Chapter 14

Communication and Knowledge Flows in Transnational R&D Projects

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Abstract

Multinational companies exist in part because of their ability to tap into worldwide centers of expertise and disseminate this knowhow within the global firms. However, sharing knowledge efficiently is difficult even in highly networked organizations. Knowledge flows are hindered by spatial distance, costs of set-up and maintenance of communication structures, and lack of trust between distant sites. This chapter focuses on three key dimensions of virtual organizations: 1) knowledge transfer, 2) communication quality, and 3) coordination, and analyzes them in transnational R&D projects in industrial companies. Based on a cross-case comparison along the three dimensions, this chapter proposes inter-, intra- and multilocal aspects of virtual R&D teams, suggests three propositions, and concludes with managerial implications.

Keywords: Global Innovation; Transnational R&D; Virtual R&D Teams; Internationalization of R&D

1 Challenges of Managing Cross-Border Knowledge Flows

Multinational companies (MNCs) account for nearly one third of global production output (OECD 2018) but are estimated to be responsible for approximately 80% of global trade (UNCTAD 2011). MNCs also dominate international R&D: 70-80% of worldwide R&D investment is attributed to the 150 largest technology-intensive companies. As Iansiti (1998) noted, the organization of R&D must be designed to selectively retain information, process knowledge, and apply know-how. Although R&D is generally more centralized than other functions, it is often dispersed internationally to seek and transfer local know-how—as a consequence, knowledge flows increasingly across multiple locations worldwide.

R&D managers in technology and knowledge intensive companies have thus been increasingly confronted with the challenge to manage projects involving team members from different business units and R&D laboratories, often separated by thousands of kilometers and multiple time zones. Conventional innovation processes are traditionally designed with collocated project teams in mind, and it is only comparatively recently that spatial dispersion has become a determinant in managing R&D and innovation projects. Such projects have been labeled 'virtual' R&D projects, 'transnational innovation projects, or 'global' product development projects (Chiesa, 1996; Gassmann and Zedtwitz, 2003a).

What are virtual R&D teams? Based on Lipnack and Stamps (1997), we define virtual team as a group of people or entities who interact through interdependent tasks guided by common purpose, working across space, time, and organizational boundaries with links strengthened

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by information, communication, and transport technologies. Participation in such virtual teams may be temporary for individual members and their actual contribution may be undefined. We do not assume that members in virtual teams never meet face-to-face (e.g., Kristof et al., 1995), but are aware that a substantial part of the communication is mostly technology-supported (Maznevski and Chudoba, 2000).

But innovation projects with distributed R&D are difficult not only because of poor communication quality. The dominant orientation of decentralized organizations towards local markets and customer makes it difficult for local R&D units to adequately invest in and establish transnational cooperation. Not-invented-here syndromes, local fiefs, localized data standards, different languages, cultures and behavioral preferences as well as incompatible work routines impede efficient cooperation between teams. Individual R&D units are strongly based in the local environment, often with little integration—and little interest—in the worldwide organization. However, willingness to share information and constructive contributions to the overall project objective are necessary for virtual R&D teams to succeed.

To address the underlying questions, data was collected as part of a number of related research projects conducted over the last two decades, all of which were focused on international R&D management and virtual innovation teams. The unit of analysis for this research is the virtual team working on a project with decentralized resources. More than 150 research interviews with project managers, senior R&D staff, and other key people engaged in decentralized teams was analyzed for this research. Interview minutes were captured in writing and sent back for review and feedback. In addition, we were able to participate in project meetings or had access to communication protocols or documented communication. In alignment with Yin’s (1994) requirement for data triangulation, we also collected secondary material on these teams and the organizations in which they were embedded. The researched teams had a strong focus on R&D, new product development (NPD) and innovation. In total, we surveyed teams in more than 40 companies, including firms in the pharmaceutical and chemical industry, engineering, consumer electronics, and IT/software.

As the goal was to identify also practical solutions to the problems incurred by spatial dispersion, most notably knowledge sharing and team coordination, we pursued our research in light of the following guiding questions:

Who do members of virtual teams communicate, i.e. formulate and transfer knowledge to other project members?

- How often and how much coordination and communication is necessary?
- How is control and communication executed via modern information technologies?

This chapter continues by identifying typical problems of virtual R&D and three critical factors for communication and coordination, and by illustrating practices of selected international R&D organizations. It then conducts a cross-case analysis of knowledge flows in different virtual R&D organization, and proposes a model that maps interdependence and spatial dispersion within virtual team organization. It concludes with the most important managerial implications for managing virtual R&D teams.

2 Reviewing Problems of Decentralized Innovation

2.1 An Example from Management Practice: Shell's Carilon Project

An example of a company with highly competent but dispersed R&D units is Royal Dutch/Shell. In 2018, Shell spent almost US$ 1 billion on R&D carried out by more than a dozen R&D centers worldwide. Shell's early experience with coordinating distributed R&D efforts is illustrated by its Carilon project, a multiple-application polymer developed between 1984 and 1997. This polymer was first developed in a Belgium R&D laboratory, but then the central laboratory in Amsterdam got involved and—as the United States was discovered to be the ideal target market—the Westhollow Research Center in Houston. For some time there was duplicate R&D activity and the presence of the Not-Invented-Here syndrome among researchers in various participating sites. Researchers were not communicating between different R&D sites, and political resistance grew. With the prospective polymer development not making significant progress, Shell eventually overcame some of the well-established 'laws' cherished in conventional R&D, and as a consequence gave one R&D center complete responsibility for the polymer's development. The additionally enforced focus on market development turned Carilon into a success story. What was initially known as "the most poorly managed project in the company's history" became the first successful multinational product development at Shell.

In retrospect Shell's multi-site configuration was considered more as an asset than as a problem, especially during the commercialization phase. Not all companies are this fortunate, and most struggle with seemingly insurmountable problems. Companies that have started to establish international R&D sites but have little experience in coordinating and integrating them towards coordinated platform development programs typically face the following issues:

- Poor coordination and exploitation of synergy between distributed R&D centers due to unclear technical and product responsibilities and poor collaboration and communication among R&D sites.
- Different standards and platforms of information and communication technologies.
- Difficulties to initiate and lead multinational/multicultural/cross-border teams as well as ineffective team management across long distances during long projects.
- Difficulties to share knowledge and experience across sites and ineffective knowledge transfer; as a consequence, low integration of decentralized technology and application knowledge.
- Optimization of local business with customers and suppliers at the expense of global partnerships.

