D processes have to be aligned better with international market needs. In order to incorporate expertise from foreign centers-of-innovation, the R&D center is opened to external

information and feedback. This trend of cultivating foreign sensitivity is particularly strong in the automobile industry.

Trend 2: When it is felt that purely central product adaptation fails to sufficiently satisfy local mar-

Fig. 13. Five major trends drive the evolution of international R&D organizations.

ket requirements or when foreign technology development becomes too significant to ignore, companies establish listening posts in areas of technological expertise around the world. Tapping of foreign technology and knowledge bases becomes the main source of know-how. The efforts of many large Japanese companies in building up basic research laboratories in Europe are part of establishing a network of tightly controlled R&D units, e.g., Hitachi's research centers for information science in Dublin and for microelectronics in Cambridge.

Trend 3: Due to increasing competencies and technological strengths of decentralized R&D units, companies that recently exerted rather tight central control over their R&D sites are now granting more autonomy and empowerment. As they are assigned a strategic role in the R&D network, their flexibility is improved and creativity flourishes. Information flows freely, and each site pursues a well defined R&D mission (e.g., Sony).

Trend 4: Company growth based on mergers and acquisitions and strong local R&D capabilities often result in relatively autonomous R&D units. If they recognize the benefits of integration and interconnection of their R&D activities, centers of expertise are created and mechanisms for international R&D coordination are introduced. For example, General Motors created competence centers for each component group such as its engine development in Rüsselsheim. As a result, duplicate R&D occurs less often, and a clear technological focus can be set.

Trend 5: All in all, we notice a trend towards the integrated R&D network. Pressure of cost reduction forces companies with an integrated R&D network to focus on a small number of leading research centers (re-centralization). The goal of this consolidation is to better exploit scale effects and to improve the coordination of worldwide dispersed R&D activities, simultaneously reducing the amount of duplicate R&D and intensifying cross-border technology transfer.

6. Organizational costs as driving factors

In this section, we intend to explain the trends toward the integrated R&D network which we have observed in the examined companies.

The search for optimal organization has been discussed in several theories of new institutional economics: Property rights (Coase, 1937), principle agency (Ross, 1973), transaction costs (Williamson, 1987), as well as new combined approaches such as the consideration of different knowledge types and their organizational costs (Jensen and Meckling, 1996). These theories explain the quality of coordination, centralization, and interaction in organizations. For our discussion we focus on those organizational concepts having dispersed R&D: The R&D hub model, the integrated R&D network, and the polycentric decentralized R&D configuration.

For simplicity, we assume a given number of R&D sites. In Fig. 14, we have depicted and aggregated the major cost drivers for organizing decentralized R&D activities in two cost curves: one for costs of central coordination (C_1), the other for costs of achieving local effectiveness (C_2). The relative height and shape of the curves are only a rough estimate because they also depend on a number of secondary cost drivers as well as company-specific characteristics. The shape of the two costs curves is concave because of increasing marginal costs of central coordination as well as increasing marginal costs of effectiveness and duplication.

Tight coordination leads to costs of central coordination C_1 . The principal factors are transactions costs in the widest sense (TA), costs for maintaining a sophisticated information system (IN), and opportunity costs for ignoring local market requirements (MA) and not exploiting local resources (RE). Strong local market orientation leads to costs of achieving local effectiveness C_2 which consist of duplication costs due to 'reinventing-the-wheel' and unintended parallel development (DU), costs due to subcritical mass such as fix costs for infrastructure and administration (SU), agency costs resulting from conflicts of interest in cooperative behavior (AG), and opportunity costs for the lack of know-how spill-over and synergy between the R&D sites (SY).

It is important not to confuse the combination of the two main cost aggregates. Clearly, the costs of coordinating an integrated network is much higher than the costs of coordinating a number of essentially dyadic relationships between the center and foreign R&D units, as in the hub model. The compilation of the typical cost drivers in the two cost

Fig. 14. Minimizing total organizational costs by balanced coordination.

curves results in average cost intensities for central coordination and achieving local effectiveness.

The total costs of organizing decentralized R & D is minimal where the sum of the two cost aggregates,

$$C_T = C_1(\text{TA,IN,MA,RE}) + C_2(\text{DU,SU,AG,SY}),$$

is minimal. It appears that the total organizational costs C_T are lowest in the integrated R & D network which is characterized by balanced coordination and global efficiency with leveraged competencies.

There are weaknesses in such a mathematical formulation of this complex organizational issue. This mathematical expression is only an attempt to explain the observed trends in organizing international R & D by clarifying the decision situation in a more formal way.

We realize that the strategical shift from one organizational concept to another, i.e., from the poly-

centric decentralized or the hub model to the integrated network, is:

1. Determined rather by careful consideration of opportunities and risks than by the output of a mathematical formula;
2. Driven rather by decisions external to R & D such as the reorganization of the entire corporation and by political interests;
3. Rather a smooth transition than a sudden switch; short-term quantum leaps in reorganization are next to impossible.

7. Conclusions

While the internationalization of industrial R & D of the 1980s and 1990s has reached a remarkable level, it has been predominantly limited to large

MNCs. In our study of some of the largest R&D spenders and the most global industrial innovators, we analyzed some organizational and strategic aspects of cross-border innovation processes.

From the investigated companies, we generalized the following five types of international R&D organization which differ in organizational structure and behavioral orientation:

1. Ethnocentric centralized R&D,
2. Geocentric centralized R&D,
3. Polycentric decentralized R&D,
4. R&D hub model, and
5. Integrated R&D network.

We described major strengths and weaknesses of each of these types along with clarifying examples. Moreover, within these organizational types, we observed five principal trends:

1. Orientation of R&D processes towards international markets and knowledge centers;
2. Establishment of tightly coordinated technology listening posts;
3. Increase of autonomy and authority of foreign R&D sites;
4. Tighter integration of decentralized R&D units; and
5. Increased coordination and re-centralization of R&D activities in fewer leading research centers in order to improve global efficiency.

The trends towards the integrated R&D network can be explained by the minimization of total organizational costs. In the entire research sample, we identified a clear trend towards the presence in a few but leading geographical areas. These regions stand out because of excellence in technological innovation or because of their characteristic as lead markets. Simultaneously, a large number of companies are striving for an enhanced exploitation of synergy between decentralized R&D locations. Global efficiency prevails at the costs of local effectiveness.

These trends of R&D internationalization further increase the significance of transnational R&D projects. They represent an invaluable tool to handle multi-site coordination, the reduction of duplicated R&D efforts, and the realization of synergy effects. With the rapid development of new information and communication technologies it is expected that the costs of coordinating decentralized R&D will further decrease. The importance of R&D internationaliza-

tion and global knowledge creation processes for competitive advantage will therefore further increase for technology intensive multinationals.

Our research is not concluded. The organizational types and trends need to be verified quantitatively on a wider basis. The evolution of international R&D organization should be tracked over an extended period of time in individual companies in order to understand better the underlying forces of their development. In general, the cause and effect of organizational change in international R&D organization requires further scrutiny and elaboration.

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