

Management of dispersed product development teams: the role of information technologies

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In recent years, international corporations such as IBM are increasingly relying on dispersed R&D teams in order to keep pace with resource availability and the demands of global markets. The advantages of this approach arise mainly from the utilization of differences in personnel costs and gaining access to a broader knowledge base to satisfy the demands of international clients. The disadvantages of teams of this kind are obvious: geographic distances, differences in culture and work habits as well as the necessity to bridge time zones place greater demands on communication, synchronization and management.

The application of specific project management methods and the intensive use of information technology (IT) lessens the disadvantages in transnational development projects. Recently completed projects involving large-scale commercial software development at IBM demonstrate the potentials of IT in transnational development. The authors advocate the application of IT adapted to specific situations. The central fields of application of IT in dispersed R&D teams are the development of a personal network, the promotion of creativity, the exchange of technical information, and the coordination of decentralized project activities.

1. Significance of dispersed teams in international R&D

The globalization of R&D activities is one of the key management topics of the nineties. The most important forces driving internationalization of R&D are market-oriented development and access to the best resources worldwide. In order to realize synergistic effects despite decentralized R&D locations it is necessary to improve transnational cooperation.

The drawbacks of internationalized R&D are particularly visible in the loss of efficiency. Often the critical mass of personnel and capital which exist in traditional centralized R&D laboratories are not available in decentralized R&D units. In order to exploit the

advantages of international R&D and at the same time overcome a sub-critical mass of separate R&D sites, dispersed teams conducting joint large-scale projects across national boundaries are increasingly being created.

The main challenge is the communication between the worldwide spread team members. The often cited empirical study by Allen (1977) shows that the probability of communication $P(D)$ between two R&D employees decreases markedly with increased physical distance D . The logarithmic relationship between $P(D)$ and D was demonstrated both in the microrange (meter distance) and in the macro-range. However, due to massive utilization of information and communication technologies (IT) in R&D and the increasing

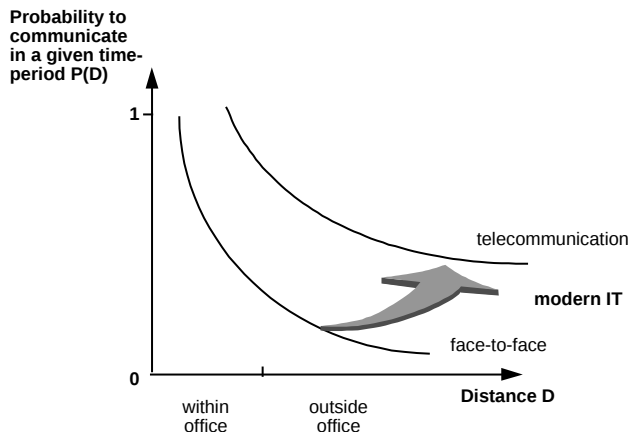


Figure 1. IT changes 'Allen Curve' — but with different communication quality.

experience with transnational R&D projects this relationship is expected to become weaker.

Industrial R&D processes are increasingly being supported by IT. Initially the focus was placed on numerical calculations and later the support of information processing and construction activities (CAD, CAE). Although communication has traditionally been one of the main productivity problems in R&D (De Meyer, 1991, p. 49), the communicative aspect of IT in R&D has only been considered in depth in recent times. Supporting dispersed R&D teams places the greatest demands on IT, as Howells (1995) stated: '...the establishment of a scientific and technical team located at several different sites but working on the same project represents the most far-reaching aspect of the use of ICT in R&D'.

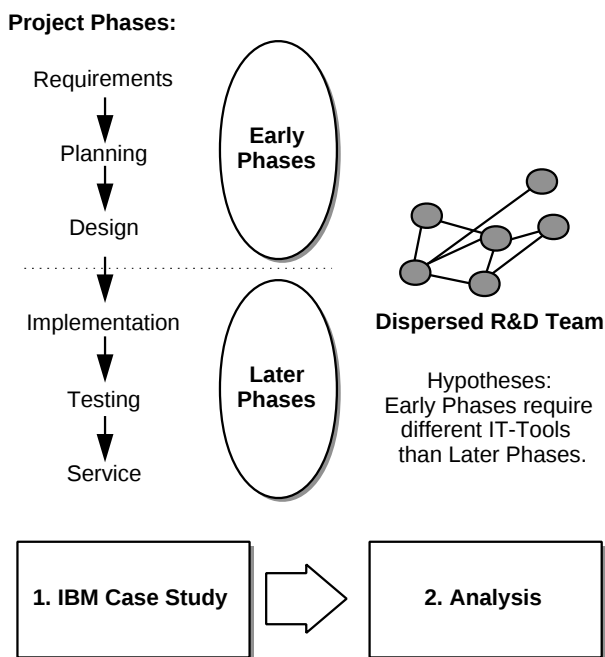


Figure 2. Overview.

As the case study from IBM demonstrates, efficient and effective cooperation within dispersed R&D teams is only made possible through intensive utilization of IT. The authors show that early project phases require other kind of IT-tools than later phases. The inductive analysis in the second part of this contribution is mainly based on the IBM case study: the IBM case study demonstrates the practical view of the whole issue in the sense of 'best experience'¹.

2. IBM case study

Traditionally, large-scale commercial software development projects such as the development of the VSE/ESA (Virtual Storage Extended/Enterprise System Architecture) operating system for IBM's S/390 Enterprise Server Family has always been conducted across national boundaries. Already back in the seventies, the division of development responsibility among different product houses required close international cooperation. The demands of customers for integrated solutions has tended to reinforce this trend in the eighties. As a consequence of the environment in which the company operates — IBM as a manufacturer in the IT industry — IT methods were used in projects earlier and to a greater extent to overcome the drawbacks of geographical separation by promoting team formation.