In summary, these R&D organizations are struggling to align diverging objectives across multiple locations.

2.2 Review on Critical Factors in Virtual R&D Project Management

Despite substantial research in project management, many open questions remain with respect to the management of dispersed collaborative R&D projects (vom Brocke and Lippe, 2015). The literature either adapts conventional (i.e. non-dispersed) R&D project organization for transnational uses (e.g., Wheelwright and Clark, 1992; Gassmann and von Zedtwitz, 2003a), or develops novel conceptual schemes (e.g., Chiesa and Manzini, 1996). Most research stresses the importance of informal or soft coordination tools in addition to traditional project management methods (e.g., Reger, 1999), but often fails to spell out their integration in multi-site R&D project execution and organization.

Most research on R&D project management makes little distinction between global and local project execution. Handbooks and project manuals have been developed for conventional local projects. With the advent of the Internet and online communication, project management has been updated with respect to mobile IT solutions. When managers of international projects consult this literature, they are either applying conventional wisdom to a new environment and thus risking sup-optimal behavior, or they are forced to improvise and make intuitive decisions where established knowledge is lacking (Boutellier et al., 1998; Griffith et al, 2003). Conventional projects are not fundamentally different from virtual projects, but key elements long taken for granted are often applied to virtual project environments without adapting them to potentially new requirements.

One such key element is the role and *power of the project manager*. Burgelman (1984) describes the problems internal group and venture leaders are faced with, recommending additional support roles by corporate and middle-level managers. In a study on the locus of power between project and functional managers, Katz and Allen (1985) argue for considerable power in the hands of project managers in order to improve organizational support and coordination authority. Four types of team structures-from functional to heavyweight-were finally typified by Clark and Wheelwright (1992). Closely related to the degree of leadership authority in teams is the *significance of the project* and its success to the corporation (e.g. Burgelman, 1984; Thamhain and Wilemon, 1987; Roussel, Saad, and Erickson, 1991).

While much has been written about *funding* of R&D in general, the allocation criteria for funding specific R&D projects were intensively debated (e.g., Madauss, 1994, EIRMA, 1995). Different exposure and assessment to risk asks for different funding models. Based on comparative analysis of 300 companies, Szakonyi (1994) points at the poor relations of R&D with finance and accounting departments. Funding sources and costs of projects are disclosed in case studies and other accounts of R&D project management (e.g., Borgulya, 2008; Wyleczuk, 2008). Large-volume projects are categorized and reviewed differently from regular projects, and their project management is often given more autonomy and authority. Although *costs* are typically better accounted for in projects than in functional environments, hidden costs occur particularly in accelerated product development (Crawford, 1992).

Clear *project aims* seem to be a necessary condition for project success (e.g., Roussel, Saad, and Erickson, 1991: 151; Dimanescu and Dwenger, 1996: 82). However, innovation effectiveness depends on the initial diversity of project ideas and the appropriate and timely definition of product specifications. Two important determinants come into play. First, at the time of specification freezing, all *system interfaces* must have been negotiated and defined. Technical uncertainties (Madauss, 1994), organizational inertia and structures (Henderson and Clark, 1990), reciprocal interdependencies (Nadler and Tushman, 1990) as well as difficulties in knowledge mode conversions (Nonaka and Takeuchi, 1995) make this a less than trivial task. Second, the *project owner* as the main protagonist and champion of the product idea exerts significant influence over technology and market targets (see e.g. Rubenstein 1989). Project ownership and commitment creates direction, momentum and a common purpose (Katzenbach and Smith, 1993; Leavitt and Lipman-Blumen, 1995).

Besides content-specific integration, appropriate planning, reporting, control and information systems help to manage the R&D process (e.g., Roussel, Saad, and Erickson, 1991: 157). But special efforts in establishing team culture or align individual project objectives are needed to achieve *project coherence* (van de Ven, 1986; Thamhain and Wilemon, 1987). R&D groups that create their own dynamic orderliness have been referred to as 'self-organizing teams' (Burgelman, 1983; Imai, Nonaka, and Takeuchi, 1985). Self-organizing teams as well as project teams composed of members of diverse functional specializations are capable of cross-fertilization. In above-mentioned study, Szakonyi (1994) observes that the commitment towards establishing *cross-functional integration* is present but in general weakly supported. Such structural linking could be achieved by liaison officers, cross-unit groups, project integrators, or matrix organization (Nadler and Tushman, 1990).

During integrated problem-solving, communication between members of the team is particularly intensive (Wheelwright and Clark, 1992). *Communication tools* and communication facilitators have long been recognized to improve R&D quality and effectiveness. Based on Allen's (1977) seminal work, R&D managers lay-out R&D facilities to enhance and facilitate communication. Tushman (1979) observes, however, that communication patterns differ with function (research, development, technical service) and operational needs both within and outside the firm (operational, professional). As Dimanescu and Dwenger (1996) argue, it is important to maximize the opportunity for interaction and information exchange and not the actual information flow. This also extends to the project manager’s ability to communicate directly with each team member (Hoegl et al., 2004). Frequent interaction may not lead to interpersonal *trust* automatically, but absence thereof certainly does not help either (Breu and Hemingway, 2004; Muethel et al., 2012).

With the ongoing trend towards empowerment and decentralization (see e.g. Albers and Eggers, 1991), communication tools have become a vital ingredient for effective *coordination*. Conventional R&D coordination tools (e.g., Cooper and Kleinschmidt, 1991; Madauss, 1994; O'Connor, 1994) are being complemented by new organizational structures (de Meyer, 1991), modern communication instruments (O'Hara-Devereaux and Johansen, 1994) and boundary-crossing individuals (de Meyer, 1991; Ancona and Caldwell, 1997). However, it is still unclear whether dispersed projects require disaggregation along task lines, or whether organic coordination mechanisms compensate for deliberate (or inadvertent) lack of formal coordination (Perea and von Zedtwitz, 2018).