In the following sections, the authors describe how IT technology is being used during the software development process to solve problems arising from the widespread use of dispersed teams.

2.1 Planning and design phase

The gathering of requirements, the product planning and design phase play an essential role in the development of products: the aim is to collect customer requirements, to develop adequate responses to these requirements, and to validate the solutions with the customers.

Requirements. 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, collect and prioritize requirements and pass them on to IBM. At IBM the requirements are gathered in databases, distributed to the development organizations, where they are analysed and answered. The time from the entry of the requirement to the answer given to the customer is tracked, measured, and regularly reported throughout the company.
- IBM's service organization is another important channel for customer requests: employees in this function have daily contact with customers who

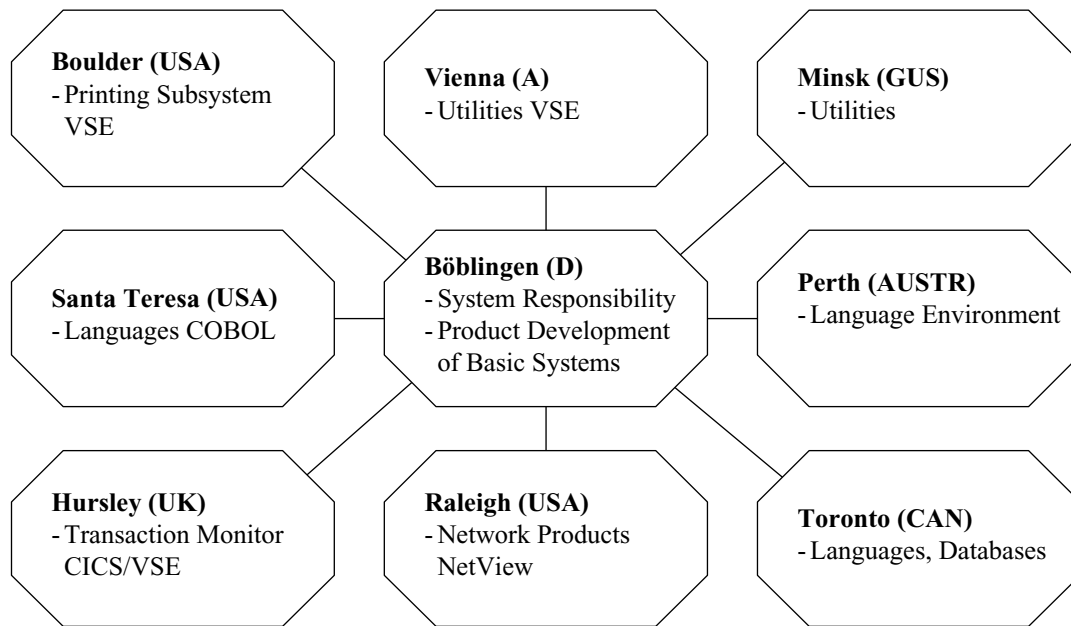


Figure 3. Organization of international VSE development at IBM (1996).

experience problems with current products. These problems are entered into a database (RETAIN) which can be accessed world-wide. Problem resolution is tracked and later on, problems are classified as either 'defect-oriented' (cause of the problem was a program defect) or 'non-defect-oriented'. Conclusions about product deficiencies and new requirements can often be drawn from the 'non-defect' problem reports.

The development teams operating world-wide access the available data and define the suitable small product improvements in close cooperation with the system house. Bigger improvements, especially with impacts on several 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 personally to the customers by R&D members and their feedback is requested and analysed. This process is used to reduce the number of implementation alternatives. Frequently tools supporting the well-known 'rapid prototyping' methodology are employed: in the area of user interface prototyping in particular, programming tools like Smalltalk suggest themselves. Using visual programming methods, product ideas can be quickly prototyped and validated with customers.

Planning. For the subsequent coordination and planning processes both IT-based and traditional methods (travel and meetings) are employed.

- First approaches are often defined in internal face-to-face meetings and conferences. Lately video-

conferencing (fixed image and more recently full-motion video) is also being used. This medium allows frequent, effective discussions lasting several hours without the stress (waiting periods, travel time, jetlag) and cost 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 telephone contacts: in the first place it is cheaper, in the second place it has been observed that many German IBM colleagues dislike talking to answering machines and therefore avoid the use of the available voice mail systems.
- For final planning coordination personal meetings are preferred.

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.

Design. The design represents the first phase of transforming the plan into a product. The design phase is especially critical because during this phase the foundations of the implementation are laid. Revising them at a later stage of development is only possible at considerably higher expense.

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 being defined and component and module structures are developed locally in small teams.

This staging is possible because interfaces between components and products are generally being described comprehensively and completely. The description takes a written form and is published throughout the team: the design document describes the layout of interfaces, all inputs, and outputs. Checking the design for completeness and correctness is labor-intensive, error-prone and requires careful coordination with others.

- Coordination takes place initially in face-to-face discussions lasting several days. Implementation alternatives 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 takes place in the local teams. 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.

2.2 Implementation and testing

It is frequently desirable to transform the design into executable code and to remove defects in inspections and tests strictly locally: this approach significantly reduces the communication overhead between developers and testers in a development project: the need to transmit large amounts of data over networks can be eliminated, interactive debugging is made easier when developers and testers reside in a single location. In large-scale international projects, especially in operating system development, this division of labour is not always possible, even when clear structuring and separation of functions has been pursued during the design phase. To resolve mutual dependencies and allow work to proceed in parallel, either pre-versions

of the code of other teams must be available for test purposes or code scaffolding is utilized.

In large-scale projects the management of dependencies represents the greatest challenge. If several teams are dependent on each other the resolution of these dependencies via pre-versions leads to a high degree of complexity in project management and tends to prolong the project: both factors are undesirable.

- Pre-version of a product or a component are characterized as code under development which only contains part of the final functional content. In pre-versions a subset of the final functional content can be executed. When the code is passed to others for test purposes, it is 'frozen', i.e. no further development takes place with this piece of code.
- In the 'scaffolding' process software is written which only serves test purposes. The scaffolding code is designed to simulate the existence of missing products or components. The extent of this code can range from small units, so-called 'stubs', to complete components. An extreme case are hardware simulators which may take on the size of complete software products.

Pre-versions have the advantage over scaffolding that the same developer provides both the pre-version and the product version of the function. This ensures that misinterpretations of the design or interfaces become apparent at an early stage of development. Scaffolding code is usually written by the person who needs to call the as yet non-existent function. Simulation is based on system characteristics documented during the design phase: errors in the documentation or failure to communicate later modifications to the design will inevitably lead to extra work.

The disadvantage of the pre-version becomes apparent when complex mutual dependencies exist. Under those circumstances code frequently has to be supplied to other teams for testing purposes early in the cycle. This procedure tends to put the development teams under substantial pressure. Defects which have occurred in tests at other locations or even in early customer tests with the pre-version must be eliminated by the developer. At the same time, however, he or she is pushing ahead with the development of the final version. Typically, after a short while the two versions will cease to have much in common at all.

Pre-versions are being used for example in an upcoming large product release of IBM's VSE/ESA operating system: the release requires the coordinated development of the VSE/ESA supervisor and CICS/VSE (Customer Information Control System/Virtual Storage Extended) transaction monitor. In this case certain functions and interfaces in the VSE/ESA supervisor were developed and frozen and passed onto the CICS/VSE development. These functions and interfaces will allow the CICS/VSE developers in

Hursley, England to implement and test their own code. The development of the relevant parts of the VSE/ESA supervisor will be completed and put through a single system test together with the CICS/VSE function at a later date.

'Scaffolding' was employed for example in the development of version 5 of the MVS/ESA (Multiple Virtual Storage/Enterprise Systems Architecture) operating system. In this version a new function of IBM hardware, the so-called Coupling Facility (CF) was supported. A combined hardware/software function, the Coupling Facility provides the means for very rapid communication between different processors in a S/390 Parallel SysPlex™. As the hardware environment for the development of the MVS/ESA components was not available, the corresponding interfaces and functions were simulated on the test systems. In this manner the support required in the operating system and in the applications was able to be developed and tested without the need for every developer and tester to have access to the CF resource. In the final system tests the conformity of the simulation with the real CF was validated.

For an international development team the coordination required in the context of mutual dependencies between project activities contains much potential for conflicts. There must be common understanding and trust that all involved are working towards the same goals and are working to the best of their abilities. In this phase of development there is a lot of project management to be done. In complex projects regular weekly telephone or videoconferences for all involved parties are the norm.

In the implementation phase communications between the decentralized teams primarily consist of information concerning problems which have arisen with the system structure or the interfaces. In this period the process is conducted more formally than during the development phase. In order to make sure that all problems are pursued further and solutions found, the teams use a previously defined reporting procedure. Defect reports are documented and passed on to other team members for processing. Problems remain open until all necessary changes have been implemented.

Testing. The test phases prior to product delivery are subdivided into the system or integration test and customer tests. The objective of system testing is defect removal, the objective of customer testing is validation of product quality commitments and the testing of the distribution and service processes.²

System tests of operating system components usually entail intensive use of hardware. Almost every new version of the operating systems contains code supported by new hardware such as new processors or peripheral equipment which must be included in the test environment. As the interaction of the new hardware and the operating system support has to be tested

before the first delivery of the hardware, engineering models are usually employed for testing. These devices have gone through a special manufacturing process and are therefore much more expensive than the machines which later go through the normal manufacturing process. These test phases are usually conducted centrally at the location where the hardware is being developed: potential problems with the hardware can be solved easier with the available know-how.

In the past the decentralized virtual test teams used to meet centrally in this phase and had to contend for the available machine time, typically in around-the-clock operations. Today nearly all test activities are conducted from the employee's own desk via the IBM Global Network, whether the test system is in the same building or half-way around the globe. Almost all IBM test systems are now linked into the IBM Global Network and are thus accessible world-wide. This has resulted in considerable improvements in system utilization and at the same time has improved working conditions during system tests.

Test progress is measured in terms of workload completed and number of defects removed. The test workload is planned and prepared using standardized defect-removal models in advance of the actual test activities. Defects occurring in the test are reported and tracked using an online database in the same way as defects in other stages of the implementation: defect report, defect analysis, defect correction, fix validation. In the late phases of development the development, integration and test teams work closely together. Only a team effort will permit rapid project progress to be made. In this phase the integration team often has to include defect corrections in the code libraries on demand and to build new systems in short intervals. Fast processes which lead to reproducible results are an essential requirement.

The customer tests which follow the system test differ from the internal tests in that the hardware has undergone the normal manufacturing process, and due to different objectives the expected defect rate is much lower. On the other hand demands made on defect turn-around-times will be greater: the customer demands rapid problem resolution and the goal of bringing the system into production can only be achieved after a sufficient test period.