Global R&D management literature has pointed to increased impediments of communication and coordination in international R&D (e.g., Rubenstein, 1989). De Meyer and Mizushima (1989) introduced "the half-life effect of electronic communication", pointing out that e-mail is at best complementary to face-to-face contact. Groupware and its usefulness in sharing know-how worldwide have been described by O'Hara-Devereaux and Johansen (1994), Campagna and Roeder (2008) provide an interesting example of its application. The early use of ICT in R&D has been studied by Howells (1995); in particular he summarizes some preconditions for cross-border R&D teamwork. With ICT a familiar tool for many engineers and scientists, its utilization for R&D management was just a matter of time. The adoption of global project coordination mechanisms has been somewhat slower. Nevertheless, our understanding about the value of ICT in virtual R&D management is improving (Boutelllier et al., 1998; Naman, Dahlin, and Krohn, 1998; Griffith et al., 2003).

2.3 Transnational, Interlocal, or Multilocal? – Aspects of Task Dependence

The guiding research questions thus is*: 'How to organize and control transnational R&D activities.'* 'Transnational' is defined as the quality of distance which makes regular convenient face-to-face contact impossible. In this sense, 'interlocal' may be a more suitable synonym than 'transnational'. The two R&D units of Endress+Hauser in Reinach (CH) and Maulburg (GER), both situated only a few kilometers away, would then have a large share of transnational projects, while research between UTC's East Hartford site and the one in California would not be considered as 'transnational' even though both sites are in different time zones.

The motivation behind measuring interlocality is that once the determinants of transnational R&D are identified, the quality of interlocal or multilocal activities may be measured and controlled, and this in turn allows to improve the planning and organization of transnational R&D activities. This is in line with one of the primary objectives of R&D controlling: Making the R&D process transparent in order to provide a sound base of information for future decisions and planning.

The prerequisite of multi-site research activities is that the work must be separable. The concept of transnationality can be further refined by taking into account that interaction between partners differs during the execution of the project.

If the workload of a project is spatially separable, two forms of transnational R&D can take place. Interlocal work is characterized by high interdependency of the work tasks. Frequent communication and strong coordination are required to take place during the entire project. Since communication and travel costs tend to be high, a strong reason for this form of transnational project execution must be present, such as time-critical projects, high uncertainty of the project outcome, the usability of information technologies, and a firmly defined spatial distribution of resources.

The clinical research phases of pharmaceutical innovation processes fall into this category. Time-to-market is extremely critical, as profits almost exclusively depend on early market penetration. Government regulation agencies often require local testing, and participating hospitals as well as R&D centers are globally distributed. Failure rates in drug testing are extremely high (up to 90 % in clinical phases alone), but test results can be easily communicated to the global project coordinator, who is in firm command of the entire process.

Multilocal work is suited to projects with little interdependent work tasks. Coordination takes place particularly in the beginning of the project, when workloads are defined and assigned to partners. Each partner carries out his part of the project. The results are collected at the end of the project. Communication and travel costs are much lower, as the need for coordination during the project is less intense. Multilocal project execution is called for when resources are: i) not relocatable, ii) work tasks can be carried out in parallel, iii) changes to a plan are quickly executable, iv) the outcome is well defined at the beginning, and v) the degree of modularity is high.

Some collaborative projects funded by international bodies can serve as examples. A project coordinator acts as a central information officer, but has no directive authority over participating partners. Work packages are defined and distributed among the participants, usually according to their individual interests and capabilities, and then carried out largely intramural.

In fact, work tasks are deliberately defined such that interpartner communication is minimized while combined output is maximized. The individual results are assembled to the final product. This is not to say that interaction between different participants is prohibited, but because of the high costs associated with highly interactive projects, these projects are more likely to be cut or dismissed by the central approval committee.

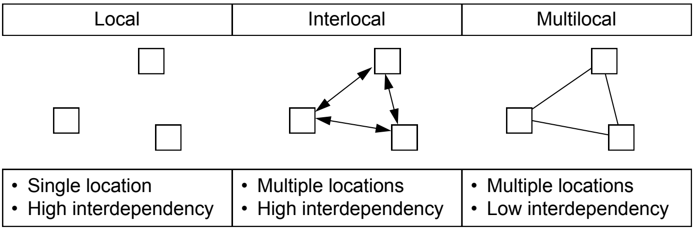

Figure 1: Degree of Interlocality and their Interdependency

As a means to track transnational R&D processes better, the following indicators can be considered:

- number of flights
- number of videoconferences
- number of telephone calls
- number of face-to-face meetings
- telephone costs
- travel costs
- number of e-mail contacts.

The number of co-authored paper and patents is not a useful indicator, as the project is usually long terminated before patents are granted or papers are published. Given they are not the primary objective of most R&D projects, papers and patents are unreliable indicators for the effectiveness of R&D. Man-years per project and per location are useful for distinguishing between local and multi-site projects, but this ratio does not capture the difference between interlocal and multilocal projects.

The quality of information exchange differs within transnational R&D projects. The traditional view holds that research requiring informal relations cannot be carried out internationally, because interpersonal trust and richness of communication suffers from the spatial distance of the communicators. Interlocal research is characterized by intense (and costly) communication and frequent travel - members in such projects repeatedly meet and can maintain close links that sustain a level of informality with the use of modern ICT. Due to the reduced amount of interlocal communication, communication and relations tend to be more formal in multilocal projects. Informality or formality is difficult to measure directly. Possible indicators for formality are the degree of meeting official deadlines, the involvement of senior executives, or the definition of timetables.

3 Knowledge-Intensive Transnational Innovation in Practice

This chapter presents several examples of virtual R&D teams, illustrating how these critical factors influence project management in real projects. In this retrospective description of especially successful virtual R&D projects, there are hints at solutions or ‘best-practices’ of coordinating and managing communication in dispersed R&D teams. We list five such examples:

1. Hitachi’s Holonic management of dispersed research
2. Shared goals and managed communication flow in a European research project
3. Bridging trust and language barriers with Unisys’s 24-hour laboratory
4. ABB’s IT-enabled PIPE project management tool
5. International product development at IBM

3.1 Hitachi’s Holonic Management of Dispersed Research

Hitachi had no significant manufacturing operations in Europe until the mid-1990s, but nevertheless aimed to pursue fundamental research in close connection with local universities and research institutes. Starting with research centers at the Universities of Cambridge (microelectronics) and Dublin (information science), Hitachi expanded to Munich and Milan, employing more than 80 research people in 1997. The administrative headquarters remained at the European research headquarters in Maidenhead, UK.