The development of system software is increasingly characterized by close cooperation between the development engineers, customers, and independent software companies. The software suppliers are important partners for the system manufacturers as IBM and have to be included in the development processes early on. Customers will only be willing and able to make use of fundamental innovations if the software of the different suppliers has been tested together and runs properly. This means that large-scale system-related projects also have to take the product range of independent partners into account.

Software suppliers receive information at an early stage of development which allows them to adapt their own software to new functions of the operating system. During later development these partners are treated similar to an IBM organization: support can range from early code shipments to support during tests. With important software firms more extensive agreements usually exist which for example enable defect corrections to be exchanged rapidly and with very little red tape via the company networks.

Close cooperation with reference customers may arise in the context of the migration to new versions of the operating system. The system installation in the customer's firm represents an extension of the IBM in-house test cycles and developers might even have direct access to the customer's systems.

- Parallel to the final internal test phases, the latest version of the MVS/ESA operating system and the Parallel SysPlex™ hardware environment it supports were subject of a Joint Customer Study (JCS) with a small number of customers. The objective was to observe and test the system under production conditions.
- Last year the Böblingen VSE/ESA software development team conducted a study with one of its largest customers in the USA to determine if a new processor series together with the VSE/ESA operating system was able to satisfy the customer's performance demands. For this study an analysis of system performance was conducted from Böblingen via the link between the IBM Global

Network and the customer installation in New Jersey, USA. In the course of this analysis both optimization of the customer's workload and modifications to the operating system were conducted in order to achieve optimal utilization of the processor performance.

In all these cases the developers work closely together, with other software suppliers and with the customers via the IBM Global Network: the network is used to operate systems in remote control, to analyse problems, exchange information about problems and to distribute corrections. The telephone and the video conference are employed in conjunction with the IBM Global Network to make arrangements and to analyse problems in the group.

Service. The final stage in the software life-cycle is service. During the maintenance phase of a product the developers at different locations and the international service organizations cooperate closely with the objective to deliver best service to the customer. The vehicle of communication is the IBM Global Network and the RETAIN database. The RETAIN database serves as vehicle for problem communication, problem tracking, and the documentation.

2.3 Major factors confirmed by IBM case study

For dispersed teams the disadvantages of running decentralized projects must be compensated by consistent dependency and project management. This is

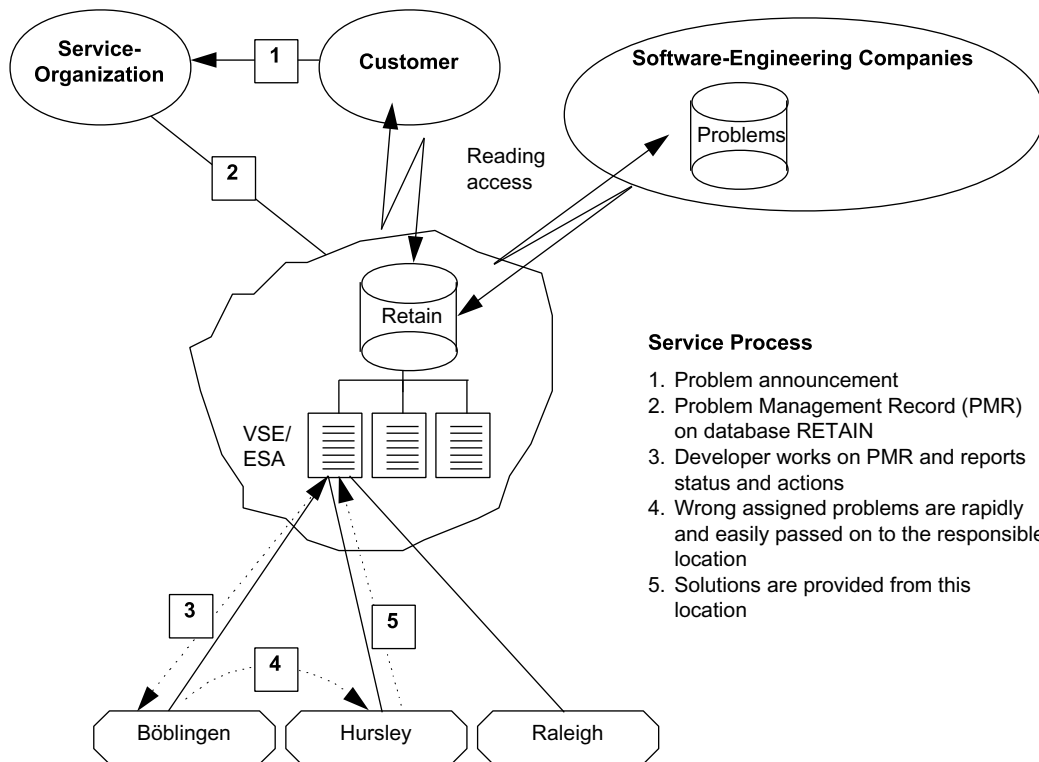


Figure 4. The VSE service process.

supported by a number of IT-based aids:

- The core of the project information is the project plan. It always reflects the current status of the project and the progress of the project so far. It gives a preview of tasks and checkpoints which have yet to be performed. It is maintained online and distributed via e-mail to all functions involved in the project.
- Various tools form the basis of project planning and tracking. These are used for visualizing relevant information in the form of Gantt charts. For instance, Computer Associates SuperProject product is used at IBM for scheduling and project tracking purposes.
- Managing technical, logical and time dependencies between the dispersed team activities requires intensive communication with suppliers and customers. The project office makes regular and extensive use of telephone and videoconferences. At these conferences several locations with several participants each switch in. To ensure that conferences run in an orderly fashion, meeting agendas are distributed by e-mail in advance. Following the meetings the participants receive minutes of the discussions and 'to do' lists.
- To track dependencies the project office utilizes online database systems to which all involved parties have either read access or whose contents are distributed via e-mail. Via the project management online database all employees involved are informed continuously about the current status of the work units. If this is used consistently it is to a large extent possible to dispense with conventional release modes with signatures.
- At essential checkpoints in the development cycle the overall status of the project is documented and distributed via e-mail. In this manner the progress

of the project can be tracked precisely and evaluated regularly.