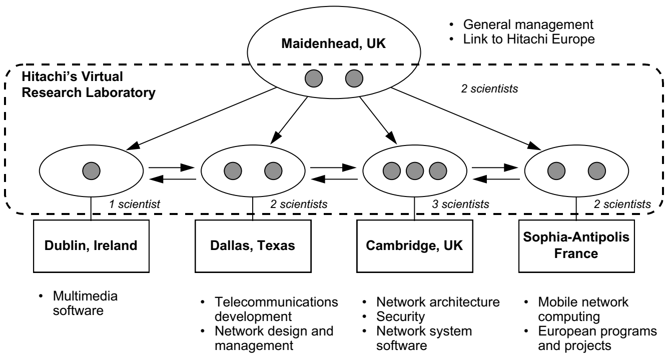

Figure 2: Hitachi’s competence-based virtual R&D laboratory.

Based on these locations, Hitachi formed a virtual research laboratory called Hitachi European Telecommunications Lab in 1997. The goal was to pursue research in telecommunications systems and the development of network system software. Research was designated to four of the most suitable locations: Cambridge (UK), Dublin (Ireland), Sophia-Antipolis (France) and Dallas (US) dynamically group and operate collaboration projects that can change in location and partners (Fig. 1). The network includes Dublin because of its competence in multimedia related contents software, and Cambridge because of the Centre of Communications Systems Research at Cambridge University, which is engaged in security issues and future network architectures. The Dallas Laboratory provides network design and network management competence. Overall research administration remains in Maidenhead.

Access to standardization consortia was also important. At Sophia-Antipolis, a science city in the south of France, Hitachi found not only competence in mobile computing and communications but also local partners engaged in European framework programs and committees such as EURECOM, ESPRIT, and ETCI. Research is distributed among ten scientists in those five places. Individual scientists are given a lead by holonic management which yields a maximum of power and freedom to the individual while making sure that the research understands and pursues the overall goals of the research laboratory and how his work affects his own research and that of his colleagues. Although each scientist is a fully integrated researcher in his local community, he relies on the work of his virtual colleagues and shares his results with them.

3.2 Shared Goals and Managing Communication Flow: The European ESPRIT Project REWARD

R&D activity in European projects is extremely decentralized. Reward, a one-year project aimed at designing and implementing re-engineering methods in R&D, was formed by teams from Daimler-Benz, Philips, Nokia, SEC Electrocom, and Thomson-CSF, teams from smaller companies (GSM Software Management, ATM Computer, Planisware) that ensure exploitation of the project results for a wide range of companies in Europe. Teams from research and consulting service providers (KPMG Management Consulting, University of St. Gallen, and Fraunhofer Institute for Industrial Engineering) provided the required theoretical background.

A total of 25 researchers were involved. One of the partners (SEC Electrocom) assumed coordination responsibilities to organize and administer start-up workshops, regular face-to-face meetings, and intensive e-mail communication. His central location was important for frequent personal contact between contributing partners and the coordinator himself (Fig. 3). Apart from managing a highly dispersed research activity, the management of different cultural backgrounds, not only by ethnic, but also by professional standards posed a key challenge to the success of the project. Much patience and sensitivity were required to align the individual objectives of each partner team to agree on a shared understanding of what was to be achieved, and how each partner would contribute to this goal.

The entire project work was split into small work packages to be executed by each team. Three problems occurred. First, hand-over of preliminary and final work package results was often complicated by incompatible computer and information systems. Second, after a team had concluded its part of the work, the entire project was given a lesser priority, thus hindering the efficient project continuation for the rest of the teams. Third, the project coordination office responsible for coordination and control was given only weak influence and decision power, thus lacking the strong authority needed to keep decentralized activities on track. It was learned that decentralized project work involving several partners required a different mind-set from the efficiency-oriented work routines used in single-location projects. Every individual at each partner had to gain an understanding for his collaborators' needs and weaknesses. Communication between teams was essential; the change of intensity often provided a clue when a particular sub-task was delayed or the anticipated outcome could not be reached.

Due to the distances between the teams, initial workshops were designed to last at least two days. Time is required for future partners to build up a relationship of trust and respect. This can be best achieved during the time aside from the formal meeting. The project office must be aware of such needs and consequently arrange appropriate start-up meetings, face-to-face meetings, and regular events to strengthen team culture and team spirit.

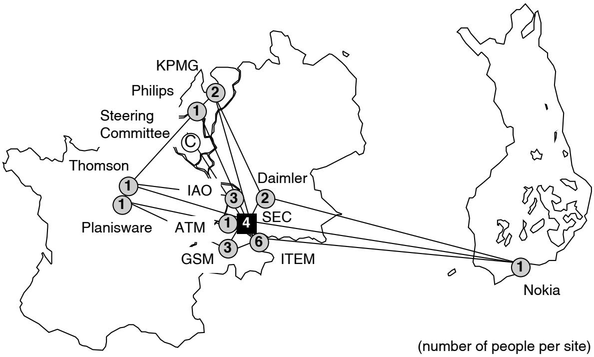

Figure 3: Decentralized R&D in a European project.

Since much of the effective communication takes place by modern information technologies, the access to shared databases and the error-free operation of e-mail and file transfer exchange must be ensured at the beginning of the project. Too often, project members are frustrated when communication breaks down during the critical ramp-up phase of a project. Personal friendships will last longer than the original project, spanning across corporate boundaries to form an informal network by which much of the know-how and technology transfer will take place for which European projects are initiated in the first place.

3.3 Bridging Trust and Language Barriers: The 24-hour Laboratory at Unisys

The exploitation of different time zones helps to circumvent labor laws concerning total work hours per week and the general aversion of R&D personnel towards working in shifts. Since around-the-clock research depends largely on the efficient transmission of information, the codability of the information and its rapid re-utilization at the recipient's location are crucial success factors. These preconditions are more likely to appear in the later stages of R&D, e.g. development, and in industries that work with highly codable data such as the software development industry.

Software development at the Unisys Personal Computer Division has been implemented in what is sometimes called the '24-hour laboratory' or 'Around-the-clock'-research in order to exploit different time zones of R&D units (see Winkler and Edgar, 2008). System software development is highly time-critical. Many companies have installed integrated information systems on which their businesses depend. When they approach Unisys with a service, update or development request, rapid delivery of the solution is crucial. Unisys has chosen around-the-clock R&D over night shift work. In commodity markets such as operating systems, software or microelectronics, the customer does not care where the product was developed, and neither does Unisys.

Unisys R&D units in San Jose, Tokyo and France participated in this project (Fig. 4). In one large software development project, consisting of many smaller software packages to be encoded, design of software modules was carried out in San Diego and sent to Tokyo where the specifications were programmed. Testing of parts of the software took place in France. The test results were analyzed in San Diego the next morning, prompting possible programming changes in the software or refinement of the specifications. After their day's work, these changes were in turn tested in Japan – the cycle continued.

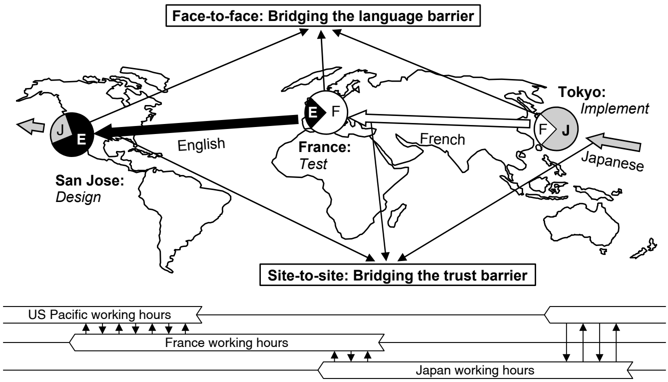

Figure 4: At Unisys, remote teams ensure efficient communication between R&D locations.

In transnational R&D processes, communication plays a central role. Soft factors determine the R&D process more significantly than the effective transmission of program code. The acceptance of the work done by the transferring team depends on the trust and confidence of the recipient team in the capabilities of their predecessors and a general understanding of the predecessors' working routines. Directions and explanations are well-meant but may offend the recipient when not formulated appropriately. Also, the means of communication affect the effi-cient transfer of information and acceptance of intermediary products. Speaking and communicating in the right language, as well as understanding cultural issues for and by the recipient, are part of the soft factors affecting the efficient transfer of information between geographically separated R&D groups.

Hence, Unisys complemented the utilization of ICT with the placement of members from the recipient team to the transferring site. For instance, Japanese engineers are seconded from the Tokyo office to the San Jose group. By being involved in the product conception in San Jose, they guarantee the consideration of efficiency in subsequent programming stages. They also learn hands-on and face-to-face about the requirements and expectations of the San Jose team for the implementation group. But local Japanese engineers can communicate these requirements back to the Tokyo team better than their American co-workers. They speak the same language and understand well the peculiar problems of misunderstanding and cultural noise at the receiving side. While the problem of information sharing and language difference is solved by face-to-face communication, the trust and culture problem is taken care of by the communication of team members of the same cultural and interpersonal background. Unless the other person behind the computer is known, teamwork is unlikely to harness its full potential. The familiarity between members of the same team tends to decrease after some time. Frequent e-mail communication may prolong this time period, but the half-life period of trust cannot be overcome without face-to-face communication. Unisys therefore replaces the seconded engineers after three months with other members of the recipient group. This prevents a loss of trust by the recipients, as well as potential misunderstandings due to assimilation or alienation of the remote engineers.

Intertemporal cooperation across geographic distances as in around-the-clock research requires standardization in reporting, project management tools and problem-solving in general. The routinization of such transnational development activities greatly enhances the exploitation of interlocal R&D.

3.4 ABB’s PIPE: Project Idea, Planning and Execution

During ABB’s reorganization towards greater integrated R&D management, ABB introduced a work flow application to support the research organization’s core processes. This tool is called PIPE – Project Idea, Planning and Execution. PIPE is based on Lotus Notes: Since all scientists in ABB Corporate Research have Lotus Notes on their desks, they can communicate, share knowledge and access relevant databases independently of the PC platform The same applies to many ABB employees in the businesses, Lotus Notes being the ABB standard tool for communication.

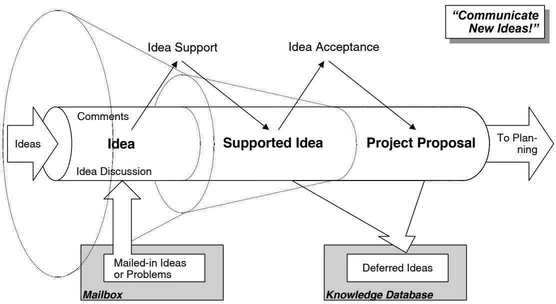

Figure 5: ABB's PIPE system module 1: Communicate new ideas!

PIPE consists basically of three main applications. It supports the creation and communication of ideas and projects, portfolio planning and assessing their value, and project execution and decision making. It is consistent with project portfolio management including resource allocation and project ranking.

A scientist can create an idea any time, test it, i.e. discuss it with suitable, selected colleagues around the globe. He then seeks support either from business area colleagues or from corporate research management, e.g. the program manager. Upon positive feedback a project is generated and it flows into the portfolio planning stage. After a ranking process it flows into the execution phase, if resources are available. Otherwise it is put into a "project storage" data base. In March 1997, the average user activity in the PIPE system were 36 entries or 11.7

Mbytes for idea creation, 203 entries or 49.8 Mbytes for reporting, and 171 entries or 44.5 Mbytes for planning (Tedmon, 1997).

At idea creation, the principal motivation was to keep track of all ideas and make them available throughout ABB. The idea creation module (see Fig. 5) also supports the formation of virtual teams. It was learned that most ideas were 'public,' meaning that they were not limited in visibility to restricted user groups. Software-related R&D was quick to accept PIPE as an R&D tool; quicker than researchers in traditional R&D fields.

PIPE supports the creation and planning of new projects with the second module (Fig. 6). This includes the selection of the project leader, preparation of project cost estimates, access to local accounting systems, and easy project tracking. Data consistency is ensured because there is only one point of entry for each kind of data. PIPE is accessed by the main project leader, local project leaders, department managers, program managers, and financial controllers. Several databases for process control, support manuals, knowledge and soft data repositories, fund requests and accounting enhance visibility and process-orientation in research.

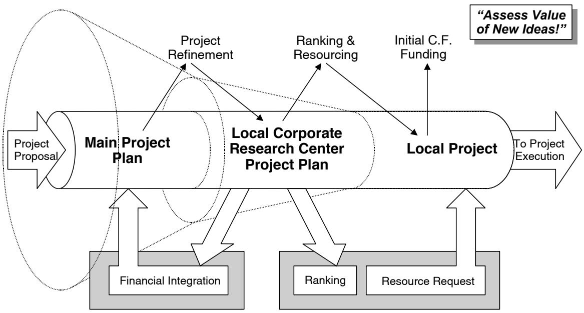

Figure 6: ABB's PIPE system module 2: Assess value of new ideas!