3. Analysis: information technologies in dispersed R&D teams

The following is an attempt to develop general recommendations for the use of IT in dispersed R&D teams.

3.1 The need for IT in transnational R&D projects

Conducting R&D projects at different locations using existing communication techniques requires both frequent travel and the use of IT. The study shows that travel still plays a major role but is increasingly supported by the use of modern IT. It must be said, however, that the importance of the socialization phase at the start of a project has again been clearly confirmed. IT can prolong the times between face-to-face contacts, but it cannot replace them.

At first glance IT entails high costs. For example, a video conference lasting one hour ($2 \times 65\text{ kbit/s}$) between Zürich and New York on the company's own premises costs 324Sfr at Swissnet. For a dedicated line between MTU (Munich) and Pratt & Whitney (East Hartford) over 120,000DM is paid in rent per year. On the other hand the total cost of IT in most companies constitutes less than 10% of the total R&D budget. Therefore it is rather the cost of not using IT which must be considered.

These indirect costs are the opportunity costs of traditional face-to-face communication: for a decentralized team to meet, considerable travel costs and travel times have to be accepted. The productive time lost during the non-productive travel time represents a considerable cost factor. Moreover, the specialists are often indispensable in their home locations. Their absence is usually very costly, although it is not easy to put a price on it.

In addition, the 'social costs' of travelling are ignored in the cost considerations of R&D controllers. Extensive travelling is associated with stress and is also a burden for the family. It is often the family which sets the conditions for longer-term personnel dispatching in the context of large-scale transnational projects. Through reduced creativity and motivation the social costs influence the efficiency and effectivity of project work. If these indirect costs, which are difficult to quantify, were included in decision making, the use of IT should definitely be approved from the point of view of costs.

3.2 Application areas for IT — a contingency theory approach

IT can only be helpful in increasing efficiency and effectiveness of transnational R&D projects, if the IT

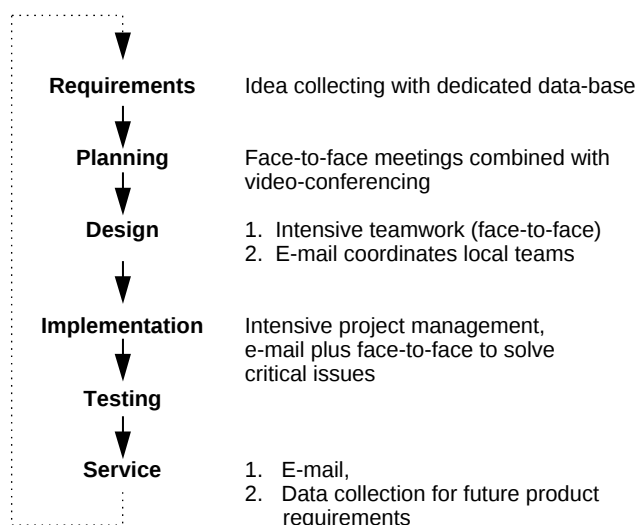


Figure 5. Phase-dependent use of IT.

application is appropriate for the project task. In dispersed R&D teams IT can support four basic tasks:

1. Coordination of decentralized project activities
2. Exchange of technical information
3. Promotion of creativity and quality
4. Formation of a personal network and development of trust.

(See Figure 6).

On the rational level, where explicit knowledge dominates, IT should be characterized by information richness (see Trevino et al., 1987). On the emotional level, where tacit knowledge dominates, IT should promote social presence:

Therefore *project coordination* and the *exchange of technical information* require media which are characterized by information richness (see Trevino et al., 1987). Important is the online availability of scheduling and technical information in all locations. The currency of the information, e.g. an interface specification, is often vital. The factual content of the communication dominates. Daily communication can usually take place via e-mail. CAD systems, remote file systems, and online links to common databases are very important for the exchange of technical information.

Media which promote social presence of the participants appear to be more advantageous for *promoting creativity* and the *development of an informal network*. Creativity requires extensive *ad hoc* communication in

which the need to communicate arises in an unplanned fashion. In the same way, activities aimed at building trust and developing informal ties cannot be schedule driven.

The emotional level of communication plays an important role here. Media which allow a broad spectrum of non-verbal communication (such as body language and gesturing) and are dialog-oriented (mutual exchange of information) can come close to face-to-face communication. Videoconferences, teleconferences, and the telephone come closest to meeting this demand.

In order to be able to evaluate the overall advantages of IT in dispersed R&D teams, the suitability of various IT methods with regard to the above tasks and economic efficiency has been drawn up in Figure 7. Examples are given from the software development at IBM.

3.3 Selected IT instruments

Electronic mail (e-mail) for day-to-day project communication. E-mail makes communication via computers in computer networks possible. The project leader can transmit information affecting all project members in a time-saving manner. Managing a decentralized distributed project team is greatly simplified. E-mail systems also support the application of a series of workflow-related programs in transnational R&D projects. Resource management programs can give the

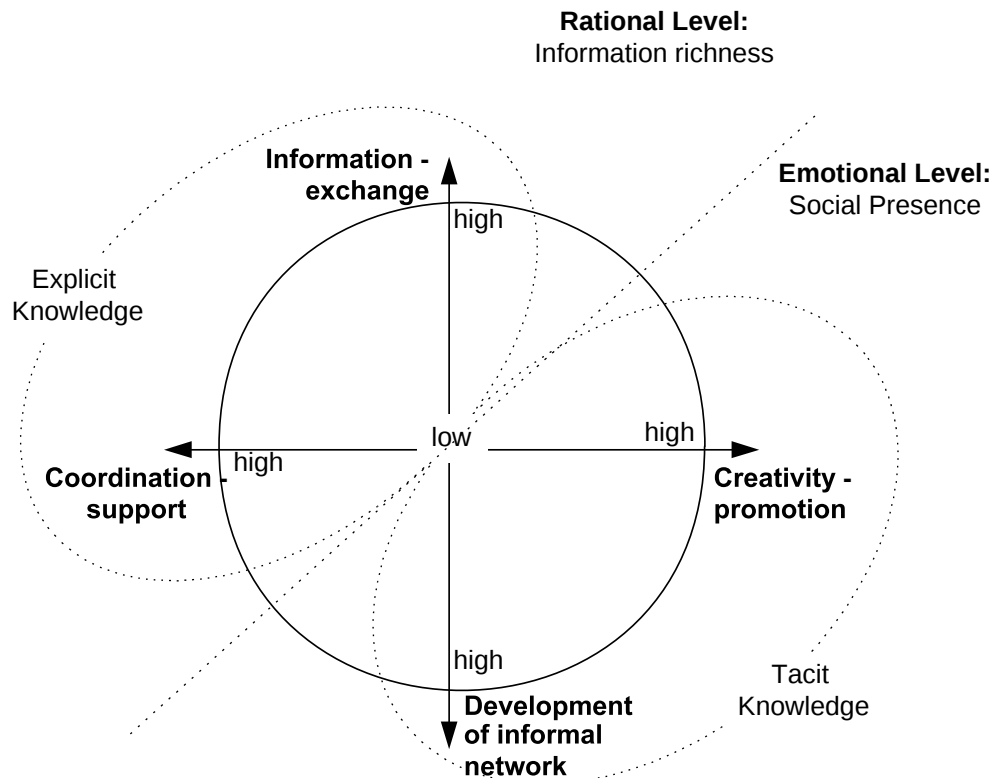


Figure 6. Tasks of IT in dispersed R&D teams.

Technology	Developing informal network	Promotion of creativity	Information exchange	Coordination support	Efficiency	Examples from Software development
Videoconferencing	●	●	◐	◐	○	Project control, meetings, concept
Teleconferencing	●	◐	◐	●	◐	Project control, definition of interfaces,
Telephone, Voicemail	●	◐	●	●	◐	Definition of interfaces, project progress, escalations
Groupware	◐	●	◐	●	●	Electronical Brainstorming, process documentation
Forums	◐	◐	●	◐	●	Exchange of information, questions & answers
Intranet	◐	◐	●	●	●	E-Mail, communication
Client/Server environment	◐	◐	◐	○	◐	Development environment, shared databases
E-Mail, Memos	◐	◐	●	●	●	Mails, revisionable documentation
LAN/WAN/GAN	◐	◐	●	◐	◐	Development library, development environment
File Transfer	◐	◐	◐	●	●	Presentations, Spreadsheets, protocols, FTP
CAD	◐	◐	◐	◐	◐	Hardware-display
CASE Tools	◐	◐	◐	◐	◐	Design concept, Code generation
Telefax	◐	◐	◐	◐	●	Transfer of hard-copy-documents
Electronic Calendar	◐	○	◐	●	◐	Meetings organizing
Project management systems	◐	○	◐	●	●	Project planning and control
Software-library (database)	○	◐	●	●	◐	Progress of testing, Sourcecode
Remote Systems	○	◐	◐	○	◐	Compiling, driver development, tests, telnet

not suitable ○ ◐ ◑ ◒ ◓ very suitable

Figure 7. Evaluation of information technologies in dispersed R&D teams by experts at IBM (1996).

project members access to a central schedule database which lets them see meetings, conferences or employee absences. Here, programs can even automate the usually laborious task of finding common dates for meetings.

Compared with fax, the additional advantage of e-mail is that graphics can be sent easier and faster. Moreover, with increasingly high-performance computers and networks audiovisual data (audio recordings, films) and files with other formats can be transferred. This increases the attractiveness of e-mail over traditional information media.

The extent to which e-mail is accepted depends on the country involved: in Japan, for example, due to the language problems with the Kanji characters the use of e-mail is a lot less widespread than in the USA and Western Europe (see Shapard, 1994). The Japanese language and the dominance of internationally incompatible character sets has led to the formation of Japanese e-mail islands.

R&D databases for common access to project data. R&D databases can store all the R&D results of a company. If all R&D units have access to such databases, redundant developments of the same

components can be reduced. For example, all central activities of the IBM Research Division are available in a database. Every IBM researcher can access this information. If a new problem is tackled in a project, every employee can first gain an overview of whether something similar is already being worked on at another location within the research division by using this database.

By means of this broad range of common information communication between employees at different locations is intensified. Prerequisite for this process is the integration of all information systems of the R&D units participating world-wide. At Ciba-Geigy, for example, almost every regional company had its own information system right up to the mid-nineties. These were largely mutually incompatible. In 1995 a very costly project for standardizing and integrating these information systems was begun.

It is also possible to introduce a central CAD system to which all peripheral R&D units have online access. By this means, R&D projects can be conducted centrally up to the implementation phase and then be transferred to the peripheral R&D units. Here the detailed design and the implementation are conducted

in accordance with the requirements of the local market. In a large number of interviews it was emphasized that access rights to international databases still represent an unsolved problem.