The project reporting module (see Fig. 7) does not only keep track of projects, it also ensures common notations and reporting standards. It presents different financial and budgetary summaries, project statistics, and business area consolidations. All information is condensed, updated and saved online. Since the introduction of PIPE, several duplicate projects were terminated and many local projects were coordinated. Often, a local project becomes part of a global project. This is the case when resources for execution are not exclusively available in one lab. In such a case colleagues are working as members of a global virtual team on various aspects of a main problem.

The process dramatically supports:

1. Forming cross-border project teams;
2. Overcoming multicultural barriers;
3. Improving transparency and trust in collaborations.

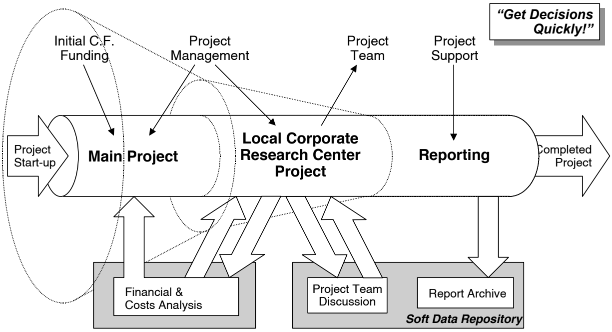

Figure 7: ABB's PIPE system module 3: Get decisions quickly!

With the help of advanced IT tools the world-wide R&D activities and resource allocations are completely visible and transparent to the management team. Shared information is available to an international team. Many new ideas are transferred to ongoing projects – processes are faster and simpler. Redundant efforts in the projects within the corporate research organization can more easily be avoided because the program managers have control over the funds.

PIPE also has a strong educational aspect, as now all ABB employees are used to think and consider in the ABB core processes. In a multinational-multicultural company like ABB the most important coordination tools - besides control of funds - in international R&D is openness and transparency of all R&D activities and resource allocation through one common database and groupware applications.

3.5 International Product Development at IBM

The significance of multi-site R&D activities is exemplified in the following study on the development of a new operating system involving three IBM R&D sites in the US, and one each in Australia, the UK, Germany, Belorussia, Canada, and Austria. This description is based on the IBM case study in Boutellier et al. (1998).

Traditionally, large-scale commercial software development projects such as the development of the VSE/ESA operating system for IBM's S/390 Enterprise Server Family has always been conducted across national boundaries. The gathering of requirements, the product planning and design phase play an essential role in the development of products: the aim is to collect the customer requirements, to develop adequate responses to these requirements, and to validate the solutions with the customers.

In system software development at IBM, requirements are brought to the attention of the development organization via a variety of channels:

- World-wide operating user organizations such as GUIDE, COMMON, or SHARE.[1] collect requirements and pass them on to IBM. At IBM the requirements are gathered

[1] GUIDE, COMMON, and SHARE are world-wide operating organizations for users of the IBM operating systems. E.g. GUIDE represents primarily the users of the VME/ESA and the OS/390 operating systems.

in databases, distributed to the development organizations, where they are analyzed and addressed.

- The service organization is another important channel for customer requests: employees in this function have daily contact with customers who experience problems with current products. These problems are entered into a database (RETAIN) which can be accessed world-wide.

The development teams operating world-wide access the available data and define the necessary small product improvements in close cooperation with the system house. More extensive improvements, especially when there are dependencies between products, are only introduced in close cooperation between all affected development locations. For extensive new developments, customers are involved in the validation process after the conceptual design has been created: One or more concepts are presented to the customers and their feedback is requested and analyzed. This process is used to reduce the number of implementation alternatives. For the subsequent coordination and planning processes both IT-based and traditional methods (travel and meetings) are employed.

- First approaches are often defined in face-to-face meetings and conferences. More recently, video conferencing (fixed image and more recently full-motion video) is also being used. This medium allows frequent, effective discussions lasting several hours without stress (no waiting periods, travel time, jetlag) and costs of long business trips.
- For later stages of coordination in which details are settled, the possibilities of electronic mail (e-mail) and telephone contacts are sufficient. At IBM, e-mail is preferred over the telephone: It is less expensive, and it has been observed that many German IBM workers dislike talking to answering machines and therefore avoid the use of the available voice mail systems.
- For final planning coordination personal meetings are used.

These early activities and the close cooperation between the different functions involved lead to a common understanding of the requirements and the content of what is eventually produced. At the same time the close cooperation promotes team building in the virtual team. The development engineer views the design process as a creative activity independent of whether the job is a new product development or extensions to an existing product. In this phase intensive team work is necessary. In the initial phase, all organizations are involved in the definition of system structures and interfaces between components and products. In the second phase of the design process, interfaces between modules are defined and component and module structures are developed locally in small teams. This staging is possible because interfaces between components and products can generally be described comprehensively and completely. The description takes a written form and is published in the team: The design document describes the layout of interfaces, all inputs, and outputs. Checking the design for completeness and correctness is labor-intensive and error-prone and requires careful coordination with others.

- Coordination takes place initially in face-to-face discussions lasting several days. Technical alternatives and implementation suggestions must be discussed and weighed against one another. The discussions serve to develop a common understanding among the various local teams about the functionality and the implementation.
- In the second phase of design, as the definition process progresses, documents are exchanged via the e-mail system of the IBM Global Network. This phase establishes

the normal communication flow between decentralized teams: a common understanding among the teams about the progress of the work is guaranteed.

The component and module design process take place in the local team. It is completed with a series of inspections of the overall design. During these inspections the correct implementation of the user requirements, consistency of interfaces, and the clear separation of functions is checked. The inspections take the form of highly interactive face-to-face discussions. Project leaders and those responsible for the design are included. By the end of the design phase all members of the team have a common understanding of the objectives and the project scope. This understanding is supported by intensive daily contacts between all team members via the internal e-mail system of IBM Global Network.

4 Interdependency and Informal Communication: Coordination in Transnational Projects

Within the last two decades, cooperation of internationally dispersed R&D units has increased, and the pressure on performing global R&D as efficiently as possible has become very intense. This puts extra emphasis on de Meyer’s (1989) prediction that individual face-to-face communication were to improve the productivity of an R&D organization, and that geographically decentralized R&D were not an efficient organization for such communication.

While new information and communication technologies have helped to bridge often great distances between R&D teams, they are limited in their applicability in creative brainstorming sessions, start-up meetings and trust building between project members. Research findings from this thesis support Reger's (1999) conclusions that, unlike many European companies, "Japanese companies make much more intensive use ... of informal mechanisms such as conferences, workshops and especially the transfer of scientists to the business units and job rotation systems, in order to create a cross-company culture."

The extent to which an R&D project can be carried out simultaneously in separate locations is determined by the degree of interdependency of the project work tasks (Gassmann and von Zedtwitz, 2003a). Fig. 8 illustrates a possible typology for international R&D projects, arranged by interdependency of work tasks and physical separation between individual R&D project groups. For example, 'individual projects' denote projects carried out by individual researchers with relatively little need of mutual coordination or communication. These projects may be short in duration, or they are undertaken by a research specialist who does not need or does not want to work with other scientists.

'Intralocal projects' are characterized by a strong interdependency of the project work tasks undertaken in one location. Because of the complexity of the project task, strong coordination and hence communication between the researchers is required. An example is the development of the ABB GT24/26 turbine or the Necar advanced development project house at Daimler-Benz. If a project is characterized by high interdependency but R&D sub-teams are forced to be located away from each other (because of, e.g., immobility of resources and facilities such as heavy testing equipment, customers, or qualified personnel), it must be carried out as an 'interlocal project.' Continuous coordination and management of diverging interests are crucial for the success of such projects.

Because international projects require significant management attention and coordination costs are high, project coordinators try to break down international projects into work packages as independent of each other as possible, thus creating a 'multilocal project.' In the ideal multilocal project, a work plan is defined centrally. The resulting tasks are grouped in independent work packages, meaning that interfaces between work packages are predefined and transparent. Each work package is assigned to the location most suited for its execution. At completion of the work package, the result (e.g., a feasibility analysis or a product component) is returned to the central project coordinator who is in charge of system integration.

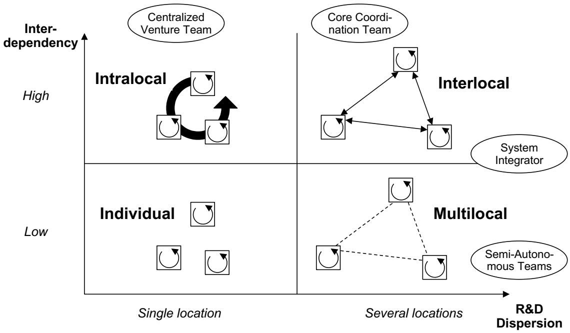

Figure 8: In interlocal R&D projects, prearranged communication is a critical success factor. The Gassmann and von Zedtwitz (2003a) classifications are given for reference.

From a cost-driven point of view the multilocal project form is to be preferred because the costs of coordination and communication are small and there is no costly relocation of resources. Although supposedly most international R&D projects are designed that way, most of them are later characterized as coordination, communication and travel intensive. Apparently, these projects assume less favorable organizational forms. How can this be explained?

We must look at international R&D project management from several angles. First of all, complete independence between work packages can never be achieved. At one time or another, system reviews must be conducted and the whole project structure and workload may require adaptation. As long as the project team is small and not dispersed physically, and the technology is still in its formative stage, there is nothing wrong with making the technology or product development project more effective. However, once the team has grown, several R&D sites are involved in the project, and a substantial amount of the targeted technology has already been created, changes in the product structure are extremely costly. In order to reduce the risk of costly and time-consuming project rework, it has been suggested to split international R&D work into two phases: a first intralocal phase focusing on the effectiveness of the resulting product, and a second multilocal phase concentrating on efficient execution of the project (Gassmann and von Zedtwitz, 2003b). The definition of the product or system architecture marks the transition from the first into the second phase.

The second notion is that communication in projects with dispersed teams is different from communication in a collocated team. Project-internal communication is a necessary prerequisite for project coordination and management. Formal communication mechanisms include technical reports, standardized project reviews, task descriptions, shared databases, presentations and meetings. The critical role of informal communication is still largely underestimated in project success. Shared coffee-corners, open work and office space and team mixing are directly job-related approaches, but joint weekend trips and the company gym extend the reach of facilitating informal communication. However, the project-internal informal communication is hampered if project members are dispersed across several remote locations. While formal mechanisms remain to fulfil their role as a bi-directional information provider, informal communication effectively breaks down. Communication then cannot happen on the spur of the moment – no spontaneous brainstorming with a colleague next door, no discussions over a hand-written sketch at the coffee table.[2]

Therefore, even informal communication (as a basis for project coordination) in international R&D must be prearranged (see earlier case examples). Among the most important approaches are international personnel rotation in order to establish a worldwide network of contacts (e.g. Hitachi's HIVIPS), liaison officers and gatekeepers, temporary assignments with the remote project team (e.g. Unisys's 24-hour project scheme), and the education of people to exploit new communication technologies to their fullest potential (e.g. ABB's PIPE). All of these approaches involve a fundamental cultural shift: Employees must think multinationally and they must be highly computer-literate.

In anticipating such difficulties in international R&D work, some companies initiate transnational R&D projects with the not explicitly stated yet equally important motivation to foster the creation of an international network of R&D individuals. These R&D employees will be experienced in executing transnational R&D projects, and they will know their counterparts in future collaborative projects. Such experimental transnational R&D projects are often research-oriented, not time-critical, and of small scale, hence reducing economic risks. The creation of a transnational R&D workforce with strong networking and communication capabilities is more important than substantial advances in R&D. These individuals become also important in strategic cooperation between the parent company and another firm. They are the nuclei for future transnational R&D projects.

5 Theory Take-Aways

For the purpose of this chapter, the focus was on three problems of communication and coordination in virtual R&D teams. The first problem area was concerned with the formulation of knowledge and its transfer. Nonaka and Takeuchi (1995) proposed a model of knowledge conversion between tacit and explicit knowledge. It has been often noted that tacit knowledge is best transferred face-to-face and in demonstration/practice settings. The transfer of tacit knowledge has remained a problem for virtual teams even when one resorts to simple communication techniques such as emailing snapshots of whiteboards and sketches. On the other hand, the Internet and other global communication means provide convenient means for the

[2] Allen (1977) found a logarithmic relationship between the probability of communication and physical distance, pointing out that the likelihood of communication among scientists approaches zero after only a few meters away from their immediate office or work space.

transfer or large data amounts, but still lack the human touch. Video-conferencing and virtual reality communication, which promise to introduce communication richness at great distances, are still in their infancy. We summarize this research in the following proposition:

Proposition 1: Virtual teams find it more difficult to transfer tacit knowledge, which introduces a tendency to exchange explicit rather than tacit information in virtual communication.