Groupware for electronic brainstorming. Groupware is the IT-based support for decentralized project meetings and is thus the group equivalent of bilateral e-mail communication. Every participant possesses a workstation via which he or she can communicate with the other participants in a computer network. Groupware provides comprehensive methods of supporting dispersed R&D teams by means of special group-oriented, computer-based methods, as electronic brainstorming, the common drawing up of agendas, various coordination methods or automatic protocol generation (cf. Petrovic, 1992, p. 20).

It appears that electronic brainstorming will gain importance in the future because of the creativity necessary in R&D. Traditionally, group-dynamic creativity requires physical proximity. However, the latest developments in groupware also support electronically controlled dispersed team sessions in the creative project phases (e.g. Group Systems, Team-Focus, VisionQuest and Lotus Notes). This makes it possible for an internationally distributed team to conduct brainstorming sessions to generate product ideas and alternative solutions during the early phases of a project.

A brainstorming session follows a similar pattern in most groupware systems: the participants have parallel access to the system and enter their ideas simultaneously at their local PCs. A team member broadcasts his or her ideas and in turn receives a random selection or the complete collection of other people's ideas. The combination of others' ideas with one's own inspires one to completely new creative solutions. After the idea generation phase, the ideas must be examined and jointly structured according to keywords and then evaluated anonymously.

Electronic brainstorming using groupware allows cross-location idea generation and even has a number of advantages over traditional forms of brainstorming. The social pressure of group conformance and the position of the team members in the hierarchy is greatly reduced by the anonymity of the contributors.

Inherent to computer conferencing is an asynchronous communication mode which can be an advantage in solving complex problems compared to sequential face-to-face communication processes. Face-to-face sessions hinder creativity because of the sequential real time problem-solving processes. This can be overcome in asynchronous communication, since the participants are encouraged to solve the problem from their own perspective.

The parallel access to the system enables several suggestions to be generated at the same time. Particularly where groups are heterogeneous and contexts therefore diverse, this can result in very innovative

suggestions for solutions. The asynchronous mode also simplifies intercultural communication, since people who have to communicate in a foreign language have more time to read or to prepare a message than in face-to-face communication.

Our own study shows that despite the advantages listed, groupware systems for brainstorming in transnational R&D projects have hardly been used yet. Leading companies such as IBM utilize groupware almost exclusively for coordination purposes. For example, all products currently being developed are published in the RFA tool to eliminate double developments ('formal approval cycle'). IBM TERM lists all IBM terms to achieve uniform use. With the OfficeVision/VM tool, documents such as the online telephone book, IBM organizational information, time, location and meeting plans are managed via e-mail world-wide. Time planning within project groups is conducted with TIME & PLACE.

The creative phases have up to now almost always been conducted in one place. Our interviews with a large number of persons shows that the systems available to date provide too little content support besides the purely communicative support. The consequence of this is an unstructured flood of information. The complete lack of face-to-face contact also makes information exchange and processing harder to manage. However, in this area great improvements can be expected from the software so that as IT is gaining acceptance greater potential for creativity can be expected.

Tele and videoconferences for crisis meetings. Teleconferences for supporting communication in transnational R&D projects is very popular with the overwhelming majority of the companies in the study, because of the simplicity, low cost and the widely available infrastructure. Teleconferences are frequently backed up by a simultaneous exchange of graphics or pictures ('upgraded teleconferencing'). Audiographic systems of this kind are particularly useful for design-based team work in which intensive real-time communication is required.

In international teams some members are always forced to speak a foreign language. These persons are strongly inhibited in their communication because components of body language — such as facial expression, eye contact, gesturing, posture and physical movement — are lost in teleconferences to a large extent. Only vocal means (tone, intonation, pauses during speech) can convey moods in the project. In addition it is often difficult to identify who is speaking at the moment. Since teleconferences are difficult to control, experienced moderators, pre-defined agendas, and well-established group processes are critical success factors.

In transnational R&D projects the videoconference has many advantages over traditional project meetings: participants of a videoconference can always be

contacted, since absence due to travel time is avoided. The *ad hoc* participation of additional experts and immediate access to information sources at the participating locations are possible. Because time-consuming preparations for travel are not necessary the frequency of the meetings can be increased and the coordination procedures shortened. This means that the time required for development can be reduced. In comparison with other telecommunication services the additional exchange of visual information leads to greater information density and helps to improve the project members' understanding of the issues.

One disadvantage of this medium lies in the necessity of reserving times for the conference and for setting up the communication links. In addition, transmission rates of only 2-Mbytes is often available for international videoconferencing services. In comparison to the 140-Mbyte mode in national transmission in the Federal Republic of Germany, the 2-Mbyte mode means that the quality of transmission is far worse (cf. Schlobach, 1989, p. 55).

3.4 Dynamics in the course of a project

The development of personal *networks* and the build up of an atmosphere of trust plays a big role in the early phases of projects. Promoters for the project idea have to be found. The project members first have to constitute themselves and then build up mutual trust. In this early phase it is important to create an atmosphere of acceptance among the locations involved and thus overcome the 'not-invented-here' syndrome.

Informal ties must be created so that the participants are familiar with their contacts in the various locations and the official channels of escalation can be avoided. As far as possible, the use of face-to-face meetings in conjunction with informal e-mails should be promoted.

Invention, the generation of ideas, and the design of the system architecture demand a high degree of creativity. Here, the application of groupware is important. If applied properly, electronic brainstorming can foster creativity to great effect.