The second proposition is concerned with communication quality. Virtual teams are ICT based, i.e. heavily interconnected by email, telephone and shared databases. The platforms for frequent communication are present. However, De Meyer and Mizushima (1989) used the concept of half-time of trust to describe decreasing familiarity and trust relationships between remote team members. The more time passes without face-to-face contact, the greater the alienation within the team, the lower the likelihood to share critical information, and the lower the frequency of knowledge exchange taking place. We thus formulate:

Proposition 2: Knowledge exchange in virtual teams takes place less frequently than in collocated teams.

The third proposition deals with coordination issues in virtual R&D teams. Unlike in physically collocated teams, where the design of office space and functional as well as hierarchical separation delimits and defines communication boundaries, email is a truly 'democratic' communication media cutting across all such boundaries. Communication lines are added exponentially in unrestricted networks, and logarithmically only in hierarchical networks. In order to avoid information chaos, such as inundation or inconsistency, channels and platforms of communication emerge or are introduced that are specific to virtual teams and extend beyond established communication traditions. At the same time, because of the highly decentralized character of virtual teamwork, these new channels of communication are integral to the coordination of virtual teams.

Proposition 3: Virtual teams establish new forms of communication channels that are integral for virtual coordination.

6 Lessons Learned

The application of IT is absolutely vital in large-scale international projects where there is a high degree of division of labor. Although the application of IT is a prerequisite for virtual R&D teams, it is not by itself a sufficient guarantee of a project's success. Rather, the technical aids must be complemented by organizational and human-relations components.

For the application of IT in virtual R&D teams, various conditions must be fulfilled. In summary, the following recommendations can be made:

1. The spatial and organizational shape of virtual teams must be specifically tailored to the project. This means that certain situations may necessitate bringing together a virtual team in one place (e.g. for radical innovations, when there is a large proportion of implicit knowledge at the start of a difficult project), even when sufficient IT-facilities are available.
2. IT cannot act as a substitute for traditional project management in virtual teams. Replacing travel and face-to-face communication in transnational R&D projects by IT-

based communication places particularly high demands on the project leader. Cultural tolerance and empathy between the project leader and the team prove to be a basic condition for the communicative openness required.

3. A large part of the team should know one another before the start of the project. If this is not the case, intensive measures for developing team spirit are necessary at the start. For this purpose the team must be assembled in one place. Once an atmosphere of trust has been built up among the team members, this must be continually revived, as it drops off in the course of decentralized cooperation (“half-life of trust“).
4. The use of e-mail, common databases, and remote login is usually crucial if the virtual team is to be able to work efficiently. Video conferences can be a useful complement to face-to-face meetings.
5. Despite the enormous progress made in IT, face-to-face contact is still essential in transnational R&D projects. The degree of virtuality of R&D teams is determined by the degree of trust required, the proportion of implicit knowledge and the complexity of the project. Integrated problem-solving strategies often still require interpersonal communication within traditional teams. The longer the duration of an R&D project and the greater the continuity of the team, the easier it is for face-to-face communication to be replaced by IT-based communication.
6. Brief project summaries are often better than long status reports, and they offer fewer opportunities for misunderstandings, especially when backed up with a video summary.
7. In larger projects is seems especially useful to manage communication with a dedicated infrastructure, a project communication office, and a schedule when and what information to be exchanged.
8. As prearranged communication is in conflict with spontaneous creativity, it is necessary to provide a sufficient platform for the latter to take place efficiently.

7 Concluding Observations for Management

Although the drivers for and against transnational project execution are far from complete, and the set of potential indicators of interlocality and multilocality require further discussion, it is possible to apply the principle of controlling as outlined above as a means of providing a tool for the improvement of management and organization. Figure X depicts a simple chart of what conclusions can be drawn if the observed transnationality of a project does not match the planned one.

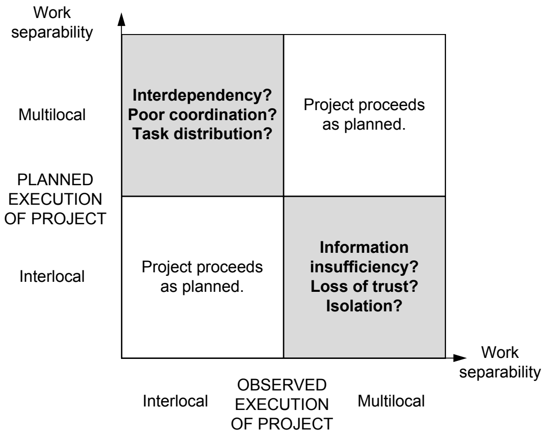

Figure 9: Mismatch between planned and observed virtual R&D projects.

If an R&D project has been conceived and designed for interlocal execution, and the observed characteristics of the transnational R&D process does indicate its interlocality, then the project behaves as planned. No interference with its project management is needed. The same logic applies to multilocal projects.

A mismatch between planned and observed transnationality occurs if a designated multilocal project is executed in an interlocal way. More communication and interaction takes place than originally planned, serving as an indication that actual interdependency of the project work tasks is much higher than anticipated. Possible other causes may be insufficient coordination or unfavorable distribution of work tasks. If an interlocal project is carried out as a multilocal project, i.e. if project members interact below the planned extent, then this can serve as an indication for too little communication and information exchange, loss of trust, and isolation. Important results may be lost; the project is prone to be delayed or may be even canceled because critical milestones are not reached in time.

In conclusion, this chapter presented some of the challenges and opportunities of virtual R&D projects and their team-internal communication and coordination. It proposes three degrees of virtuality of R&D projects—intralocal, interlocal, and multilocal—and advances three theoretical propositions. The literature review provided a quick summary of key dimensions to be considered in virtual / international R&D projects, illustrated by five mini-case studies (six, if including Shell's Carilon). While the technological underpinnings of ICT are constantly improving, the managerial tools seem to follow more slowly. Despite conceptual advances, the gap between technological potential and managerial practice in transnational R&D and innovation processes seems to be widening.

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