During the development phase itself, the structure of the informal network has already become robust and the funnel of ideas has been narrowed down significantly, so that the demand for creativity lessens. Gaining importance is the local development in the decentralized teams, which mainly exchange selective *technical information* via established interfaces.

During the implementation phase decentralized development activities are coordinated vigorously. The *coordination intensity* increases sharply just before the system integration phase. The coordinated effort to complete the development of individual modules is most important at this point.

It must be emphasized however, that in this scheme innovation processes by no means progress in a linear fashion. On the contrary, Van de Ven et al. (1989) in particular, with his event-based cross-sectional analyses, pointed out the non-linear progress rate of innovation processes. The model intends to only indicate that during a given phase certain characteristics are more dominant than others.

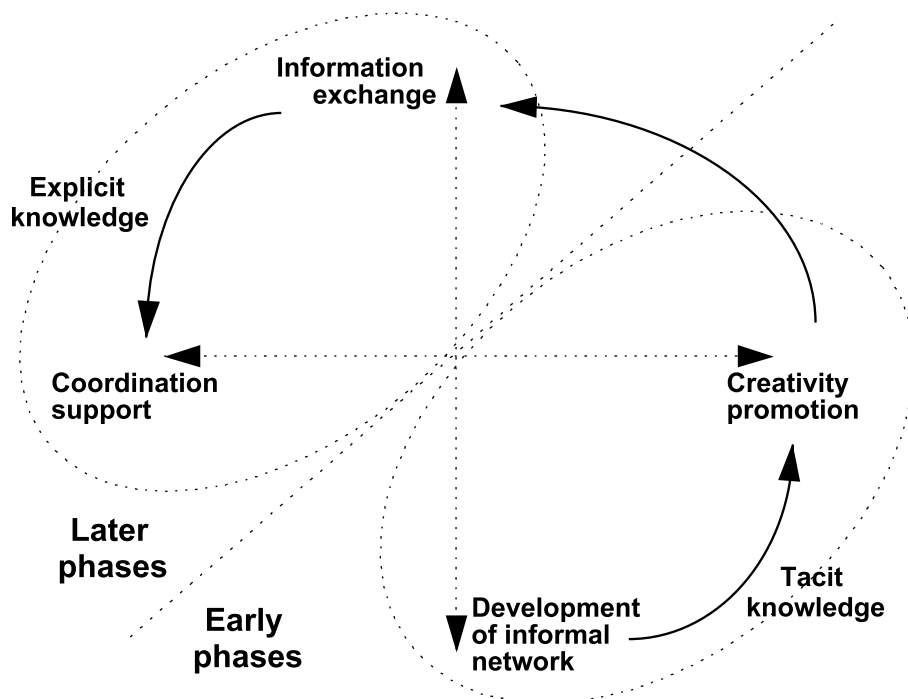


Figure 8. Changing IT demands in the course of a project

4. Conclusion: limitations and success factors

O'Hara-Devereaux and Johansen (1994) state in accordance to our interviews about the application of IT in global corporations, that: 'Global organization cannot function without information technology. But the technology itself is not the answer to the myriad problems of working across geographical and cultural boundaries. The ultimate answers to these problems remain in the realm of human ... relations.' As shown clearly in the IBM case study, the application of IT is absolutely vital in large-scale international projects where there is a high degree of division of labour. At the same time the study shows that although the application of IT is a necessary condition for dispersed 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.

The introduction of IT is frequently associated with a pronounced reduction in travel by researchers. For example, travelling costs at IBM have decreased drastically since video conferences have been introduced widely. The greatest challenges to the application of IT in dispersed R&D teams lie in the broad substitution of face-to-face communication among team members by IT-based communication. It is precisely at this point, however, that the limitations of IT lie. Employing IT in dispersed teams means that sensory information, feelings, intuition and context are largely neglected due to a lack of person-to-person contact.

Communication takes place to a large extent non-verbally by means of body language, gesturing, and intonation. This non-verbal communication is largely neglected in electronic transmission. Especially in transnational R&D projects in which communication problems already arise from the differences in the languages and cultures involved, non-verbal communicational elements are highly significant. This problem is additionally intensified if the project participants come from context-rich cultures (e.g. Japanese and Chinese people).

Substituting traditional face-to-face communication with IT-based communication therefore has clear limitations. Although dispersed R&D teams have a lot of potential, the realization of this potential depends on the extent to which suitable project management is conducted. The following success factors for IT in dispersed R&D teams can be summarized:

1. The spatial and organizational shape of dispersed teams must be specifically tailored to the project. This means that certain situations may necessitate bringing together a dispersed 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 dispersed 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 personally 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 for a longer period of time. 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-time of trust').
4. The use of e-mail, common databases, and remote login is usually crucial if the dispersed team is to be able to work efficiently. Videoconferences can be a useful complement to face-to-face meetings.
5. It is important that the IT is applied according to the situation; division of labour in network development, fostering creativity, exchanging information and supporting coordination efforts can represent a sensible framework for the application of IT. The IT instruments should be selected according to the dominant task during the phase.
6. Despite the enormous progress made in IT, face-to-face contact is still essential in transnational R&D projects. The degree of dispersity 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.

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Notes

1. Besides that case study we conducted 60 interviews in 24 technology intensive companies from Europe, USA and Japan on the theme 'Management of transnational R&D projects'. Most of these experts have been supporting this model. The results are published in a thesis at the University of St. Gallen; see Gassmann (1997).
2. In VSE/ESA contexts these customer tests are known as the 'Early Support Program' (ESP), in MVS/ESA contexts they are known as 'Early Install Option' (EIO) and 'Product Introduction Program' (PIP). The purpose of these programs is to gain initial experience in the field in a controlled environment with a small number of customers.